The application of classical architectural criteria to 3D digital library design to enhance the learner experience

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Abstract

Purpose – A new development, 3D digital libraries, involves the placement of objects and museum artefacts in a 3D visual context, often supported by learning resources and tools. This study proposes combined design principles from human-computer interaction (HCI) and architectural theory, and considers their impact on the user experience.

Methodological approach – Literature reviews into HCI and architectural principles in relevant to the design of 3D digital libraries were conducted, and a model of design criteria combining architecture and HCI applicable in to their design was proposed. A literature review into information seeking behaviour also preceded the design of an experimental methodology to investigate the role of design on behaviour. An applied study using a methodology designed to investigate 3D design's influence on user behaviour then investigated the usability and usefulness of 3D digital libraries with young people aged 13-15 and the impact of both HCI and dimensional design features on user information behaviour, in particular whether or not they have the capacity to foster curiosity and further engagement with the subject matter. Primary methods are usability tests and semi-structured focus group interviews conducted one week and then at the 7 month interval after initial use of three 3D digital libraries.

Findings – The research results in a new 3D design framework for the study of 3D digital libraries combining classical architecture and HCI principles, and offers a tailored methodology to exploring the influence of design on behaviour. Findings and analysis indicate the key features of 3D digital libraries which influence learning and information seeking with 14-15 year-old female students in an English secondary school. The research concludes that 3D digital libraries are appealing and enjoyable to most participants in the 14-15 year-old female user group and thus provide a useful tool for the creation of a learning experience combining both experiential and instructional content. As resources which users perceive they are "visiting", they are comparable to a school field trip in terms of other forms of learning familiar to school teachers, but they confer extra benefits such as convenience and comfort to both users and teachers.

Practical implications – The study provides a new framework for the design and investigation of 3D digital libraries harnessing the wisdom of classical architecture. It indicates benefits of 3D digital libraries to the user group which will be of interest to cultural providers and educators.

Keywords: *3D virtual environments, digital design, information behaviour, classical architecture, usability.*

Contents

Chapter 1: Introduction

1.1 Terminology

The term "3D digital library" is used to indicate digital virtual environments involving the two-dimensional (2D) transmission of 3D visuals with content linked to a cultural or knowledge-economy institution. The identification of emergent examples, case studies and conceptual examples refer to those intended to be generally accessible via an Internet connection.

Given the 2D interface, 3D design is defined and delineated for the purpose of this study as the arrangement of design elements within a computer interface to create an impression of 3-dimensionality. In this context, users derive 3D information from 2D images by initially processing local line junction cues and then combining information from many junctions (Bhatt and Bertin 2001). "Environments such as [these] render 2D representations of a conceptually 3D space to a computer screen, whereas virtual reality (VR) undertakes a true stereoscopic rendering of the 3D space, providing true perspective views" (Minocha and Mount 2009).

The examples hypothetically or actually cited gave the user a degree of facility to interact with the objects placed within them, by "moving around" the 3D system. They offer the user choices as to where to walk and what to look at. The combined factors of moving around and the degree of choice as to where to go is represented by the expression "walkthrough environment" or "walkthrough system" as commonly used in the IEEE XPlore Digital Library database (IEEE 2015). Many of these characteristics, including 2D renderings of 3D virtual worlds, interactivity and walkthough environments, are familiar to those who are involved in gaming (Jones 2012). In fact, a 3D digital library can be said to be a related sub-type of the virtual world – a "computer-maintained environment" that provides "3D visual and auditory displays", an environment that allows "movement and interaction by a human using some control scheme" (Singhal and Zyda 1999).

Other characteristics, such as degree of immersion and realism vary across virtual environments (Minocha and Mount 2009). Where the idea of "immersion" is discussed, this occurs in awareness that "immersion" is a term which is widely applied to a variety of experiences, from experiences of telepresence to experiences in virtual worlds which allow collaboration and exploration. Many design features vary across virtual environments and these are discussed where they appear to influence the user experience at the testing stage.

Unlike some virtual environments, 3D digital libraries tend to be heavily populated with resources from cultural institutions. For this reason the extent to which users are able to "modify" the virtual environment of a 3D digital library differs across resources, although some degree of user-initiated modification is characteristic of all virtual environments (Bartle 2003). In this study, where the terminology "virtual environment" is employed, it is related to the virtual environment of the 3D digital library, and not all virtual environments.

Apart from the terminology of the 3D digital library itself, which is discussed above, there may be some debate as to the nature of a "cultural institution", which is also referred to using the triad "museums, libraries and archives" (although this is not exhaustive). This is important because as 3D digital resources proliferate there are some whose functions are purely technical or experimental and this research is intended, among other things, to inform actors in cultural institutions and does not address the use of 3D for virtual classrooms, business scenarios, and individual virtual objects used in scientific learning without a virtual environment, or to 3D modelling environments used as professional tools by architects and planners.

The definition of a "cultural institution" may be subject to debate, but in this research a positivist legal definition in the UK context suffices. Definitions for cultural institutions are taken from the Department for Culture, Media and Sport (2014), English Heritage (2014) and from the British Standards Institute and Collections Trust (2009), where "cultural institutions" is used to describe primarily museums and galleries, libraries and archives, built heritage sites (including those used for other purposes such as worship) and collecting organisations. With reference to these last two designations, a full and comprehensive list of discussion of UK legal definitions of heritage or conservation sites using the legal category of "heritage protection" and thus being distinguished "built environments" can be found in English Heritage's publication *Identification and Designation of Heritage Assets* (2014). Cultural resources or collections may also be held by individuals, educational institutions, or the private sector with either copyright or ownership rights attached to them (Deazley 2014) and it is these which the British Standards Institute and Collections Trust (2009) describes as "cultural collecting organisations".

With the World Wide Web potentially allowing physical or virtual objects or environments to be marketed as "cultural" resources through digitisation or content creation, they are associated with "cultural institutions" where some curatorial agency can be traced – e.g. if their context suggests a museum, library, archive or heritage site or if such institutions are involved in digital content curation. Cultural institutions thus defined facilitate access to collections in either the "real world", in the digital space, or both.

Since less emphasis is placed on the distinction between different types of cultural institutions in the digital space, the generic term "3D digital library" in this research may approximate what is elsewhere designated a "virtual museum", as in the case of some examples cited by collaborations such as Virtual Museum Transnational Network (v-must 2011). The differing terminology for the type of resource under investigation is further explored in Chapter 6, where emergent trends in 3D digital libraries are collated.

1.2 Research Context and Rationale

The use of 3D in cultural research contexts has tended to be framed by the theme of digital heritage preservation. This trajectory is well documented by the 2014 book *3D Research Challenges in Cultural Heritage: A Roadmap in Digital Heritage Preservation* (Ioannides and Quak 2014). Chapters in the book focus on 3D object scanning, the challenges of curating large datasets, the use of scanning for archaeology contexts, and data preservation and reuse. This research differs because the resources in question are usually created using graphical user interface (GUI) design and may make use of scanning technologies for embedded objects. The specific trajectory of the 3D digital library is ripe for study in an evolving context whereby such applications may have benefits for both cultural institutions and users. The 3D digital library is a unique challenge for cultural institutions, the rationale for which is discussed below.

For some years it has been understood that the digital space represents a realm of communication, worthy of the consideration of library and information services (Association of College and Research Libraries 2007). Web 1.0 digital library services, such as online public access catalogues (OPACs), image galleries, and 2D ebooks have continued in web 2.0, but developments in the digital space such as social networking, 3D spaces and access across hand-held devices provide a new context for library services. According to the Collections Trust's white paper entitled "Creating Engaging User Experiences with Collections" (Poole and Payne 2012), expectations of web users are high in this context. "There is an expectation of rich, engaging content-based experiences which permit them to follow self-directed pathways, and to flow seamlessly between different contexts" (Poole and Payne 2012). Applications in the digital space which more fully utilise exploration, such as walkthrough and the detailed exploration of 3D resources are now timely for a range of cultural institutions. However, Poole and Payne (2012) contend that "many of the systems currently used to provide access to digitised collections from museum, library, archive and other cultural institutions fall short of these objectives. Current systems generally provide a keyword search system together with a basic browse function, both usually resulting at some point in a page of thumbnail images followed by a static ‘one at a time’ view.”

Given year on year changes in information-seeking preferences (Outsell Inc. 2009) and digital activity (Ofcom 2011), the research in this PhD is conducted at a time of flux and transition. Museums, libraries and archives, which currently make use of catalogues, databases and search engines, also have the option of making use of visualisation, technologies associated with entertainment such as gaming, and communications tools such as social networking.

It is potentially more immersive to encounter collections in 3D, mediated by design elements that enhance the encounter and create a more engaging learning experience. Where “one-at-a-time view” exists, and catalogue resources presuppose information retrieval, the lack of existing online support for the information-seeking process and exploratory information behaviour in digital libraries is made more explicit. They thus fall on the exploratory side of the dichotomy between exploration and “one-at-a-time” view: according to information scientists Krestel *et al*. (2011), exploratory searches exist “in contrast to regular search, which is typically aimed at obtaining a specific answer to a specific question”. Thus 3D resources not only concur with user expectations in the digital space; they also provide a new way of exploring information in the digital space. However, if such assertions are to be maintained, there is a need for improved theoretical underpinnings to the user experience of 3D digital libraries and scientific testing of emergent examples.

This investigation requires a conceptualisation of a digital library beyond one which is “hardwired to the functionality” (Poole and Payne 2012), but one which participates in the dimensional space and mediates its own user experience. It is noted that much research into the end user experience focusses on information retrieval. There persists a conceptual difference between non-graphical or character-based interfaces, of which library catalogues are a development (Macaulay 1995) and the GUI, which is based on principles of direct manipulation and is the starting point for the 3D delivery of services, as in gaming. The key difference is that 3D digital libraries create a dimensional experience which frames the encounter with information, enabling connections and facilitating information seeking as a process of exploration. While previous metadata may not be suited to the purpose of creating this kind of connected experience (Poole and Payne 2012), the development of 3D digital resources as specific applications bypasses concerns about metadata by creating unique experiences and spaces in which the user encounters exhibited materials.

Where cultural institutions develop 3D resources, they do so in the context of a world where the Internet is becoming more and more associated with the search for information (Lenhart *et al.* 2001), with Internet search engines the most popular way in the world of seeking answers to information enquiries (Outsell Inc. 2009). In this context, libraries and other similar institutions have an important role as mediators of the encounter with information commanding a high degree of public trust. Kuhlthau (2004) argued that there is a need to develop library services and systems that enable people to seek meaning within an increasing amount of information, and mediated online systems are a way of providing this service in the digital space.

Cultural institutions may also benefit from 3D applications as a way to attract younger users. Many users become averse to and develop negative attitudes to library services when they reach their teens (Green 1994; Curry 1999; Mahoney and Laszcazk 2009; New Westminster Public Library 2011). The idea of “reaching beyond the walls” is seen as a part of the future configuration of library services, including moving to a greater degree into virtual spaces (Reading Agency 2011). The appeal of other types of 3D digital environments, such as computer games, is also noted, since the association with fun and enjoyment in 3D digital environments may increase engagement if applied to library resources among a currently disengaged group. It is not only teens who may prefer a more exploratory, browsing trajectory. The Collections Trust contents that search-based systems “meet the needs of experts and researchers well, but for the "lay" visitor the experience is often not very engaging and usually limits them to viewing a narrow slice of the collection, not the overall view they are more likely looking for” (Poole and Payne 2012). A 3D digital library may therefore confer specific benefits to the user experience regardless of age.

Developments in the 3D digital space warrant a visual exposition. Below four examples are given: first, a still from a popular “shooter” game which shows how architectural walkthrough environments are used in this space. The first example is *Assassin’s Creed 2* (2009), a video game set in an open world environment resembling Renaissance Florence and Venice. The game is targeted primarily towards entertainment, and without specific learning objectives, although there may be concomitant learning improvements such improved kinetic abilities and hand-eye coordination or architectural knowledge. By embedding information and learning resources users could have an experience which promotes engagement with the resources themselves.

Fig. 1 (above): Still from *Assassin's Creed 2* (2009).

In other contexts, the architectural space has been harnessed by town planners and by archaeologists. The second example, the Glasgow Urban Model uses digital documentation using 3D scanning technology to create a photorealistic image of areas of Glasgow, UK, which can be walked through by the user (Glasgow City Council 2007). At present, the use of digital documentation causes the resource to require high processing power, whereas *Assassin's Creed 2* (2009) creates structures not through digital scanning but through the use of computer-generated imagery (CGI) which relies on repetition to reduce memory requirements.

Fig. 2 (above): Glasgow Urban Model (Glasgow City Council 2007).

In the heritage sector, digital documentation can be used both for digital preservation but also for creating narrative experiences. The third example, a virtual representation of Skara Brae, a World Heritage Site on the island of Orkney, allows people to visit the site remotely as well as see historical figures within the virtual environment. This development is typical of 3D digital heritage, and in this case, priority is given to mixed media and narrative representations to convey ethnographical information.

Fig. 3 (above): Still from a virtual heritage resource of Skara Brae, Orkney, developed by Alice Watterson (Watterson *et al.* 2012).

To facilitate walkthrough of virtual worlds, other developers have focussed on using game-like CGI. The Open Virtual Worlds project at the University of St Andrews generated virtual worlds of reconstructed historical sites, such as St Andrews Cathedral and Linlithgow Palace. Each environment is a digital reconstruction of an historical site. The user adopts an avatar and is able to walk around and fly through the environment. The virtual worlds can be accessed via personal computer using a mouse, or using a joystick in a game-like set up.

Fig. 4 (above): still from *St Andrews Cathedral 1318* (Open Virtual Worlds 2013).

These resources set visual precedents and user expectations for 3D digital libraries.

It was considered apt[1] to investigate 3D digital resources in relation to young people, who are often "digital natives" (Prensky 2006; Robertson 2008; Ofcom 2011, 2013), but who nevertheless often lack aptitude with traditional online library catalogues, which has been shown to precipitate disengagement (Blocks 2004). The alternatives – usually search engines which do not necessarily deliver results that have clear provenance, and may even contain "misinformation" (Adriaans 2012) – do not therefore always present a useful alternative to the library catalogue. This is compounded by information illiteracy whereby especially younger users fail to make value judgements as to provenance (Ofcom 2011) or recognise the possibility of inaccurate information (Shenton 2004, p.193; Eastin *et al.* 2006, p.213; Hirsh 1999, pp.1267-1281). Van Deursen (2010, pp.58-70) distinguishes skills that are medium-related from those that are content-related. Medium-related skills involve the use of a system, such as the ability to undertake necessary operational steps. Content-related skills include information literacy skills to assess and evaluate the information. It is argued that for a teenage user group, medium-related skills will be fairly strong (although this hypothesis would need to be confirmed with a demographic questionnaire), while information literacy skills will be in a developmental stage and not necessarily strong. This opinion is based on research that indicates that young people often struggle to translate their search objective into

[1] Apt is used as explained by E. Sosa (see Ibarra 2008).

appropriate keywords, to formulate search queries, and to understand the logic of search results (Druin *et al.* 2009; Beheshti *et al.* 2010; Dhillon 2007). When faced with such difficulties, young people often resort to search strategies such as browsing and clicking through links, which require less cognitive load (Beheshti *et al.* 2010). For example, Horst *et al.*'s (2010, p.54) ethnographic study interviews found a strong majority of the participating youth engaging in what the authors term "fortuitous searching", involving moving between links in an unplanned manner.

At the same time, 3D digital libraries being a new conceptual reality with emergent examples, there is a need to establish which key elements constitute a 3D digital library. "Design" can be construed both as a question of aesthetic design in the 3D space (dimensional design), which comes from built architectural theory, as well as a question of usability and usefulness, whereby heuristics put forward by specialists in human-computer interaction guide the design of digital resources to improve the user experience. The design of a system also pertains to the communicative aspects of the information environment which are involved in displaying information to the user. In 3D spaces, these communicative aspects take place in a dimensional context – for example by placing information in a way that the user must progress towards it before seeing it, as well as in a more traditional click-per-view way. Multimedia features may play a part. It is not possible to create controlled experiments to test all of these features, but by studying the user experience in relation to resources containing a variety of features a number of conclusions may be reached and new research directions proposed. Given the scope of an exploratory study, this approach establishes theoretical frameworks for the study of 3D digital libraries and allows for future investigation of variables with new resources and user groups.

1.3 Research Goals

1.3.1 Research Aims

RA1 Investigate the young person's user experience of 3D digital libraries through an information seeking frame of engagement and curiosity.

RA2 Where possible map which elements (especially of design from an HCI and dimensional perspective and the communication of information) influence the user experience.

1.3.2 Research Questions

RQ1 What are the key criteria relevant to the design of 3D digital libraries?

RQ2 How do 3D digital libraries encourage exploration and curiosity?

RQ3 What types of information behaviours take place with 3D digital libraries?

RQ4 In what ways do 3D digital libraries deliver benefits to the learning experience?

1.3.3 Research Outcomes and Wider Contribution to Knowledge

The research will generate the following original outcomes.

- A model of the associated criteria between Human-Computer Interaction (HCI) and classical architecture operating in 3D digital environments following literature reviews into the relevant subject areas. No existing models reflecting the operation of these two research fields on virtual environments have been identified, and hence this model is a new contribution to the literature which may be open to revision and refinement on further research into design principles and evaluation of 3D digital libraries as they evolve.

- Empirical identification of existing emergent examples of 3D digital libraries conforming to research parameters (see Chapter 6).

- A testing methodology for 3D digital libraries with young people, built around an HCI framework which is additionally designed to encompass new qualitative areas of evaluation relevant to the user experience with 3D digital libraries (such as young people's engagement and information seeking in digital environments) (see Chapter 7).

- Analysis of the role of design and communicative aspects of 3D digital libraries in relation to findings showing engagement or curiosity (see Chapter 9).

The research responds to the need for improved theoretical underpinnings in user experience of emergent 3D digital libraries and for research into their effects on the user experience. The outcomes of the research reflect the need to identify salient features of both the system and of the user experience – of both design and behaviour. Information systems research produces knowledge under two paradigms, behavioural sciences and design sciences (Hevner *et al.* 2004). Gray (2010) argues that the disciplinary approaches of design science and behavioural science are tied to one another, since design scientists create artefacts that create utility and behavioural scientists create theories based on the results.

The aptness of HCI and 3D architectural design subjects to the system visual interface, and of information seeking subjects to the user experience are justified in their respective literature review chapters. The research into the subject fields then informs the methodological and analytical outcomes of the study in a way that is appropriate to the young person's user experience in relation to the object of the 3D digital library.

The research has potential benefits to wider society. New design criteria and user experience findings could help digital library designers and service providers to increase the provision of virtual world-type environments where users can encounter cultural resources. The research will also be useful to 3D digital designers who are interested in using design frameworks drawn from prior knowledge and research findings. The research testing with young people will improve the capacity of educators to make informed decisions about the use of similar resources in educational environments. Research findings in the experimental setting of the classroom could increase uptake of appropriate resources in the educational environment and may result in the increase of any user benefits identified.

1.4 Summary Methodology

The methodology aims to generate associative criteria and inferential conclusions between the user experience of exploring the systems and the design of 3D systems.

The research involved 69 students, initially in Year 9 and 13-15 years old. Focus groups one week later involved 24 of the initial 69 students in Year 9, and after 7 months, focus groups involved 17 of the initial 69, now in Year 10 and aged 14-15, and 5 History and Art teachers.

The study begins from an overall HCI perspective. HCI has been defined as "A discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of main phenomena surrounding them" (Hewett *et al.* 2009). The study makes use of user testing as a usability measure. A user testing approach is used to explore the user experience with selected examples, where participants are offered the choice of exploring from a selection of 3D digital libraries, with at least 10-12 participants for each condition then completing a usability questionnaire.

The qualitative approach in this study departs from traditional usability methods such as user testing and heuristic evaluation and explores further factors of the user experience. It is argued that the study of the main phenomena surrounding the new field of 3D digital libraries, through a theoretical framework of information behaviour and architectural design, justifies a qualitative exploration of the main factors influencing the user experience, both from a design framework and an information behaviour framework. In order to understand the specific problems encountered and opportunities facilitated by the information space, it is important to incorporate focus groups into the methodology. Focus groups allow the flexibility to handle a wide range of design topics and domains (Hevner and Chatterjee 2010).

Focus group interviews of a semi-structured nature are designed according to qualitative research methodologies with the aim of generating thematic codes characterizing the user experience. Participants are asked what they did when using the 3D digital library, what they liked/did not like, whether they would like to use similar resources in the future, their reasons for selecting the 3D digital library and their subsequent interest in the subject matter, aesthetics of the system, and information seeking since using the resource.

The research incorporates a follow-up interview seven months after focus groups to gain a more longitudinal impression and with a focus on information seeking as a result of using the 3D digital libraries, and to further explore the information seeking frames of engagement and curiosity.

Work with a special population (see Beheshti and Bilal 2014): 13 to 15 year-olds in an English fee-paying school occurs because information behaviour research often takes place in relation to a specific group and allows for a control of variables against the technological variable of the 3D digital library, allowing for a focus on the influence of the interface design on information behaviour and attitudes. This user group is also fairly homogenous when we consider how socio-economic status and gender are a predictor of digital skills (Hargittai 2010; Hargittai and Hinnant 2008) but variables within the demographic will be taken into account. The study was conducted in a school – a true-to-life contextual setting for learning with this age group, with the first laboratory session structured as a class period, and subsequent interviews taking place voluntarily during the school day. The learning context also suggests that a follow-up interview with teachers (the gatekeepers to the use of 3D digital libraries in learning tasks) provided contextual data and information.

The quasi-experimental approach is preceded by four literature review chapters. These reviews are as follow:

Interface design

- Chapter 2: usability and usefulness criteria impacting the success of the interface design.
- Chapter 3: 3D architectural design impacting on the design of a 3D environment.
- Chapter 4: a proposed associative model of design criteria for 3D digital libraries.

User behaviour

- Chapter 5: explores the fields of child and adolescents' information behaviour online, and information seeking as it pertains to engagement and curiosity.

The research design involving qualitative user testing requires a prior research frame in information behaviour and seeking, pertaining to engagement and curiosity, for the purpose of analysis. The research methodology builds upon researching design of the 3D digital library user interface in order to draw meaningful associations in the interaction between user and system. Indeed, this initial focus on design allows findings about human behaviour to feed back into the design of information systems in an iterative and scientific way.

1.5 Thesis overview

Having defined key terminology, the research context, research goals and a summary methodology, it remains to explain the structure of the thesis. The thesis is broadly divided into three Parts, with Part I reviewing the relevant literature and summarising the proposed interdisciplinary reading of the 3D digital library with reference to a Model of interdisciplinary design criteria. Existing 3D digital libraries are also reviewed with a view to investigating the analytical criteria in the practical context of system and user. Part II begins with the planning and execution of the experimental methodology to investigate the role of combined design criteria on the learner experience with 3D digital libraries, and the findings are reported. Part III combines the analytical research outcomes of Part I – which culminated with the Model of interdisciplinary combined criteria – with the research findings by analysing the role of 3D design criteria on the learner experience using the themes identified in the literature reviews. Part III culminates with a Conclusion chapter which summarises the scope and relevance of the research. A summary of the content of each chapter and its role is given below.

Part I: literature review chapters

Chapter 2 reviews HCI, identifying "usability" and "usefulness" as key subjects within this field through which to analyse the success of digital library resources. These subjects are reviewed and a list of usability / usefulness themes identified and listed.

Chapter 3 reviews architectural literature, seeking those 3D design criteria applicable to the 3D virtual space. The chapter identifies dimensional criteria from the classical architectural corpus which guide the design and analysis of the built world. These are summarised and listed as themes relevant to 3D digital library design from the architectural discipline.

Chapter 4 presents the themes identified from the HCI and architectural literature as principles which can exist together in the 3D digital library space and influence different aspects of the design space. These are summarised by means of a conceptual Model which proposes the applicability of both HCI and architectural criteria to the 3D digital library.

Chapter 5 assesses the user experience of 3D digital libraries – whilst the prior chapters have principally addressed design questions, Chapter 5 addresses the question of user behaviour in 3D digital systems. This chapter therefore ensures that the thesis assumes a theoretical perspective which takes into account both design and behaviour. The chapter identifies "information behaviour" and, more specifically, "information seeking behaviour" as key subjects within information science through which to understand the young learner's use of 3D digital libraries. In keeping with the research aims and questions of the research, the themes of motivation and curiosity are explored within the Information Behaviour (IB) and Information Seeking Behaviour (ISB) literature. The chapter ends with the identification of different types of search behaviours identified during the literature review as a basis for thematically analysing the research findings.

Chapter 6 reviews extant 3D digital library resources, focussing on the 10 years prior to the cut-off date of 15 December 2013. The review consists of an empirical research of resources and a summary of those conforming to 3D digital library criteria. The chapter describes the process of selecting 3D digital libraries suitable for the experimentation scenario.

Part II: User testing with selected resources

Chapter 7 concerns methodology for a user testing and qualitative research study involving 3D digital libraries. The research aims and questions are revisited and different potentially applicable designs are discussed, before an appropriate quantitative and qualitative research methodology is proposed. The practical application of a quantitative and qualitative study us outlined with reference to participants, environment, resources used and ethical considerations. The management of resulting datasets is considered and appropriate analysis methodologies for the quantitative and qualitative data are proposed and planned.

Chapter 8 reports the findings from the execution of the research methodology. Following appropriate collation of the data e.g. in spreadsheets and through transcription, a summary of the data is given. While the raw data is available elsewhere according to the University of Strathclyde's researcher requirements and this chapter is necessarily of a summary nature, graphics, tables and narrative expositions are intended to inform the reader of the key findings from which subsequent analysis can take place.

Part III: Analysis and conclusions

Chapter 9 describes the results of analysis of the data from Chapter 8, and relies on the researcher's interpretation of the relationship between design and behaviour, using as a theoretical framework the themes identified in Chapters 2, 3 and 4. The analysis draws out trends which were found to be common between more than one 3D digital library in the research context and identifies trends unique to each library which was analysed.

Chapter 10 concludes the thesis by revisiting the research questions and proposing what associations between design and behaviour can be made from the study into the role of design criteria on the learner experience. The chapter discusses limitations and further research avenues that are proposed as ways to verify the conclusions in different contexts or to further explore the role of design on behaviour which were beyond the scope of the design or findings of the present study. Since the research is original in its offering up an analytical framework based on the combination of design principles from HCI and architecture in the study of the 3D digital library, the Model of associated criteria is revisited at this final stage in the research in the light of the findings. An updated mapping between the architectural criteria and HCI criteria represents the revisiting and revision of the Model as a result of the research findings, showing those relations which were found to be the most important or have the strongest relationships.

PART I: LITERATURE REVIEW CHAPTERS

a. *Foreword*

The approach to the literature considers what key characteristics can inform 3D digital library design and key information behaviours that can occur within them. The literature review thus provides the necessary contextual information to inform our understanding of the user experience in 3D digital libraries because it analyses both the features that the user will encounter in the world as well as the relevant user-end information seeking theories that pertain to this experience. It is pertinent to investigate design features in the information seeking context because "the effect of information sources' structure have been acknowledged in the information behaviour literature as one of the many intervening variables in the information seeking process" (Tsakonas and Papatheodorou 2008), and design can be "supportive of information use, as well as preventive" (Wilson 1999). Theories of information seeking behaviour, meanwhile, provide valuable insight into the user-end experience (Tsakonas and Papatheodorou 2008).

The conceptual basis of the study is that the 3D digital space is experienced as a dimensional space. The dimensionality of this space goes beyond metaphor because the user is immersed in a dimensional environment. 3D interfaces correspond to the architectural space insofar as they create experiences that look and feel more like real life. According to Benyon (n.d.), we "can argue that 'Navigation of Information Space' is not (just) a metaphor, it is a paradigm shift. Navigation of Information Space is a new paradigm for thinking about HCI, just as Direct Manipulation was a new paradigm in the 1980s".

Several researchers from within HCI have argued for the usefulness of architectural criteria to digital design. Barfield (1993) was one of the earliest HCI theorists/practitioners to use architecture as a metaphor; Benyon (n.d.), writing in the 2010s, refers to the relationship between architectural wayfinding and navigation, although he critiques the metaphor using critical theory, a different approach to the realism assumed in this study. Architectural design has also been adopted as an analytical or design approach by Hong and Kim (2004), Hevner and Chatterjee (2010), and Hernandez Ibañez and Naya (2012), each of whom operates within a rationalistic or objectivist framework, citing primarily classical approaches.

In the professional literature, Jones (2012) described how architectural GCI was evolving into a professional and educational discipline with applications in the gaming world. He explains how 3D visualisation in film and computer games often involves detailed and specialised research in architecture. As of 2012, notable examples included the environment in Guy Ritchie's *Sherlock*

Holmes, Christopher Nolan's *Inception*, and the *Harry Potter* series of films (Jones 2012). At the same time, features resembling an architectural cityscape are found in virtual worlds which are designed and developed by a user community, such as in *Second Life*, where a spatial virtual environment has been created through user activity in building and developing areas (Minocha and Mount 2009).

Other facets of the digital space differ from "bricks and mortar" (Benyon n.d.). These factors depend on the configuration of elements of interface design, usability, and what is known about constructing a beneficial user experience online. Hence, the behaviour of the user in the information space and the usability of a system are paramount to create a complete picture of the complex information environment under investigation. For this reason, usability is retained as a foundational discipline in understanding the design and configuration of the user interface (see ISO 2009; Nielsen 1993, 1994, 1995). Furthermore, it is beneficial to validate design research with an apt user-end experience theory. In the case of the digital library, users explore information architects in a 3D digital space. Information seeking behaviour is an apt user end theory in this context, since this theoretical framework is applied in a range of scenarios investigating how users encounter information, from using 2D digital interfaces such as catalogues and search engines, to ethnographic and everyday life information seeking scenarios (see Wilson 2000; Savolainen 1995).

Chapter 2: Human Computer Interaction Heuristics Literature Review

2.1 Abstract and Methodological Approach

Purpose – The main focus of this literature review is driven by the normative approach to construct a list of principles from the HCI literature governing successful design of interactive systems. For this reason, the primary areas of interest are literature, usefulness literature and compositional principles for the design of the graphic user interface. The chapter adopts an analytical attitude (cf. Beaney 2012), breaking down a field or concept into simpler parts in order to reveal its logical structure.

Methodological approach – Databases on Human-Computer Interaction were searched using defined search terms. The main databases searched were:

- ACM Digital Library
- Computer and Information Systems Abstracts (ProQuest)
- IEEE Explore

The following search terms were used:

Usability AND principle*

Usability AND heuristic*

Usability AND evaluation

Usability AND comparison

Usability AND usefulness

These searches were then repeated with the edition of the criterion “and 3D”.

Findings after 2006 were prioritised, due to the need for currency in this particular field. Findings were purposively sampled and references within findings were explored using a snowballing approach.

Findings – General principles of usability and usefulness can be discerned for digital design. Some lower-level taxonomic principles point to the emergence of principles for 3D digital environments. Some of the existing general usability and usefulness principles were not task- or representation-specific to the 3D digital library domain, and this creates a need within the literature which now encourages us to look at complementary disciplinary angles to better conceive of this reality.

Practical implications – The findings allow for both analysis of design principles operating in 3D digital libraries, and anticipate analysis of the real-world user experience where usability and usefulness impact upon that experience. The chapter contributes to an overall design analysis of 3D digital libraries by allowing for the isolation of HCI principles and allowing for their future comparison with classical architectural principles. It also anticipates user testing with 3D digital libraries, where the usability and usefulness of the systems are key constituent parts of the broader user experience. In anticipation of analysis of quantitative and qualitative data, a list of key concepts is provided at the end of the chapter.

2.2 Introduction

HCI research aims to bring about an optimal user experience for users of computer systems, through practical development and research into appropriate design principles and normative ends. HCI theory draws on a broad range of complementary disciplines. At its inception, it drew on the perspectives of cognitive science, encompassing cognitive psychology, artificial intelligence and linguistics, which had emerged by the end of the 1970s and therefore provided ripe empirical foundations for a new study of computers and their users (Department of Trade and Industry 1990). By the early 1990s, the main contributing disciplines came from computer science, cognitive psychology, ergonomics and human factors; additional areas of interest were artificial intelligence, philosophy, sociology, anthropology, design and engineering (Department of Trade and Industry 1990). In 2007, Sharp *et al. s*tated that HCI also takes into account how people act and react to events and how they communicate with each other, as well as "how emotions work, what is meant by aesthetics, desirability, and the role of narrative in human experience". At the same time, HCI research is cognizant of social issues (Winograd and Flores 1986) and the question of usefulness (Buchanan and Salako 2009).

Since the research takes a rationalist and normative perspective subjects within HCI, such as usability and usefulness, rather than the extra-disciplinary lenses through which it has sometimes been considered, are the main focus of the review. Since the beginnings of HCI, usability has had a great impact on the way interactive systems are designed and developed (De Angeli *et al.* 2006). The International Organization for Standardisation (ISO) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO 1998).

It is considered beneficial to analyse the 3D digital library through a usability lens. According to Uldall-Espersen (2005) some of the benefits of usability for websites are that users will be satisfied and not frustrated by the site, users will enjoy interacting with the website, users will accomplish their goals both efficiently and effectively, and user errors and thus costs will be reduced. Secondly, usability has relevance and saliency to the digital space. According to UIdall-Espersen (2005) some examples of the relevance of usability is that it is a way of collecting quantitative data on aspects of the user experience such as error percentage and time spent, it meets user expectations which increase with experience in the digital space, it increases user loyalty, and it decreases feelings of insecurity among users. Poor usability, according to Uldall-Espersen (2005) results in wasted time, unnecessary increases in Internet traffic, user frustration and the discouragement of exploration.

Additionally, the notion of "usefulness", proceeding from information behaviour, is explored which takes into account the user context and represents more "humanistic" (Oulasvirta 2004) concerns within human-computer interaction. Both usability and usefulness have gained significant attention in user-centred evaluation (Tsakonas and Papatheodorou 2006). The combination of both aspects are found at the heart of the development of systems that enhance user satisfaction and performances (Tsakonas and Papatheodorou 2006).

Graphic design is "the first and last part of the user interface observed by the user" (Nielsen 1994), although the literature on the graphic design of the user interface is more limited than the usability and usefulness literature. Lauesen (2005) observes HCI texts often say little about "the actual design of user interfaces", and this is where lending added emphasis to the graphical user interface, as proposed by Nielsen (1994) as well as Mallet and Sano (1995) is beneficial, however early these graphic approaches within human-computer interaction may be, and can add to the breadth of approaches considered within HCI. These design elements may well provide insight into how the user processes the 2D screen, which modify how best the illusion of 3 dimensionality is achieved on the screen.

The approaches within usability and usefulness literature, on the one hand, and compositional principles for the graphic user interface, on the other, are connected by an ontological approach which can be described as rationalistic and cognitive. Mullet and Sano (1995) call this meeting of the objective and the intuitive the "communicative" approach. Both traditions have in common that, for the main part of their literary corpus, they assume an objective reality (a building or a computer system) and a human (or user) in relation to that design. Hence they both fall within a cognitive paradigm. This paradigmatic approach also allows for later matching with extra-disciplinary theories from classical architecture and information behaviour which will take place in this study when a design model is proposed, and analysis of the multi-faceted user experience takes place.

Nevertheless, slightly different approaches are found to govern usability/usefulness, on the one hand, and compositional principles, on the other. Usability literature tends to be governed by metrics and measurements based on abstract concepts, while compositional design tends to take a more objectivist approach to design, making use of applied techniques. Within this body of thought, for example, we find Newman and Lamming (1995), who argue that "[t]he best way to guarantee [successful design] is to go about the design in an organized way, making systematic use of the practices and methods that successful designers have used in the past". Much of design research is therefore means-end orientated (Hevner and Chatterjee 2010, p.57), and also interpretative in approach (Livari 1991), but although it is not dominated by a critical imperative, Hevner and Chatterjee (2010, p.57) point out that constructive research is also capable of adopting a critical approach.

2.3 Usability

A number of works listing and defining the key usability criteria are frequently cited in usability testing literature (e.g. Al-Badi *et al.* 2013; Alsumait and Al-Osaimi 2010; Chisnell *et al.* 2006; Nabovati *et al.* 2014). The main identified criteria refer to lists by Nielsen (1993, 1994, 1995), Macaulay (1995), Abran *et al.* (2003), Holzinger (2005), Chisnell *et al.* (2006), Thatcher *et al.* (2006), and Tsakonas and Paptheodorou (2006). These aim to have universal applicability and are therefore characterised as representing a "design for all" approach (Porrero 1998).

In addition, lists have been proposed for specific user groups. One common use group is the elderly (Czaja and Lee 2003; Chisnell *et al.* 2006). Some lists of usability principles are drawn up for specific domains, such as health (Zhang and Walji 2011) or for children and e-learning (Alsumait and Al-Osaimi 2010) because the generic principles are found to be too general for some specific contexts. Since many of these lists refer to and overlap previous schemas of more general applicability, they do not form part of our synthesis of principles, unless they refer to the specific user group and context, as in Alsumait and Al-Osaimi's (2010) study example, cited above.

Shackel and Richardson (1991) propose four attributes that determine the acceptance of a product: “effectiveness”, “learnability”, “flexibility” and “attitude”. Attitude is strictly a psychological component of the user, while the other three attributes are usability attributes.

Nielsen (1995) identifies the following heuristics or principles:

- “Visibility of system status”
- “Match between system and the real world”
- “User control and freedom” (e.g. users can exit unwanted parts of the system easily)
- “Consistency” of words, situations and actions
- “Error prevention”
- “Recognition rather than recall” (e.g. memory load of system is manageable, and instructions are retrievable when appropriate)
- “Flexibility and efficiency of use”
- “Aesthetic and minimalist design”
- “Help users recognize, diagnose, and recover from errors”
- “Help and documentation” (i.e. help and documentation should be easy to search, focus on the task, list concrete steps and be minimal in content) (Nielsen 1995).

Macaulay’s (1995) heuristics are summarised below:

- Naturalness: the user does not have to alter significantly his or her approach to the task and encounters processes which are self-explanatory
- Consistency of processes and layout throughout the system
- Non-redundancy: the user is not required to undertake laborious tasks that could be avoided
- Supportiveness: the system offers guidance to the user in its responses
- Flexibility: the system is able to support unpredictable or novice use.

Abran *et al.* (2003) propose the following criteria:

- Effectiveness
- Efficiency
- Satisfaction
- Security
- Learnability.

Holzinger (2005) referred to the following usability attributes:

- Learnability
- Efficiency
- Memorability
- Satisfaction(i.e. the system is pleasant to use)
- Low error rate.

Tsakonas and Papatheodorou (2006) propose:

- Learnability
- Ease of use
- Aesthetic appearance
- Navigation
- Terminology.

Sharp *et al.* (2007) propose the following criteria:

- "Easy to learn"
- "Effective to use"
- Provide "an enjoyable user experience".

Shneiderman and Plaisant (2010) isolated the following principles:

- "Consistency"
- "Offer informative feedback"
- "Cater to universal usability"
- "Prevent errors"
- "Support internal locus of control", which refers to making users feel that they are in control of the interface
- "Reduce short-term memory load".

ISO/IEC 25010:2011 specifies the following attributes:

- Understandability
- Learnability
- Operability
- Attractiveness.

Very few attempts have been made at identifying and organising usability factors from a range of thinkers in a systematic way (Frøkjer *et al.* 2000; Heo *et al.* 2009). Exceptions to this are found in Buchanan and Salako's (2009) identification of top-level usability heuristics and related measures, and Heo *et al.*'s (2009) identification of heuristics and related measures for mobile phones. Buchanan and Salako (2009) conducted a literature review of usability literature and selected the following attributes as key universal usability criteria:

- Effectiveness
- Efficiency
- Aesthetic appearance
- Terminology
- Navigation
- Learnability.

Before accepting these or other synthesised criteria, we need to ask if they are valid constructs and whether they retain currency at the time of writing. Buchanan and Salako's (2009) synthesis involved a methodological process of identifying usability and usefulness attributes and associated measures from the usability literature. They then tested the validity of the heuristics by compiling an integrated measurement framework and applied the framework in the context of a pilot study on an interactive search system developed by a health service library. Their pilot study suggested that the attributes and associated measures are persuasive, usable categories that encompass most of the attributes described by the principle usability theorists and practitioners This research can help verify the applicability of such characteristics in a 3D digital library, since as well as verifying existing proposed lists of criteria, it is important to consider whether in the changing digital environment any other criteria have become salient in the time elapsed since Buchanan and Salako's (2009) writing.

2.3.1 Efficiency

"Efficiency" refers to task completion and user productivity. Task completion time is considered a valid measure of efficiency (Petrelli 2008). Efficiency can also be measured by reference to error percentage and time spent on errors (Buchanan and Salako 2009).

Task completion time as a measure of usability depends on the activity performed, as do most usability measures (Newman and Lamming 1995). A visit to a 3D digital library could be completed in a variety of lengths of duration which subjectively leave the visitor satisfied. In addition, information may not be displayed in the most "efficient" way if users have to navigate through a walkthrough environment in order to access it, yet this is a defining characteristic of a 3D digital library.

When focussing on componential aspects of the interface (as is recommended the “component”-based approach to usability defined by Brinkman 2003 and Brinkman *et al.* 2008), these may be better measures because “dead ends” and other frustrations can disrupt “flow” and impact upon the user experience. (“Flow” is defined by Norman [2013] as the user’s complete immersion in an activity, to the extent that they may use track of time and the outside environment.) For this reason, measures of efficiency are well suited to the object-level analysis components within a system, but less to the speed with which information is retrieved, since 3D digital libraries do not offer the quickest way of achieving this possible and rather focus on the exploration, co-location, and contextualisation of information. The realisation that efficiency cannot precede the context pre-empts the definition of “effectiveness”, below.

In a 3D interface, navigation flaws could be an issue, measured by the number of failed commands on navigating through the system and encountering obstacles that impede progress, as well as the number of available commands not called upon (Abran *et al*. 2003).

2.3.2 Effectiveness

Effectiveness is the degree to which an interface helps users to achieve tasks as they were intended (Rubin and Chisnell, 2008). The ISO defines effectiveness as a top-level standard of usability (2009).

For task-based interaction, time-to-completion and task outcome are both measures of effectiveness (Marshall and Novick 1995; Abran *et al.* 2003). However, especially where the fundamental question of interaction is at stake, this approach can have its limitations (Novick 1997). The weakness associated with effectiveness measures is the possibility of weak relationships between inputs and outputs (Novick 1997).

Perhaps cognizant of such criticisms, Frøkjaer *et al.* (2000) propose quality of solution as the primary indicator of effectiveness. This approach emphasizes outputs and measures over task-based analysis. Frøkjaer *et al.*’s (2000) notion of effectiveness approaches the usefulness principles of “relevance”.

2.3.3 Aesthetic Appearance

Aesthetic appearance, in HCI, refers to how the human perception of beauty lends itself to the user experience. From an HCI perspective aesthetic appreciation can be associated or even has a causal effect with other favourable aspects of the user experience (Hartmann 2006; De Angeli *et al.* 2006). Specifically, attractiveness has even been shown to be correlated to user perceptions of system usability (Tractinsky *et al.* 2000; De Angeli *et al*. 2006; Dillon 2001) in a relationship referred to as the ‘‘halo effect”, since the attractiveness of a system appears to transcend the object and influence other judgements (De Angeli *et al.* 2006). There is also evidence that aesthetics can influence our decision-making, for example, in building online trust with consumers (Vieira 2010).

It is helpful to note in this research, which involves teenage participants, that the role of visuals in establishing positive responses to information resources is an especially important factor among young people. In an intervention study with 82 Dutch fifth graders (10 to 11-year olds) and four teachers, Kuiper *et al.* (2008, p.686) find that the aesthetic appearance of a website was an aspect all students mentioned whether positively or negatively. Agosto (2001) asked female young people aged 14-15 how they evaluated a set of preselected websites, concluding that “the importance of Website multimedia quality and quantity to young women cannot be overstated” (p.321).

Aesthetic appearance has been related to the use of specific design principles in the GUI. Mullet and Sano (1995) consider “reduction through successive refinement”. This is consonant with the idea of “simplicity” advanced by Minocha and Mount (2009). Mullet and Sano (1995) propose criteria drawn from graphical design which govern the arrangement of information and images on the screen. One technique is *symmetry*, which is governed by the simple 1:1 ratio. According to Mullet and Sano (1995), use of symmetry, especially that along the vertical axis (axis is “a line established by two points in space, about which forms and spaces can be arranged in a symmetrical or balanced manner” [Ching 1996 – in the architectural literature]) appeals on the aesthetical level, as well as being functionally appealing. However, certain efforts are required to make the 3D world more translatable to computer screens, such as *alignment* (Mullet and Sano 1995) which involves moving elements into alignment with each other. *Optical adjustment* (Mullet and Sano 1995) refers to the phenomenon whereby on the computer screen, objects may need to be resized so as to be pleasing to human perception. Ordinarily, adjustments such as these are made by the design professional before a prototype is seen and so they seem connatural to us. For example, in order to adjust to human optics, in the case of a square and a circle side by side, the height of the circle will often be slightly higher, because the human eye perceives the reduction in the surface area of the circle occasioned by its shape (Mullet and Sano 1995).

Following on from this principle, Mullet and Sano (1995) identified three elements of aesthetically attractive interface design: “scale”, “contrast” and “proportion”, as elements of good compositional arrangement. Scale, contrast and proportion are most relevant to interface design under three specific configurations, according to Mullet and Sano (1995). They are *establishing perceptual layers*, which is the technique of dividing the display into distinct layers using scale and contrast, which can be processed selectively or in sequence (Mullet and Sano 1995). It is therefore identified when the interface can be "read" in layers of detail. Mullet and Sano (1995) note that such contrasts can be used to differentiate different types of information. *Layering* is similar, in that a process of analysis is used to group different "layers" or qualitative types of information and that perceptual variables are used to layer the effect in presentations. *Sharpening visual distinctions* is a technique whereby contrast is found to be better achieved by subtle, non-naturalistic emphases in virtual environments. We would expect to see evidence of all three in the translation of 3D architectural design to digital environments, in order to render the visuals suitable to a screen medium.

Contrast can be used to establish meaning (Mullet and Sano 1995). Mullet and Sano (1995) point out that "any irregularity will be interpreted as significant by the user". The application of irregularity is suitable in instances when it is favourable to draw the user's attention to a specific element. There are several techniques for creating contrasts (Lauesen 2005). Sharp differences, like thicknesses, use of colour and movements create contrast within an environment (Lauesen 2005).

Mullet and Sano (1995) establish that visual contrasts are achieved by "manipulating the perceptual qualities of size, value, hue, orientation, texture, shape, and position. These characteristics were described by Bertin (1983) as the retinal variables, which, being "automatically" perceived, must be the "fundamental units of visual communication" (Mullet and Sano 1995). These visual variables can also impact upon understanding. Mullet and Sano (1995) point out that gradation in colour can be used to map semantic relationships among windows.

2.3.4 Terminology

Terminology refers to good terms used to describe functions and clarity of labelling (Buchanan and Salako 2009).

Agosto (2002a, p.22) found that sites with large blocks of text can subject youth to "textual overload" and associated feelings of anxiety, and simultaneously that a lack of visual engagement can lead young users to conclude that a website is "boring". However, this effect may diminish with age: Rose *et al.* (2009, p.12) studied 162 students in two groups aged 7-9 and 10-12 and suggest that the importance of graphics in preference to terminology diminishes in the older age cohort, with younger students experiencing more success with a visual aid as compared to a navigation aid employing terminology, whereas this difference did not exist among the older cohort.

2.3.5 Navigation

Navigation refers to the ease with which the user can traverse the interface using the tools which are available to him/her. Navigation rules emerge from a largely guideline-based approach to HCI (Shneiderman and Plaisant 2010).

Navigation is considered an important factor in user performance, as they are enabled to trace their place in the system, and to direct to previous or next destinations (Hartson *et al.* 2004; Theng *et al.* 1999). In any system's navigation, therefore, location awareness is important (Flavian *et al*. 2006). Location awareness relates to psychology, and has formed the basis of psychological studies, often across academic disciplines (Beaumont *et al.* 1984; O'Neill 1991a; O'Neill 1991b; Weisman 1981). The architecture literature review which has a section entitled "wayfinding" presents useful architectural findings that can complement HCI research. The ease with which one can form a cognitive map of an environment has been found to be related to orientation (Evans *et al.* 1980). The crossover with architectural research is highlighted by the shift to dimensional vocabulary in the case of virtual environments. For example, Darken and Sibert (1996) found that enabling landmarks to show themselves at a distance was an important wayfinding strategy in large virtual worlds, because they enable the user to feel orientated. However, some findings suggest that certain architectural criteria may not transfer successfully to the virtual world. For example, Lee *et al*. (2010) found that angular paths in VR resulted in a greater number of collisions, which suggests that the virtual user be afforded a smooth path through which to progress without collisions.

2.3.6 Learnability

"Learnability" is a requirement in the usability literature referring to whether users feel that they can productively use the system straight away, and quickly learn new functions (Ferreira and Pithan 2005; Jeng 2005; Sutcliffe *et al.* 2000). Folmer and Bosch (2004) suggest that time taken to learn tasks using the system or number of errors made while performing such tasks are valid objective measures of learnability. They qualify this statement by noting that these measures should be defined and considered relative to each type of interaction and user.

Brinkman (2003) studied the influence of excessive demands on mental efforts on the usability of a system. Following other researchers, he found that when "faced with a control strategy that is mentally too demanding to maintain, users may start deploying other strategies at the expense of efficient control to reach the primary goal or to remain within acceptable operational limits". This relates to the concept of cognitive load theory. Cognitive load theory (Sperandio 1971; Meister 1976; Sweller 1988, 1994; Hockey 1997; Cnossen 2000) is concerned with structuring learning so as not to put unrealistic burdens on working memory.

In the usability context, this means that a system should help users to cope at times of heavy human memory load by displaying information needed to accomplish a task, rather than placing the burden of keeping information active in the memory too heavily on the user (Brinkman 2003; Zhang and Norman 1993). Testing for mental effort may also be useful at usability testing stage (Brinkman 2003) because it highlights where the burden of user memory is high.

Where learnability is concerned, it is important to take into account a person's background because they may have more or less experience with digital environments, levels of digital literacy or ease of use and dexterity in 3D virtual environments. There are a wide range of computer literacies in society, and some people are especially literate in specific areas of computing, such as gaming, or finding and critically evaluating information. The abilities of "advanced users" and "non-advanced users" are often contrasted. Some conclusions about non-advanced users are that they do not understand how a tool works or have an incorrect understanding of it. In other cases, they try to accomplish all tasks with a single instrument (Fitzmaurice *et al.* 2008; Ware and Osborne 1990), e.g. only using one navigation tool rather than the whole toolkit.

Learnability may be altered in a 3D virtual world due to the use of visual representation, as well as written resources drawing on semantic memory. This new reality corresponds to the idea of "episodic memory" in cognitive psychology. Encouraging learning through episodic memory correlates to incorporating visual salience which is achieved by displaying items that would otherwise be displayed in discreet lists in a "walkthrough" or narrative fashion.

2.3.7 3D Interaction

With the transition from the WIMP interface (windows, icons, menus, and pointing device) to 3D user interfaces (3DUIs) (Baumgartner *et al.* 2007) in recent years, new principles for 3D interaction have arisen. Sharp *et al*. (2007) identified certain interaction principles which are especially relevant in 3D environments, because of the user's need for added guides and pointers in order to be able to interact effectively with virtual spaces. These were: visibility, feedback, constraints, and consistency (Sharp *et al.* 2007). Investigating virtual learning environments in *Second Life*, Minocha and Mount (2009), identified key design principles of: affordance, consistency, metaphors, ease of use and navigation, aesthetics, and simplicity. These all-encompassing features are reflected in Pinelle *et al*.'s (2008) "heuristics for the gaming environment".

Shneiderman and Plaisant (2010) codified yet further general measures that 3D designers can take to improve the interface for users:

- Minimize the number of navigation steps required for users to accomplish their tasks.
- Avoid unnecessary visual clutter, distraction, contrast shifts, and reflections.
- Simplify user movement (keep movements planar, avoid surprises like going through walls).
- Simplify object movement (facilitate docking, follow predictable paths, limit rotation).

"Visibility" (Sharp *et al.* 2007) can be associated with the specific application of principles in practice:

- Provide unobstructed views that are appropriate for the user's current actions (Pinelle *et al.* 2008)
- Avoid unnecessary visual clutter, distraction, contrast shifts, and reflections (Shneiderman and Plaisant 2010).

"Consistency" (Sharp *et al.* 2007; Minocha and Mount 2009) can be associated with providing consistent responses to users' actions (Pinelle *et al*. (2008).

These techniques cover aspects such as providing a larger field of view or supplying motion queue (sequencing the appearance and affordance of features in the environment). Some examples include: automatic speed adjustment, depending on scale; detection and deflection of obstacles; and tools for creating pivot points around objects (Andrade *et al.* 2011).

In a study on 3D Computer Aided Design (CAD) systems, Lee *et al.* (2010) found that there were specific principles specific to 3D parametric design. These were:

- "Maximisation of Workspace: Providing maximum screen space for carrying out the primary functions of the CAD system".
- "Graphical Richness: Replacing textual information with graphical information like imagery or animation to enhance user comprehension where appropriate".
- "Direct Manipulation: Providing interaction that is perceived by the user as directly operating on an object or entity within the system".

Tasks in immersive virtual environments are associated to 3D interaction and to specific devices (Dennemont *et al.* 2012). These tasks necessarily differ across applications, and many principles are representation-specific. One solution is to adapt the interaction to the needs and context (Bowman *et al.* 2006). Interaction techniques that may vary across context include:

- The choice of other techniques ("specificity") and to make variations to techniques ("flavour") (Octavia *et al.* 2010);

- Adding or managing modalities (Irawati *et al.* 2005; Octavia *et al.* 2010);
- Performing parts of the task automatically (Celentano and Nodari 2004).

Dennemont *et al.* (2012) note that these adaptions can be done manually by the developer or user, or automatically by the system.

Some of the key principles of 3D interaction are offered below. Most of them modify naturalistic interaction to make virtual environments more usable.

- Where possible, take steps to speed up interaction (Celentano and Nodari 2004);
- Diminish the cognitive load (Dennemont *et al.* 2012);
- Tailor the interaction (Wingrave *et al.* 2002; Octavia *et al.* 2010)

From a usability disciplinary perspective, Baumgartner *et al.* (2007) state that findings on the usability of 3DUI are mixed. Several studies take a cognitive approach, focussing on spatial abilities and memory tasks. Tavanti and Lind's (2001) results indicate that realistic 3D displays can better support spatial abilities and memory tasks, whereas Cockburn and McKinsey (2002), on comparing 2D and 3DUIs report that subjects' ability to relocate webpages deteriorated as their freedom to use a third dimension increased. Users in this study found the 3D interface less efficient and more cluttered (Cockburn and McKinsey 2002). However, these results are not conclusive because the 3D interface can have a variety of designs. For example, Cockburn and McKinsey (2002) went on to redesign Tavanti and Lind's (2001) experiment and concluded that spatial memory is fairly unaffected by the presence or absence of 3D interfaces. Attempts to create more natural and intuitive interfaces are ongoing. For example, Baumgartner *et al.* (2007) attempted to create an optimal system by matching task, interaction and visualisation demands.

A small number of studies have focussed on gender differences in orientation in virtual environments. In a ten-year review of empirical research in educational virtual environments from 1999-2009, Mikropolous and Natsis (2011) located three studies which found no gender differences in task performance in a virtual learning environment (Ketelhut 2007; Nelson 2007; Roussou *et al.* 2006), while two others reported that boys perform better than girls (Adamo-Villani and Wilbur 2008; Hokanson *et al.* 2008). On the other hand, they found that Roussos *et al.* (1999) found that females were better than males in orientating themselves in the environment.

Minocha and Mount (2009) identified consistency as a key design principle in 3D learning environments in Second Life. They argued that "consistency improves learnability by allowing people to leverage existing knowledge about how the design functions" (Minocha and Mount 2009).

Pinelle *et al.* (2008) have developed 10 heuristics for video games, which have similarities with Nielsen's (1993, 1994, 1995) heuristics, but raise specific issues relating to video games, such as customisability, skip non-playable content, etc. These heuristics were based on reviews posted by professional editors on a gaming website (Pinelle *et al.* 2008). A further set of heuristics were developed for playability by Desurvire *et al*. (2004), who took into account aspects of the gaming experience such as game play, game story, game mechanism, and game usability". A predictive evaluation for "usability and fun" developed by Baauw *et al.* (2005) contains a list of questions based on Norman's theory of action (1984, 2004, 2013) and fun-related concepts), so that as well as considering usability measures, they ask "global" questions such as "is the curiosity of children stimulated?" and "are the story and interface tuned to the fantasies of children?".

The precise design intersection between 3D and 2D design often requires that the insights of classical architecture are modified using digital design techniques in order to produce a similar result to real-life on a 2D screen. For example, in classical architecture, Scruton (2009) argues that the beauty of many landscape spaces depends on the lack of prescribed edges, and the changing perspectives and new views that emerge from traversing around them. HCI thought tends to appeal to the concept of "gestalts" where the important factor is the perception of units or objects, with rules about their definition (Lauesen 2005). The application of this approach, developed with 2D interfaces in mind, to achieving architectural perspective is a problem in which HCI and architecture intersect.

There is scope for using extra-disciplinary insights. For example, Alsumait and Al-Osaimi (2010) state that in their evaluation of HCI principles for children's e-learning, the defined approach should "address aspects of pedagogy and learning from educational domains, as well as usability factors such as the efficiency, effectiveness and satisfaction of interfaces".

A key difference between 2D and 3D environments is the creation of an interface whereby the user is able to directly manipulate the objects within an environment, as if it were real life. Hutchins *et al.* (1986) reviewed the concept of "direct manipulation" in digital environments and described the "feeling of involvement directly with a world of objects rather than of communicating with an intermediary", explaining that direct manipulation builds a bridge between the "gulf of execution" and the "gulf of evaluation". Direct manipulation interfaces are characterised by "visibility of the objects and actions of items; rapid, reversible, incremental actions; and replacement of typed commands by a pointing action on the object of interest" (Shneiderman and Plaisant 2010), and are therefore most marked in the context of the realism of a 3D virtual environment. Hence, the concept of "affordance", which has long been used in GUI design to denote placement of objects that suggest interaction possibilities (Mullet and Sano 1995), becomes a key design principle in the context of the 3D virtual world (Minocha and Mount 2009). In 3D environments, virtual objects can be manipulated by moving, selecting, opening and closing (Sharp *et al*. 2007). Extensions to these actions involve actions which are not possible with objects in the real world, such as zooming in and out, stretching and shrinking (Sharp *et al.* 2007).

In such environments, the aim is to produce direct manipulation interfaces that embody three main principles, according to Shneiderman and Plaisant (2010), with additional insights from Nicholson and Sarker (2002) and Minocha and Mount (2009):

1 "Continuous representations of the objects and actions of interest with meaningful visual metaphors" (Shneiderman and Plaisant 2010). Metaphors are "tools or processes that enable understanding of one thing in terms of another" (Nicholson and Sarker 2002). Minocha and Mount (2009) recommend metaphors as design features improving usability in *Second Life*.

2 "Physical actions or presses of labelled buttons, instead of complex syntax" (Shneiderman and Plaisant 2010).

3 "Rapid, incremental, reversible actions whose effects on the objects of interest are visible immediately" (Shneiderman and Plaisant 2010).

2.4 Usefulness

Usefulness, according to Rubin and Chisnell (2008) concerns "the degree to which a product enables a user to achieve his or her goals, and is an assessment of the user's willingness to use the product at all". In the digital library context, usefulness "answers the questions if [digital libraries] support users' information needs and work completion" (Tsakonas and Papatheodorou 2006). A product will not be used if it fails to achieve the specific goals of a specific user, even if it is highly usable, learnable and even enjoyable to use (Rubin and Chisnell 2008). A comprehensive approach to the HCI literature considers criteria relating to the concept of "usefulness" as well as the accepted attributes pertaining to "usability" (Landauer 1995; Buchanan and Salako 2009; Zhang and Walji 2011).

Usefulness is an important concept because, as the philosopher Chesterton (2007) points out: "'efficiency', of course, is futile", because, under that philosophy, "if any operation has occurred, that operation was efficient" but in the first place, in the abstract, it must be "right or wrong". There are limitations when usability criteria are applied without respect to usefulness. A person may be required to use a system as part of his/her work, and find it usable, but not useful to their goals, and thus find it an unpleasant imposition to use. For this reason, many of the search results in the literature review referring to usefulness involve studies with groups of users with respect to establishing if a system is both usable and useful.

In studies it is established practice for researchers to group data as pertaining to either usability or usefulness issues (e.g. Hong *et al.* 2002; Anderson *et al.* 2014). Studies in the healthcare sector testing specific applications with patient or clinician users have found that systems can be considered highly usable, but score lower on usefulness among users (e.g. Buchanan and Salako 2009; Tran *et al.* 2012). In other contexts, Lin *et al.* (2011) found that an interactive menu application provided by fast food chains to help customers make nutritious choices were "highly usable but not necessarily useful".

In their taxonomy of heuristics for a digital library, Buchanan and Salako (2009) suggest that usability and usefulness measures can be readily combined, with mixed-methods research yielding valid results. Their study of the application of usefulness in the literature yielded measures of usefulness under the headings "relevance", "reliability" and "currency" (Buchanan and Salako 2009). In other top-level summaries of usefulness, Tsakonas and Papatheodorou (2006) list "relevance", "reliability", "level of the provided information", "format" and "temporal coverage"; Liu (2004) lists "information reliability" and "credibility". Xie (2006) lists "content coverage", "reliability" and "level of provided information". It is considered that Buchanan and Salako's (2009) concepts sufficiently cover these aspects. Each heuristic is listed below with references to its application in the literature.

2.4.1 Relevance

Relevance can be said to refer to how well a system enables the accomplishment of user tasks and how well it contributes to the user requirement. The discussions of context of use can lead to the discovery of discrepancies between designer intent and situated usage, with indicative statements such as "I wouldn't use this in practice", or "what is the purpose of this?" demonstrating lack of relevance or situational currency (see Buchanan and Salako 2009). This closely relates to Frokjaer *et al.*'s (2000) conception of effectiveness, cited above, when they propose the quality of solution as the primary indicator of effectiveness.

Clarifying the appropriate way to test relevance using established investigatory techniques, Buchanan and Salako (2009) state that "within the context of system usefulness, relevance is associated with how well the system enables the accomplishments of user tasks and in particular, how well information retrieved contributed to the user requirement". In their conception, therefore, relevance relates to information retrieved. In short: a usable system which is used for the retrieval of information becomes useless if the information retrieved is unsuitable for the user. If other tasks beyond information retrieval are required, then the relevance of a system would be judged in relation to these.

In Hong *et al.*'s (2002) study of the determinants of user acceptance of digital libraries, uptake was predicated on usefulness, and among the criteria constituting usefulness, relevance was the main determinant of perceived usefulness.

2.4.2 Reliability

A second aspect of usefulness identified in the literature is *reliability* (Buchanan and Salako 2009). Reliability describes the accuracy, dependability and consistency of information retrieved using the system (Yang *et al.* 2005). As previously noted, reliability is an important measure in an information age, because people are often exposed to inaccurate, non-dependable and inconsistent information (see Wolton 2009).

2.4.3 Currency

Currency refers to the extent to which information is sufficiently up-to-date for the task it is to be used for (Pipino *et al*. 2002). Current information is of high value on websites where it is at a premium, such as commercial, financial and news websites. In libraries, and especially where history is concerned, information may remain valid for the task based on its overall importance to the community of interest long after it is written (Gonçalves *et al.* 2006) and may retain a research value beyond the later non-currency of the information contained within.

2.4.4 Credibility

Hilligoss and Rieh (2008) define credibility as a constituent of "information quality". They regard information quality as "people's subjective of *goodness* or *usefulness* of information […] with respect to their own expectations of information or in regard to other information available".

Wathen and Burkell (2002) propose that there are three stages of user interaction which serve to establish credibility. The surface level, which is based on aspects of usability, involves appearance, interface design and the organisation of information. The second "message" level is based on the credibility of source (competence, trustworthiness and credentials [Buchanan and Salako 2009]) and of message ("content, relevance, currency, accuracy, tailoring" [Buchanan and Salako 2009]). Finally, the "content" level is based on the user's cognitive state, such as knowledge and motivation. Credibility will to a large extent determine whether or not the source is accepted and put to further use (Burgoon *et al.* 2000).

Children and young people may have yet to develop their full capacity to evaluate a website's credibility. This is suggested by findings such as Eastin (2008, p.39), who note that children's evaluation of cues to determine "credibility" are often limited, for example "to an author's use of dynamic content, such as pictures or animation", which falls short of "accurate credibility assessments".

2.5 Future Directions

In the future, computer science may see developments as newer multimodal interfaces support more "flexible, efficient, and expressive means" of HCI, "more akin to the multimodal experiences humans experience in the physical world" (Oviatt 2002). As a result, Sharp *et al.* (2007) state that it is likely that future research will take account of the holistic experience of interaction, which aligns with perception, phenomenology and being "in the world". The 3DUI suggests the development of theory in interdisciplinary directions, as occurs in this study, with the addition of findings and insights from information behaviour and dimensional (architectural) design.

We suggest that one way is by adopting the hypothesis taken in this research, of the applicability of architectural criteria to 3D digital spaces. In software engineering, architectural vocabulary has become common to describe universal solutions which may be applied to a range of challenges and domains. Drawing from the "pattern" architecture of Alexander (1977), design patterns in programming languages have been deemed "pattern languages" since the expression was coined by Gamma *et al.* (1995). Pattern-oriented software architecture is thus a clear strand of thought in software engineering (see Brinch Hansen 1995; Buschmann *et al.* 1996; Schmidt *et al.* 2000; Fowler 2002; Hohpe and Woolf 2003; Freeman *et al.* 2004). In some ways, the application of 3D architectural criteria deriving from the built world may be said to build on such approaches. Though the metaphor is used more literally in the 3D sense, the idea of the applicability of rules across domains, albeit from beyond programming languages and instead deriving from classical architecture, may build on existing thought in the development of websites and enable them to engage with the wealth of theoretical perspectives relating to the 3D space and all the embodied action that this implies.

Another potential trajectory concerns applying the principle of the design of everyday 3D objects to the digital world. A key thinker to propose design principles for everyday objects was Don Norman, whose 1988 book *The Design of Everyday Things* was republished as a revised and expanded edition in 2013. His work is relevant because he proposed that the overarching design concern which made the human central was relevant to different domains of design, such as industrial, interaction and experience design, and may therefore have applicability to the 3D virtual space where few codified design rules specific to that domain exist.

Norman's (2013) design principles for 3D objects are:

- Discoverability
- Feedback
- Conceptual models
- Affordances
- Signifiers
- Mapping
- Constraints

Norman (2013) describes "discoverability" as the user's being able to work out what actions are possible with an object and how to perform them. "Feedback" is important in product design, and is successful when the product conveys information about what has happened with no delay, and the information is not excessive to the user requirement (Norman 2013). "Conceptual models" consist of conceptualisations that make things easier to understand – where "understanding" is described as clarity in both what the product is and how it is to be used (Norman 2013). Conceptual models thereby correspond to "mental models" in people's minds – with "mental model" a commonly accepted term in cognitive psychology.

The concept of "affordance" refers to the relationship between a physical object and a person – the object having certain properties and the person, as agent, having the capability to make use of the object (Norman 2013). The role of perception is important in the concept of affordance: "Perceived affordances help people figure out what actions are possible without the need for labels or instructions" (Norman 2013), a design feature that Norman perceives to be superior to signage in the 3D world. "Signifiers" are signs or objects that have a perceived affordance (e.g. a handle on the door carries a perceived affordance of openability. "Mapping" is the use of maps to correspond to spatial outcomes (Norman 2013). Finally, "constraints" are characterised as "anti-affordances" that invite people *not* to do something (Norman 2013).

Although architecture, and not the 3D object oriented principles of Norman (2013), is the subject of this thesis, it is suggested that Norman's principles may also be relevant to the 3D virtual space, since they are not altogether alien to the design of the 2D digital interface: in many cases they overlap with existing heuristics, and in others they depart in their 3-dimensional tenor. For example, when we hold Norman's (2013) principles against Nielsen's (1995) HCI principles, several parallels are found: between Norman's (2013) "discoverability" and Nielsen's (1995) "recognition rather than recall"; between "feedback" and "visibility of system status respectively; between "conceptual models" and establishing "match between the system and the real world"; between Norman's (2013) "mapping" and Nielsen's (1995) "help and documentation". In Nielsen (1995) we see some principles oriented more towards the usability problems specific to on-screen navigation, such as "flexibility and efficiency of use", "user control and freedom", and "helping users recognise, diagnose and recover from errors". In Norman (2013), on the other hand, some principles are more orientated towards 3D object manipulation: for example, "affordances" and "signifiers" can be seen as 3D versions of "consistency" in Nielsen, and Norman's (2013) "constraints" as a 3D version of Neilson's (1995) "error prevention". Hence, there is no difficulty in principle with HCI taking on principles from other design disciplines developed from the 3D world in order to furnish 3D digital design with a wider range of heuristics.

Even with the potential of HCI research taking on new trajectories such as those suggested in this thesis, usability and usefulness criteria remain foundational in the study of HCI. Their representational validity has not yet been convincingly challenged, although their applicability, it can be argued, is only to certain aspects of the user experience as systems become more multimodal and computer technologies surround and shape our experience in ever growing ways. It is therefore the researcher's conclusion that they should not be jettisoned as a framework through which to consider key aspects of the user experience, but that they can be complemented by newer angles that take into account the changed digital reality of the 3D digital library. Usability "has always been accepted as a major contributor to the perceived success of a system" and "for web-based systems, it is absolutely critical" (Al-Badi *et al.* 2013). Meanwhile, Buchanan and Salako's (2009) and Buchanan and McMenemy's (2012) justification of usefulness lends weight to the development of relevance, reliability, currency and credibility in relation to the context of the child user. With the advent of 3D environments, usability and usefulness criteria can be bolstered by research with reference to the 3DUI, gaming and virtual environments.

2.6 Key Themes

The key themes to be sought in the analysis of the user experience through the lens of HCI are therefore the following usability aspects:

- Efficiency
- Effectiveness
- Aesthetic appearance
- Terminology
- Navigation
- Learnability

As discussed, some of these themes may have specific applicability in 3D environments.

The following themes are relevant to the analysis of usefulness:

- Relevance
- Reliability
- Currency
- Credibility

Chapter 3: Classical Architectural Principles Literature Review

3.1 Abstract and Methodological Approach

Purpose – The main focus of this literature review is driven by the normative approach to construct a list of principles from the architectural canon to append to those drawn from the HCI literature, augmenting the scope of design principles for the 3D digital library space. HCI principles and architectural principles offer independent disciplinary approaches to 3D digital libraries, which in combination and applied to the 3D space can augment existing usability and usefulness criteria drawn solely from HCI. A key challenge is to identify what attributes can summarily be presented from the architectural canon for the use of 3D designers, given the wide scope and longevity of architectural literature. The purpose of this chapter is to present a list of architectural principles which may combine with HCI principles.

Methodological approach – A literature review identifies key principles of classical design. Given the compositional, rather than end-user, approach within classical architecture, a measurement framework is not proposed at this stage, but the combination of high-level principles from HCI and architecture is attempted in the subsequent chapter.

Databases on architecture were searched using defined search terms ("classical architecture", "classical architecture principles" and "architecture principles"). Due to the currency of much older materials in the classical architectural literature, a list of key classical works was derived in a snowballing fashion from citations in the literature.

The following databases were searched, although other articles were referenced elsewhere during the search and these were accessed to.

- Journal of Architectural Education
- Architectural History
- Architectural Research Quarterly
- Journal of the American Society of Architectural Historians
- Journal of Architectural Historians
- Design Issues

Articles were purposely sampled. Normative listings of design criteria were sought and inductively analysed for common attributes, and a list of principles drawn.

Findings – The main architectural principles drawn from the classical tradition are suggested as symmetry, proportionality, ornamentation, propriety, arrangement, commodity, and wayfinding features, with "beauty" as an overarching principle informing the others. In the literature, these aspects are often described in overlapping terms, but they are divided in this way due to their conceptual coherence across the literature.

Practical implications – A list of thematic codes for architectural analysis as a component of the user experience is provided at the end of the chapter. These concepts will be explored and their relationships with other codes from HCI and information seeking behaviour explored when it comes to the analysis of the data collected in this study.

3.2 Introduction

The chapter is predicated on the dimensional congruence between 3D architectural design and 3D digital design. We argue that in order to study the design of 3D digital systems more fully, it is apt to combine relevant architectural principles with HCI principles. This is because the scope of design is, according to Eames, met when there is a plan "for arranging elements in such a way as to best accomplish a particular purpose" (cited in Hevner and Chatterjee 2010, p.1). In the dimensional virtual environment, "elements" include architectural features, and not only abstract heuristics, and so it is appropriate that we turn our attention to the visual and dimensional way in which they are arranged, by looking beyond usability to the traditional discipline that concerns itself with the arrangement of the built world, namely architectural theory. 3D architectural design has one of the longest histories of any design discipline in developing design recommendations for the built world.

The approach of the following chapter represents a "researching design" approach to the 3D digital library (Hevner and Chatterjee 2010). According to Hevner and Chatterjee (2010, p.16), the researching design community has been concerned with methods of designing since 1960. "Researching design" differs from "design as research" which relies on *doing* innovative design, whose "contributions to the knowledge base" is said to "constitute research" (Hevner and Chatterjee 2010, p.16). Researching design, does not rely on the construction of an artefact, and has as its focus a more theoretical exploration of principles including those from domain-independent disciplines, such as architecture (Hevner and Chatterjee 2010, p.16).

The field is apt for more rigorous theoretical study. Jones (2012) notes that, in practice, architects are contributing in unique ways to CGI environments. Features native to classical architecture but not to any other disciplines, such as the milestone, via (way), crossroads, and demarcations of area (Lorda 2012) exemplify how 3D prescriptions and formulae are made within classical architectural compositional design, but not within objective-based HCI frameworks. The dimensional or "symbolic" aspect of architecture can thus be argued to fill a significant omission in current HCI heuristics.

In order to better define how researching design from an architectural perspective is going to occur, it behoves us to step out of the HCI framework and into architecture as a community of practice. The approach taken in this chapter is that of a principle-driven literature review, leading to an overall rationalistic design assumption, drawing on the field of compositional analysis in classical architecture within the architectural literature. The literature review focusses on the classical architectural canon, where certain principles of composition, although not always explicit, or taking different nomenclature, nonetheless "prevailed as invariants through the evolution of Classicism (Renaissance, Mannerism, Baroque and Rococo)" (Crespo and Martinez 1982). These principles are expounded in several treatises on architecture, which form the basis of the literature review. A brief overview of that canon is given at 3.3, before principles are isolated.

A justification of why the classical canon was chosen may also be warranted, since despite the longevity of that tradition, more recent movements in architecture such as Modernism (also encompassing Internationalism) and Postmodernism each challenge the classical tradition in their own particular way. As in other philosophical and cultural contexts, the use of these terms serve as umbrella terms for trends and movements in architecture in the twentieth and twenty-first centuries, with modernism coinciding with the rapid industrialisation of society with attempts to apply principles of architecture in a functional way, and with postmodernism coinciding with postmodernist ideas that worked playfully and critically with the existing canon, often by using a mixture of past styles (Conway and Roenisch 2014).

Because 3D digital design takes place on what is effectively a blank canvas, where the only given is 3-dimensionality and spatial configurations, there is no especial need for it to conform to only one style of architecture; indeed, even many of the laws of physics which govern or limit built architecture are no longer applicable in the digital space. Jencks observed in 1997 that "the contemporary museum is a spectacular contradiction of old requirements and new, mutant opportunities" (Jencks 1997), and we might say that no more so is this the case at present than in the digital space. Hence, given the relative novelty of 3D digital design in comparison to the architectural canon, direct representation of any built world architectural design in the 3D digital space can be said to bear always some degree of anachronism or irony.

One of the main reasons for using the classical canon in this research was our observations of 3D digital libraries, extant to 15 December 2013, which formed the basis of the study. When the research came to explore existing 3D digital library resources it was concluded that the architectural metaphors within had been applied quite conservatively, and in many cases uncritically. Every resource investigated in Chapter 6 depicts an aestheticized environment, whether having features reminiscent of the "white space" museum, the classical museum or as a reproduction of a classical environment. To this extent, we argue, the current 3D digital library examples employ somewhat "conservative" design motifs, compared to recent developments in the built museum world. Giebelhausen (2008) points out that in the built museum world, design has evolved to favour more casual or self-referential: in such spaces, the "flair of the abandoned" predominates. Perhaps this concrete reality would find its virtual equivalent in more folksonomic environments or user-constructed spaces, such as areas of the *Second Life* virtual world (see Minocha and Mount 2009). In contrast, the 3D digital libraries documented in this study were largely not open to this kind of bottom-up colonisation of the virtual space. While they could be argued to apply built world metaphors in a playful sense, since they were built on a virtual blank canvas of bits and bytes, the irony of recolonising urban spaces was somewhat lost to a somewhat more conservative and less critical reproduction of built world design. Furthermore, Giebelhausen (2008) wrote that in the built world, museums have increasingly come to "accommodate diverse collections and therefore can no longer be conceived as a unified and unifying representation of culture". However, the resources identified in Chapter 6 tended to be curated around a sole collection or historical period and therefore neither approximated the collecting mania of the modern museum nor the more fragmented or multi-cultural content of the postmodern museum. Curation around a sole subject, sometimes facilitated by the freedom of the virtual environment, is arguably another traditional facet of the 3D digital museum, compared to some recent ideas of museums which "no longer share the … aspiration to totality" (Giebelhausen 2008).

Since the 3D digital library bears some traditional hallmarks, the study is associated with more traditional norms of architectural design. Giebelhausen contrasts the postmodern as representing "use, flux and change" and the classical or modernist "white space" as representing "stasis and timelessness". Perhaps the metaphor would apply equally to the virtual spaces under investigation, since whereas sites like *Second Life* or folksonomic environments can be said to represent the former in the digital space, the 3D digital library resources under investigation represent more readily the "stasis and timelessness" of the classical building or cityscape. The reader may be interested to review the 3D digital libraries identified in Chapter 6 and the discussion when it is taken up again in the Conclusion chapter to consider whether they agree with this conclusion. We suggest that perhaps more recent ideas of 3D digital design will be reflected in future 3D digital library examples, and may have interesting ways of reflecting the realities of consecutive generations being online, each building on the Web of previous generations, in which case, as digital design evolves, perhaps we can expect an evolution of architectural theory in the digital space similar to developments already seen in the built world? To build upon what is set forth in this thesis using the classical canon, by employing newer theories of architecture, would therefore seem an appropriate way to advance 3D digital library research as examples worthy of study preponderate.

The discussion of the appropriateness of the classical understanding of architecture, as contrasted with other approaches, will be taken up again at the end of the research when the findings allow for the analysis and conclusions about the applicability of the design framework advanced in this literature review.

3.3 Principles of Classical Architecture

According to the famous top-level definitions of the Roman architect Vitruvius, a building should have usefulness (*utilitas*), robustness (*firmitas*) and beauty (*venustas*). Prak's (1968) translation is "function, construction and aesthetics", while Hevner and Chatterjee (2010), citing Mitch Kapor, refer to "commodity, firmness and delight".

However, over the centuries the classical canon has expanded to furnish us with a greater number of and more detailed principles that are said to accomplish good architectural design. The Renaissance architect Alberti (1988) derived main principles such as appropriateness or decorum, imitation of harmonic ratio found in nature and the human body, following an Aristotelian conceptual approach (van Eck 1999). At the functional level, he proposed practical feasibility and available resources (van Eck 1999). Another Renaissance architect, Palladio, produced designs and writings that strongly feature the use of light and materials, laying emphasis on the principles of proportion (in *I Quattro Libri dell'Architettura* 1965), by which he advanced practical methods for the sizes of rooms, and in symmetry as a feature of structural robustness (in *I Quattro Libri dell'Architettura* 1965). Palladio also incorporated principles of harmonic arrangement and ratio into his theory of symmetry and seems to equate harmonic arrangement with symmetry. Scamozzi (1964), who was influenced by Palladio's work, diffused many of the same principles in *L'idea della Architettura Universale.* Scamozzi (1964) considers *Ordinatione* (Order) or great importance, explaining that this entails use of appropriate grandeur (size), placement of parts, and commodity. *Dispositione* (propriety) is understood by Scamozzi as the selection of appropriate site, form and materials. Scamozzi also points to a principle which he names *Eurythmia*, which combines beauty "to the eye" with proportionality. Scamozzi follows Palladio in appearing to subsume both *symmetria* (symmetry) and *distributione* (arrangement or correspondence) into a principle of "correspondence" (or *distributione*). *Decore* (ornamentation) corresponds to the beauty of ornamentation on or in the building. A number of classical architectural theorists spanning the classical, Renaissance and early modern periods also compiled principles relating to the classical Orders (Ionic, Doric and Corinthian) (e.g. Serlio 1964, Barrozzio da Vignola 1562, Fréart de Chambray 2005, D'Aviler 1691, Chambers 1825). However, according to Mallgrave (2006), Orders only pertain to a particular application of classicism, characteristic of high-Renaissance classicism and therefore are not considered primary in our analysis.

The canon established by the above architects has endured, although it is clear from reading them that some of their definitions of principles and how they are applied overlap and are not exclusive, which has warranted some inductive sorting on our part. The history of classical principles continues to this day, where a degree of relativisation of the principles is relevant to our consideration of their enduring role. By the end of the 18th century and during the early 19th, classical architectural ideas were evolving, so that principles lost their "absolute" value as ideal norms associated with earlier thinkers to be conceived more as ordinary formal conditions subject to selection and application (Crespo and Martinez 1982). Principles instead began to be listed as "canonical systems" (Crespo and Martinez 1982). Numerous books from the 19th and 20th centuries were devoted to identifying and codifying the key characteristics of classical architectural design (e.g. Semper 1878-1879, Riegl 1893, Christie 1910, Robertson 1924, Summerson 1963; Gombrich 1979). Thinkers such as Robertson (1924) and Summerson (1963) referred to the application of principles as the "classical language of architecture", and to compare learning the criteria and motifs to learning a "grammar". Some classical architects, such as Stratton (1931) and Summerson (1963) continued to adhere closely to the role of Orders in defining a classical structure, and thus to a specific application of Classicism as a specific and time-bound aesthetical achievement, while others saw principles as subject to evaluation and acceptance or rejection (Crespo and Martinez 1982). More recent "grammatical" approaches such as Ching's (1996) adopt this latter path, by continuing to propose the application of classical principles to modern buildings. Meanwhile, modernists such Le Corbusier and Theo van Doesburg proposed a new canon which, although pattern-based, broke with many of the principles of the part. According to Crespo and Martinez (1982) the majority of modernist texts rejected the explicit use of compositional rules, so that apart from exceptions like Le Corbusier, almost none of the modernist "Masters" mention compositional systems.

The work of evaluating key texts to codify the principles contained within is a task that has been undertaken by 20th century classical theorists, and as a result, their lists of principles, too, can form the basis of our effort to produce a representative schema of the core principles that classical architecture offers. Among these, Curtis (1935) argued that the key principles were “arrangement”, “an intelligent comprehension of the character and purpose of the building” (which we understand corresponds to the principle of “propriety”), the adjustment of proportions, “simplicity”, “proportion”, “dimensionality” and the “relationship” of rooms to each other, use of “separation” and “connection”, “symmetry” and “balance” (with allowances for “freedom of the imagination”). Curtis’ (1935) principles relating to the urban environment were the relationship of the building to other buildings around it (the principle he calls “site”), the “point of view” by which it is seen. Edwards (1952) compositional principles are “number”, “punctuation” and “inflection”, “proportion and scale” and at the psychological level, “ornament and mouldings”, “colour, tone and texture”. Ching (1996) published a volume of principles that focussed on compositional continuity between classical and contemporary architecture. He focussed on the triad of “form”, “space” and “order”, with the aim of isolating an “elemental and timeless” architectural vocabulary (Ching 1996). Ching (1996) also proposes “axis and symmetry”, “hierarchy”, “rhythm” (corresponding to an idea of the pacing of the urban promenade with appropriate features) use of “data” (“datum”: a “line, plane, or volume that, by its continuity and regularity, serves to gather, measure, and organize a pattern of forms and spaces”), and “transformation”, an idea which ultimately relates to ratio and symmetry. Smithies (1981) also sought to list principles transcending classicism and internationalism. His key principles were “unity”, “expressiveness”, “magnitude”, “function” and “stability”, all of which relate mainly to built-world structural and functional considerations.

The scope of architectural literary review is potentially very expansive given the longevity of the discipline and the continued currency of many of the principles, and so some boundaries were set to the scope of the literature. These boundaries were intended to facilitate the isolation of principles, rather than curtail the search. As a result, in cognisance of the balance to be held between theory and practice, those texts which mostly consisted of theory about universal ideas but did not focus on principles were excluded from the scope of the literature review, as were approaches that mainly focussed on the application of external disciplines to architecture. The need to define the scope of the review was not only driven by the quantity of potential resources to be consulted but also because it has been observed that “there are many ways of studying architecture – from the point of view of the engineer, of the historian, of the critic, of the client – and each way seems to propose its own favoured concepts, and seems to arrive at an organization of the subject which, if not at variance with its rivals, at least bears no clear relation to them" (Scruton 1979). Several writers in analytical philosophy have taken an interest in developments in architectural theory since the 20th century (Scruton 1979; Haldane 1987-1988; Mitias 1994), and they indicate that since the advent of modernism there started a process which aimed at "abstraction" in architecture. In a popular textbook used by architectural students in the UK, Groat and Wang (2013) explain that the latest theory is marked by a narrative turn drawing on psychological or semiological theories, and so it is towards texts of more perennial principles that we turn.

When it comes to the isolation of principles, it will be borne in mind that the epistemological approach must differ from that guiding the heuristics and metrics of HCI. In that chapter, we were able to draw on an integrated measurement framework advanced by Buchanan and Salako (2009). Similar measurement frameworks for classical architectural principles were not located in the architectural literature, since the success of architectural design is said to reside in the application of principles themselves rather than in metrics. Classical architecture is very "standard issue" and reliant on formulas (Lorda 2012), and in this sense there is a different ontological orientation to be found in HCI and classical architecture respectively. Classical formulas are reliant on a philosophical approach which begins at the ontological level and "trickles down" into principles (Lorda 2012), and so fewer metrics are extant in the literature review, but this will be accommodated in the methodological approach to investigating 3D digital libraries which will be proposed in later chapters. The following sections list the principles as they were grouped after conducting the literature review.

3.3.1 Beauty

According to Alberti (1988), "the most noble", of all architectural conditions "is beauty". Alberti's idea of absolute beauty is considered to be of paramount importance to the classical tradition (Mallgrave 2006), and establishes a paradigm of "form", over "function". Lorda (2012) explains that the strength of the form is that it has immediate impact which can often be perceived irrespective of the beholder's prior cultural knowledge. "[W]e admire the beauty we see, rather than the utility we recognise", argues Alberti (1988). The classical approach to aesthetics associates beauty with traditional concepts such as proportion, fitness, perfection and virtue (Mallgrave 2006). The classical architects are people who strive for perfections in the design sphere, corresponding to an idea of "practical wisdom" (Aristotle 2009), such as achieving easily perceptive ratios between length, height and depth of a building (Wittkower 1967).

The idea of an essential relationship between application of ordered principles and beauty is clearly made in Edwards' (1952) guide to style and composition, where he opens the text: "This book enables the average person to judge whether or not a building is beautiful". According to the main part of classical architectural thought, beauty and order exist in harmony (Alberti 1988; Wittkower 1967). Since it is compositionally driven, because observed at the level of the plan, because of the relation of abstract beauty to practice: as Curtis (1935) writes, "plans are beautiful because of what they imply as architecture". We thus isolate "beauty", conceived as being a question of ordered principles, as the first principle arising from classical architectural theory, because of its centrality to the system.

The concept that beauty mirrors transcendent ideas may be unusual to modern ears. The concept relates to Platonic philosophy, whereas more modern philosophers such as Kant hold that beauty is an intersubjectively agreed idea. Hence the operation of intersubjective philosophies such as Shaftesbury or Kant's may relate more closely to modern ideas of beauty. Other ideas of beauty which are operative in the philosophical realm include Burke (1913), whose primary intention, according to Mallgrave (2006) is to "elevate the notion of the 'sublime' to an aesthetic category equal to the idea of the 'beautiful'", which changes the focus in design to what looks pleasing without appeal to the rules of order that arise from a close association between beauty and order. Hume's aesthetics, too, "broke with unprecedented boldness with the basic axiom of all classical art-theory, according to which beauty is inherent in the object".

The classical conception of beauty both transcends and underpins virtually all compositional principles and so does not draw direct parity with the criterion of aesthetic appearance, whose philosophical roots, if investigated, could be sourced within these modern philosophers. Usability questionnaires often operate on the implicit notion of beauty by consensus, since users are asked to rate the "attractiveness" of the system. Hence, in classical architecture, beauty transcends and underpins all other classical principles, yet the usability heuristic of aesthetic appearance merely participates in a part of what the whole classical notion of beauty implied.

3.3.2 Symmetry

According to Hermann Weyl, who wrote a seminal text on the subject of symmetry in 1952, "Symmetry, as wide or as narrow as you may define its meaning, is one idea by which man through the ages has tried to comprehend and create order, beauty, and perfection". The following paragraphs seek to interrogate how symmetry has been proposed for such ends in architectural theory and how its operation in design may influence the human experience.

A key principle relating to the classical arrangement for beauty is "symmetry". Symmetry consists of the "balanced distribution and arrangement of equivalent forms and spaces on opposite sides of a dividing line or plane, or about a center of axis" (Ching 1996). Axial symmetry can occur along one horizontal axis at its most basic, to cases where a vertical axis intersects the horizontal axis, to complex arrangements of primary and secondary axes with perpendicular orientations (Crespo and Martinez 1982).

Symmetry is observable at the plan level (Crespo and Martinez 1982). On studying plans, the ideal geometrical pattern is "absolute, immutable, static and entirely lucid" (Wittkower 1967). Drawings from the Renaissance illustrate the "overwhelming importance which the centralized part of such designs held for Renaissance architects: nothing could be more significant than the meeting of all the radii in the ideal centre" (Wittkower 1967). Ching (1996) identified two types of symmetry: bilateral and radial. In bilateral symmetry, the parts are arranged either side of a median access, so that a single plane is capable of dividing the building into two identical halves. Radial symmetry refers to the balanced arrangement of similar radiating elements so that the composition can also be divided into similar halves. Edwards (1952) proposes that one way of achieving symmetry is to use "conjugation" – the design of a building so that it is perceived as having two "wings" or two constitutive halves. Rasmussen (1964 states that when symmetry is applied, the visitor "receive[s] an impression of a noble, firmly integrated composition in which each room presents an ideal form within a greater whole" (Rasmussen 1964).

Curtis (1935) adds that the use of asymmetry may also be valid, according to a principle of human freedom. Robertson (1924) echoes this, saying that the "breaking of a rule" can also "add[…] a sense of freedom and vitality", and according to Crespo and Martinez (1982), architectural freedom can be widened through flexible interpretation of the rules. They nevertheless assert that in such cases classical rules are never "completely transgressed" (Crespo and Martinez 1982), while Robertson (1924) argues that in "unsymmetrical compositions there is always strict symmetry in those parts which have a direct reference to the principle axis", and that by "removal of the unbalanced parts", such compositions can be found to have symmetry. One such application is Ching's (1996) concept of "transformation", which he describes as the "principle that an architectural concept, structure or organisation can be altered through a series of discrete manipulations and permutations in response to a specific context or set of conditions without a loss of identity or concept". Other variants include "rotation" or "extension" (Crespo and Martinez 1982).

Human preferences for symmetry are well supported in the modern psychological literature. Evans *et al.*'s (2012) findings suggested that a preference for symmetry is distributed throughout the typical population as a part of people's cognitive and neural architecture. This followed on from research with human infants which demonstrated that children begin to show preferences for vertical symmetry at four months and the preference is well-established by twelve months

(Bornstein *et al*. 1981). More recent work has focussed on the link between beauty, attraction, the preference for symmetrical faces, and the outcomes of these preferences for sexual selection (Little *et al.* 2011; Burriss *et al.* 2011). Evans *et al.*'s (2012) data revealed that subjects experience and show evidence of a cognitive conflict when asked to perform matching tasks that required the matching of positive images with asymmetrical symmetry and images of disgust with symmetry. They also demonstrated slowed reaction times when asked to do so. These results pointed to an overall cognitive bias connecting disgust with asymmetry. A number of electroencephalography (EEG) studies have identified a link between symmetry and inherent attraction: Makin *et al.* (2012) recorded both EEG and EMG (electromyography) activity from the smiling muscle (*zygomaticus major*) in response to symmetry, which they concluded indicated a spontaneous positive emotional reaction to symmetry.

3.3.3 Proportionality

The idea of a "law of proportions", with or without an attendant transcendentalism, is a common theme in classical architecture. In the Renaissance, Alberti (1988) developed the underpinning principles of classical aesthetics by adopting the Platonic belief in a higher reality to the physical or phenomenal world, namely Ideas, and accepted that architecture can embody these ideas through adherence to mathematical laws or harmonic proportions. Palladio (1965) expostulated on the "most beautiful" ratios, by which we may infer an appeal to a higher "law". Ouvrard said that in classical architecture, we must presume a "law of proportions" as buildings without proportions offend the eye (Ouvrard 1979), an idea echoed by theorists such as Edwards (1952) although these latter theorists did not specify an underlying transcendentalism.

For Vitruvius, *eurhythmy* is the original term corresponding to proportionality, denoting "beauty and fitness in the adjustment of the members" (Vitruvius 1960). It is identified when "members of a work are of a height suited to their breadth and depth, and vice versa" (Vitruvius 1960). Vitruvius contended that a well-built man fits with his hands and feet extended perfectly into geometrical figures such as the circle and square (Wittkower 1967). Hence, in the Renaissance, Da Vinci's "Vitruvian man", which was named in honour of the Vitruvian principles which it adheres to. Renaissance theses on proportionality were widely applied, by Alberti, Palladio, and Serlio, and beyond architecture, by Titian in particular (Wittkower 1967). According to Alberti (1988), beauty "consists in a rational integration of the proportions of all the parts of building in such a way that every part has its absolutely fixed size and shape and nothing could be added or taken away without destroying the harmony of the whole".

The prescriptive philosophy which arises from the idea of a “mysterious harmony which pervades the universe” (Wittkower 1967) which continues to be salient today is clearly nuanced and we would do well to separate essentials from inessentials. Those inessential elements would seem to arise from the reappraisal of what is meant by order and design that has occurred since Darwin in the nineteenth century, whereby post-Darwinian views have diminished the absolutism of what Wittkower (1967) calls universally valid ratios. This reduces the idea of fixity in the proportions of architecture, and renders some of the prescriptions archaic by virtue of their fixity. Furthermore, Palladio’s neo-Platonic system is not the only canonical way of applying harmonic ratios – Platonism has not received universal credence.

Archaic fixidity can be found in the work of several Renaissance architects. Palladio, following his predecessors Alberti and Serlio, proposed seven “most beautiful and proportionate manners of rooms” (Palladio 1965). Palladio also developed principles for determining the heights of rooms, in proportion to their size. In short, he selected three types of means – arithmetic, geometric and harmonic – where in each case, the height of a room is equal to the mean (b) between the two extremes of the width (a) and length (c) of the room (Ching 1996). One example of the employment of ratios is in Palladio’s façade of *S. Francesco della Vigna*, where a unit of measurement was applied to all dimensions in the façade. The basic measurement (of 2 feet) is proportionally expanded throughout the façade, with consistent ratios of diameter to height and of small order to large order (Wittkower 1967).

In some architectural examples, the Golden Section, a specifically proportioned rectangle, governs the overall proportions of the architectural façade (Mullet and Sano 1995). Also in modernism, Le Corbusier based his Modulor system on the Golden Section, and according to Ching its use in architecture still endures today (Ching 1996). The Golden Section is formed by “sweeping the diagonal from the lower midpoint of the square to the baseline, where it forms the longer side of a rectangle whose height is the unit square”.

When attempts have been made in psychological science to test whether the Golden Section really does correspond to human preferences, results are however inconclusive. Fechner’s (1876) early experimentation suggested a preference for ratios in the vicinity of the Golden Section, and led to the “Golden Section hypothesis”, which assumed a visual preference for rectangles following the Golden Section ratio of 1.618. Later experiments have attempted to verify the initial results, revealing, generally, a preference for forms between the 1.5 and 2.0 ratio when a range of rectangles were presented. However, the validity of such experiments is disputed, since the preference for a central figure within a spectrum may merely be an artefact of the experimental procedure (Godkewitsch 1974) – an artefact which may have occurred in the case of Eysenck and Tunstall (1968) and Berlyne (1970), according to Godkewitsch (1974). However, the influence of the central figure does not explain the results in favour of the Golden Section obtained by Fechner (1876) and Lalo (1908), where the figures were randomly arrayed. Godkewitsch (1974) also identified a methodological weakness where mean ranks were used, since this led to the lowest mean rank falling on the median of the series. The above experiments indicate that there is little psychological or aesthetical basis to the particular ratio generated by the Golden Ratio or Section. It is one of many ratios applied throughout history, often in conscious deference to an idea of a higher "Law of proportion". Other commonly applied principles can be found in mathematical laws, such as those of Pythagoras (d. c.495 BCE) (Ferguson 2011) and Fibonacci (d. c.1250 CE) (Sigler 2003). The mathematical laws, numerical formulae drawing from Platonic philosophy and Christian theology, and musical intervals which had particular bearing on Renaissance architecture are summarised by Wittkower (1967).

A wide range of optimal ratios have been proposed by classical architects throughout history (Ching 1996), and given the fact that apart from sequences such as Fibonacci, many ratios do not have a scientific basis, it is understandable that in attempting to synthesise all classical architectural literature, no one or few ratios can be arrived at as of universal significance. It may be the case that a unifying notion of proportion is found only when we eschew specific ratios and instead consider that "proportion" denotes a certain familiarity and correctitude to the eye, in keeping with stable natures with which we are already accustomed in architecture. Hence, Robertson (1924) considers that the universal commonality of all laws of proportion is that they are based on a figure "having a stable nature" (Robertson 1924), such as a square. Atkinson (1924) states that the use of proportion satisfies "our desire for strength, security, and settled repose". The application of proportionality in classical architectural design can thus be summed up by the use of stable figures, and of "reasonable" (or regular, non-subversive) proportions. Whether or not a specific formula is applied, classical architects almost universally argue for principles which are regular and reject subversive design. Curtis (1935) argued that "reasonable dimensions should be assigned to rooms [and] their relation to each other".

3.3.4 Ornamentation

In classical architecture, ornamentation is the embellishment of a building, in the widest sense, ranging from the stones used to construct the walls, to the addition of items that we could consider ornaments in modern domestic vocabulary (Wittkower 1967). It can provide unity to composition, thereby complementing the entirety of the design. The function of decoration is "to increase the degree of cohesion between the parts of the design" (Edwards 1952). For example, in the application of ornament, which is a key attribute of classical architectural design (Edwards 1952; Lorda 2012), we find "the correct orchestration of the lineaments of design, the judicious choice of the material, and the polishing and refinement of appearance" (Mallgrave 2006). Ornamentation is not purely decorative in the classical conception. For example, ornamentation can also achieve differentiation of parts, through variety and emphasis (Crespo and Martinez 1982) and is hence considered an important part of the communicative design of the building.

3.3.5 Propriety

Propriety is defined by Vitruvius in *De Architectura*, Book 1, and commodity (a related concept) in Palladio's *Four Books of Architecture.*

Palladio (1965) urges that every "part of [a] member stand in its due place and fit situation" (Palladio 1965). Curtis (1935) described a situation whereby design elements were "regulated by an intelligent comprehension of the character and purpose of the building". Propriety can be said to relate to "magnitude", although Smithies (1981) sees magnitude as a component of proportionality. Magnitude is the application of different sizes to different types of buildings to denote grandeur or prestige. Thus, magnitude refers to scale, which implies "choosing a certain relationship between architectural and man in terms of architectural meanings such as monumentality" (Crespo and Martinez 1982). For example, temples and cathedrals suggest, by their size, that they serve "something bigger, or more important, than man" (Smithies 1981). Thomas Jefferson, the American president who was also a neo-Palladian classical architect, stated that the scale of public buildings was important because it made a statement of government stability (Jefferson 2012). "Domesticity" (Crespo and Martinez 1982) is the opposite of "monumentality" as it implies magnitude appropriate for a domestic space – usually smaller and cosier. Some of the "associative values and symbolic content" of propriety in architecture are thus "subject to personal and cultural interpretations, which can change with time" (Ching 1996). According to Smithies (1981) what the building "expresses" is mediated by subjective elements such as common influence (e.g. culture and religion) previous experience (good and bad experiences in that kind of environment), and prior knowledge (of types of architectural structure). All of these perceptive aspects may influence user interpretation of a building.

Magnitude can also denote the relative parts of a building as more important than other parts, and this is often referred to as the principle of "hierarchy" (Crespo and Martinez 1982; Ching 1996; Lorda 2012). Hierarchy "is obtained by giving relative value to different parts of buildings through formal devices and their relative position in the whole" (Crespo and Martinez 1982). According to Ching (1996), hierarchy consists of the "articulation of the importance of significance of a form or space by its size, shape, or placement relative to the other forms and spaces of the organisation". For example, the main façade of a building is the one it shows to the world and it serves to create an impact (Lorda 2012), and hence a building enriched by ornamentation at its head is "an unequivocal sign of hierarchy" (Lorda 2012, own translation). Both pediments and domes leverage the idea of hierarchy (Lorda 2012). The podium or pedestal also lend physical eminence to a structure (Lorda 2012). Palladio's designs use a pediment of a portico to act as frontispieces showing the main entrance of villas, which "add very much to the grandeur and magnificence of the work, the front being thus made more eminent than the rest" (Palladio 1965). The application of grander design to specific parts of a structure can be described as the "potent use of articulating members besides areas of particular significance" (Wittkower 1967). Transgression of hierarchy "is usually produced by the unification of form" (Crespo and Martinez 1982). For example, placement of features (e.g. light sources) may strive to connote equal importance to the various parts of a building (Wittkower 1967). We could call this "use of equal articulation to denote equality of features".

Grandness can be experienced negatively by users: large concentrations of big buildings can feel "oppressive" (Smithies 1981). We might consider well known examples of high rise estates or commercial developments that can have an intimidating effect. Hence, the relation between design and its "setting" is important, because in designing a building "we consider its composition as a total potential unity, but in fact every design must be seen in relation to a much wider setting" (Smithies 1981). The consideration of the surroundings and appropriate application of magnitude relates to Robertson's (1924) "virtue of sensitivity". In addition, user testing may result in evidence about human perception in grand environments, elucidating whether it is viewed favourably or not.

Propriety also corresponds to suitability of a structure to the surrounding environment; for example, certain materials are appropriate to the natural environment surrounding the structure; considering natural light sources in the design and use of the structure; the building may depend on natural resources (e.g. a spring or energy source). We would look for features set in digital recreations of natural environments to be aesthetically sympathetic to them. Cullen (1961) highlights how in urban architecture, aesthetical considerations depend not only on the design of individual buildings as discreet entities, because they also turn upon the experience of the urban environment as a collection of buildings. In the cityscape, the virtue of "sensitivity" (Stratton 1931) plays a role whereby some parts of the building or cityscape are altered in order to take account of surrounding features. For example, on the building level, smaller features within a building may reflect the main features. At the level of a cityscape, building parts could be or be diminished or increased in size, in order to lend emphasis to the extant features of the cityscape. In architectural design which considers the relationship between the elements of an environment, "[n]othing is experienced by itself, but always in relation to its surroundings, the sequences of events leading up to it, the memory of past experiences" (Lynch 1959). Curtis (1935) argues that "the position of the building with reference to its surroundings […] is also of fundamental importance".

3.3.6 Arrangement

Curtis (1935), calls the proper distribution and disposal of the other divisions in composition "arrangement". Stratton (1931) also urges each part of natural life seems to be naturally joined to adjacent parts, such as in the human face, where features could not be inverted without the whole relationship changing and the whole pattern becoming disorganised. Palladio (1965) states that harmonic arrangement relates to beauty, since "beauty will result from the form and correspondence of the whole, with respect to the several parts, of the parts with regard to each other, and of these again to the whole", so that the structure appears an "entire and complete body" wherein "each member agrees with the other".

Harmonic arrangement differs from mere symmetry or proportion in that it includes decision making about artistic composition. Hence, harmonic arrangement lends itself to expressiveness in composition, through the unity, arrangement and detail of parts. According to Rowe (1947), harmonic arrangement is a distinguishing feature of classical architectural building. While he noted similar principles of proportionality between a Palladian villa (Villa Foscari, Malcontenta, Italy, 1558, Andrea Palladio) and a structural grid of a villa by Le Corbusier (Villa Garches, Vaucresson, France, 1926-1927, Le Corbusier) – they conformed to similar proportioning styles and mathematical ratio, the key distinguishing factor in the classical villa with the use of harmonic interrelationships. Le Corbusier's villa was "composed of horizontal layers of free space defined by the floor and roof slabs" (Ching 1996) and the rooms were asymmetrically arranged, whereas the Palladian villa, with its principles of harmonic arrangement belonged to the classical tradition. The unity implied by harmonic arrangement thus defines "connections and continuity of form". The use of similar elements in different parts of a composition is common, as is a repertory of devices such as "modular patterns, interpretation of volumes tending to clarify the relationship between parts (Crespo and Martinez 1982).

Harmonic arrangement can also be achieved by appropriate framing devices, because they contribute to the harmonic composition of a structure. The framing elements flank and frame the main elements and act as "custodians" of a building (Edwards 1952). Various elements, such as arches, towers or columns, leverage the idea of "custodianship" or framing (Lorda 2012). The use of the baldachin is the use of any kind of protection over the user or visitor, such as a canopy or roof pavilion. Lorda (2012) points out that the effect of the baldachin is to "promise you somehow higher attendances" and provide protection from danger.

Establishing a centre of gravity is another principle relating to the meta-requirement of harmonic arrangement. This corresponds to the "centre of gravity" of an architectural composition identified by Robertson (1924). This may consist of a solid element, line or point (Robertson 1924). This technique, taken from painting, helps the eye to appreciate "a balance of objects" (Robertson 1924). Arrangement taking place around a principle of a centre of gravity denotes balance to the human eye (Robertson 1924). Uses of centres of gravity as a feature which balances a building are also prevalent in design for harmonic arrangement. The centre of gravity corresponds to a solid element, line or point (Robertson 1924) in an architectural composition. Ching (1996) refers to the use of the "datum", which is any line, plane or volume that has continuous and regular characteristics, which serves to "gather [and] measure" a building, and thus render it more balanced. Meanwhile, the use of circles involves the use of a figure that is "stable and self-centring", and therefore "placing a circle in the centre of a field reinforces its inherent centrality" (Ching 1996).

Another aspect of harmonic relationship is division for emphasis. Thresholds mark divisions in buildings and is a consequence of area. An area may have a privileged entry and the threshold divides the space into two distinct and successive parts. Separation in turn creates interplay between units and forms a multi-faceted dynamic whole, serving to "reconcile" different necessary elements (Wittkower 1967). Curtis (1935) argued that attention should be given to the degree of "separation or connection" between elements.

Another principle of harmonic arrangement, relating to the human body, is that of "inflection" (Stratton 1931). Stratton (1931) compares the classical column to a body with both a head and a foot, which cannot be inverted. The existence of elements which can be readily identified as the "head" or a "foot" of a building is typical of classical architecture, but not necessarily of other forms of architecture, such as modernism, where the use of inflection in design is not afforded such importance, and where columns could possibly be inverted without looking "upside down". Edwards (1952) also proposes the use of "inflection" as a means of relating all parts of a building to its whole. The parts of a structure are assigned a have a certain "weight", depending on size, or other attributes such as "colour, tone, texture" or "strength and vigour" of design (Robertson 1924).

Arrangement also relates to the principle of consistency. Buildings should be consistent (e.g. grand entrances correspond to grand interiors) or stylistic motifs should be consistent throughout (Vitruvius 1960). Vitruvius' postulate is labelled *dispositio*, or the "congruity of all parts" (Wittkower

1967). Robertson's (1924) principles of horizontality and verticality would appear to support an idea of consistency since they refer to whether a building is designed consistently in a "horizontal" or in a "vertical" way. A tall building, for example, should not be continually sub-divided by horizontal lines, since this is consistent with the plan of the building, and is seen to express an idea of "indecision" and "lack of conviction", even when it is employed with the purpose of reducing the perceived height of the building (Robertson 1924).

3.3.7 Commodity

Commodity is the relationship of design to a particular usage and is often offered as the translation to Vitruvius´ (1966) *utilitas*. According to Scott, "commodity" means that "architecture is subservient to the general uses of mankind" and that "buildings may be judged by the success with which they supply the practical ends they were designed to meet" (Scott 1914). Many examples of how cultural design aspects can be considered "fitting" can be found in the classical architectural literature. In ancient times it was argued that it is apt that hypaethral edifices in honour of gods of the heavens, the sun or the moon, ought to have openness to the sky and bring before us manifestations of the heavens (Vitruvius 1960). In Medieval times, these principles were used in the construction of Christian churches, with architectural manuals explaining how elements of the construction were analogous to the theology of the Church (Durandus 1906). Modern culture- or tradition-bound examples might be found in great imperial buildings, which put before us an idea of empire and permanency, of power and strength, as well as symbols befitting ideologies. "Commodity" is used in some texts as a translation of Vitruvius' *utilitas* – a use attributed to Sir Henry Wotton's version of 1624. While *utilitas* is also readily translated as "usefulness" we can see from the examples above that *utilitas* goes beyond a utilitarian conception of usefulness and might therefore be rendered "fitness for purpose", of which "commodity" is a synonym.

Commodity can also embrace the notion of motif, or the use of symbols to represent function. Symbols that accompany classical architecture are usually very simple and legible (Lorda 2012). In the past, examples on the high street might be the sign of a boot denoting a shoemaker's presence. In religious art, too, we see symbols which are understood by those who are familiar with the language, as in iconography. Insofar as such motifs incorporate cultural design features which are suited to a certain environment, at some point in history the populace may lose the ability to "speak" or interpret aspects of a language, as their forms become unfamiliar, especially because it is recognised that architectural forms are connected to the society in which they arose. To put it in Robertson's (1924) language, there is "no fixed and unalterable standard of appreciation, but rather a crystallization of opinion, which, accepted to-day as final, may be to-morrow rejected".

3.3.8 Wayfinding

Passini (1984, p154) defines wayfinding as, "a person's ability, both cognitive and behavioral, to reach spatial destinations." Passini's description is based on Downs and Stea (1973), who see wayfinding as comprising four steps: orientation within the environment, choosing a route, monitoring the chosen route and recognising that a destination has been reached. In *The Image of the City* (Lynch 1959) considered how features of the urban environment, including divisions, paths and landmarks aided the urban wayfinder in finding their way to a specific location. This section can be considered especially relevant since elsewhere in the literature the transferability of wayfinding design to virtual environments has been suggested. For example, Darken and Sibert (1996) hold that knowledge about human wayfinding in the physical world can be applied in virtual worlds to aid wayfinding, too.

Architectural legibility is the extent to which the designed features of the environment help people to create an effective mental image, or "cognitive map" of the spatial relationships within a building, and the following ease of wayfinding within the environment (O'Neill 1991a). It is the "ease with which its parts can be recognized and can be organized into a coherent pattern" (Lynch 1960). The ease with which one can form a cognitive map of an environment has been found to be related to orientation (Evans *et al.* 1980). In architectural research it has been shown that disorientation can have serious consequences. It can lead to physical exhaustion, stress, anxiety, and frustration (Carpman and Grant, 2002; Evans *et al.* 1980; Lang 1987; Lawton 1994), which can threaten people's sense of wellbeing (Lynch 1959 and limit their mobility (Burns 1998). When disorientation occurs, people may decide to leave a place or not frequent it again. In contrast, an environment that eases wayfinding may augur a pleasant user experience and increase the desire to visit (Cubukcu and Nassar 2005). The expression of anger, hostility and indignation by people faced with "illegible" public buildings has been reported by a number of architectural thinkers (Berkeley 1973; Dixon 1968; McKean 1972).

It is natural that a person's movement through an architectural environment should be considered in the process of architectural design, since according to Ching (1996), architecture is experienced "movement in space-time". Ching (1996) highlights the following applications of architectural principles or features to the person's experience of wayfinding and movement through the environment: "1) approach and entry; 2) path configuration and access; 3) sequence of spaces; 4) light, view, touch, hearing and smell" (Ching 1996). Design for the wayfinder is comprised of both physical artefacts and of the perceptual element, the "sensory perception and recognition of the physical elements by experiencing them sequentially in time" (Ching 1996). We move "in time, through a sequence of spaces" (Ching 1996), and thus experience a space "in relation to where we've been and where we anticipate going" (Ching 1996). When "beauty" and "firmness" (two of Vitruvius' criteria) are applied to progressing through a built environment, they depend on "optics" and "statics", argued Wren (1998). This corresponds to Ching's (1996) isolation of the "approach", or the "distant view", and Cullen's (1961, p. 9) isolation of the existing and emerging views.

From a critical theory perspective it is not always clear whether cognitive outcomes can result from design for the wayfinder. Environments are not only perceived by people; they are also conceived by people (Benyon n.d.). People produce spaces through their activities and practices, and their actions are not reducible to those of animals in a maze, Benyon (n.d.) points out, following Ledrut (1986). This view is advanced by those in a broadly postmodernist tradition such as Lefebvre (1991) in his *The Production of Space*, de Certeau (e.g. *Walking in the City*, 1993), and semioticians such as Barthes (1986) and Eco (1986).

The "narrative experience" corresponds to "sequencing features" (Wittkower 1967) which mediate the person's experience in an environment. Wittkower (1967) identified the use of sequencing features in Palladio's architecture. Following musical antecedents in classical architectural theory, Ching (1996) refers to "rhythm" as a principle of architecture. Cullen (1961) cites the approach to the Central Vista to the Rashtrapathi Bhawan in New Delhi as paradigmatic of the planned, structured and sequential approach, since the approach makes use of changes in perspective, from the hidden to the visible, evoking psychological experiences of isolation and remoteness, revelation and immediacy (Cullen 1961). This possibility can be hard to achieve in practice, first, because buildings exist in relation to an environment (Scruton 1979), secondly because of the artistic constraint in the realisation of architecture as a meeting of raw nature and prescriptive plans (cf. Alberti 1988) which makes the reconciliation of all principles hard to achieve.

The principle of entrance may be signified by a doorway, an archway, or the use of a passage through an implied plane between two pillars. The form of opening can range from a simple hole in the wall to an "elaborate articulated gateway", states Ching (1996), referring to all types of architecture. In classical architecture specifically, the opening is articulated with ornamentation to lend it emphasis. Following ancient classical architecture, the use of the lintel as a structural element resting on stone pillars above a portal or entrance is a key element of classical architecture, where the use of the lintel as a decorative, as well as a structural element, evolved.

Good formation of circulation spaces is said to go beyond their use as functional linking devices, and accommodate movement, pauses or taking in views (Ching 1996). Enclosed spaces form a private corridor, those which are open on one side provide visual and spatial continuity with linked spaces, while those which are open on both sides, often through the use of colonnades, become a "physical extension of the space" which they pass through (Ching 1996). These different "forms" can have different effects. According to Ching (1996), a "narrow, enclosed path naturally encourages forward motion", whereas wider paths not only accommodate more traffic, but also allow places for pausing or viewing.

A number of features can create a narrative experience in the architectural environment. The *via,* or "way" (Lorda 2012) adds order to an urban environment by creating a path and referring space and attributes to one's position within the path (Lorda 2012). Its direction or goal could be another feature, such as a milestone (Lorda 2012). Lorda (2012) states that the use of the *via* as a design feature suggests ideas of journeying and a constant flow, which is akin to poetic imagery of life and time as well as motifs in Buddhism and Christianity. Use of crossroads is another narrative technique of urban design (Lorda 2012). The crossroads marks a fixed point as routes converge and is an easy reference. According to Lorda (2012), it suggests "confluence, encounter, and complexity, as evidenced by its use as a literary image". The crossroads has a social aspect in the built world, as a meeting place.

The milestone is any signal, preferably a vertical element of a substantial size or notability, which marks the environment; for example, a spire, obelisk or tower. The milestone has a certain "field of gravity", because "all the surrounding space is referred to it" (Lorda 2012). It suggests "the stable, the enduring and the memorable". The effectiveness of milestones as features conveying such attributes allows them to be imbued with meaning.

The architectural approach of wayfinding has been proposed as directly relevant to the design of 3D virtual environments by several authors (e.g. Bridges and Charitos 1997; Vinson 1999; Dickey 2005). Vinson (1999) presented a set of 13 design guidelines to ease navigation in large-scale virtual environments, based on the design and placement of landmarks, whose form is drawn from the real world. In Vinson's (1999) guidelines, design aspects such as distinctiveness and visibility, and placement of features at junctions and thresholds, are proposed as helps to wayfinding. Bridges and Charitos (1997) proposed theoretical wayfinding criteria for 3D spaces based on the architectural theory of Lynch (1960). Although largely theoretical, Dickey (2005) conducted experiments which found roles for the use of landmarks, signs, paths and thresholds in 3D virtual spaces to support wayfinding.

3.4 Key Themes

The table below summarises the key findings of the chapter – namely, the key principles of classical architecture and their indicators. These indicators will form the foundations of thematic codes that will guide the analysis of the data collected.

Table 1. Summary of the key principles and indicators of classical architecture.

Transcendent principle: beauty	**Principles**	**Indicators**
	Symmetry	
	Proportionality	Use of ratio.
	Ornamentation	Use for beautiful ends. Use as indicator of function.
	Propriety	Appropriate magnitude. Sensitivity to surroundings.
	Arrangement	Centres of gravity. Division for emphasis. Inflection. Consistency.
	Commodity	Design for particular use. Use of motif.
	Wayfinding features	Sensory elements (light, view, touch, hearing, smell). Doorways. Circulation spaces. Vias. Crossroads. Milestones.

Chapter 4: Model of Combined Design Criteria for 3D Digital Libraries

4.1 Introduction

This chapter considers how the principles from HCI and classical architecture relevant to 3D digital design might be combined in a model to produce complete heuristics to guide the design of 3D digital libraries.

The principles listed come to bear upon the 3D digital library by considering it as a unique ontological space, characterised primarily by its aesthetic appearance, its fitness for use, and the user experience of being in and navigating through a 3D space. The classification of the principles identified from both HCI and classical architecture under these three headings, broadly correspond to the Vitruvian denotation of beauty (*venustas)*, usefulness (*utilitas*), and robustness (*firmitas*) – with the latter descriptor being applicable in a 3D digital library since it applies readily to the complex experience of user interaction in the 3D space: arguably the referent where "robustness" finds its equivalence in a virtual world.

The fact that high-level principles from both HCI and architecture can be grouped under three broadly Vitruvian headings is not simply a matter of semantics; rather, it is consistently argued in this research that the application of principles from both disciplines have representational validity in a 3D digital library due to both the ontological reality of 3D digital worlds and to the existential experience of exploration.

Ontologically speaking, the use of 3D versus 2D visuals creates a new virtual "dimension". Dimensional ontology was outlined by Frankl (1988) in *The Will to Meaning*. He gives the example of how in 2-dimensional ontology, the same phenomenon of a cylinder could appear as either a square or a circle when projected onto a 2-dimensional plain. People in a two dimensional world might argue about whether it is a square or a circle, whereas in its full dimensionality it is neither. 2-dimensional design is therefore limited in what it can set before us, whereas 3-dimensional design allows us to perceive in a way that more closely resembles our day-to-day vision. Even concepts such as usefulness, which have expanded the concerns of usability researchers to include aspects such as relevance are effectively abstract unless considered against aspects of the 3D ontology that make this experience unique.

Existentially speaking, a number of theorists have noted that 3D digital design encourages a "sense of presence", and the feeling or attainment of such is often a measure of a system's success (Lombard and Ditton 1997; Brown and Cairns 2004; Biocca 1997; Lombard *et al*. 2000). In the literature, a sense of presence is a "psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience" (International Society for Presence Research 2000). The existential sense of presence in 3D virtual worlds is analogous, we argue, to the sense of "place", in architecture, which is defined as our reaction to the position of our body in its environment (Cullen 1961). Cullen (1961) cites the example of a room, where one says to oneself "I am outside IT, I am entering IT, I am in the middle of IT" (Cullen 1961), while Bridges and Charitos (1997) have documented ways in which the virtual environment is analogous to the built in its providing users with an impression of being "in it". Sense of place has been investigated as an important attribute of online learning environments (Northcote 2008), and creating a sense of space is considered important to maximising the quality of student learning (Brook and Oliver 2003; Lorion and Newbrough 1996).

Since it has been argued that combining criteria to include those from 3D architecture gives apt expression to the design principles operating in the 3D digital space, and has ontological and existential value, a suitable model is therefore proposed to visualise the relationship. A model, according to Shenton and Hay-Gibson (2011), is a "stepping-stone towards the development of a higher-order creation". In Bates' (2005, p.3) definition of a model, it provides "a tentative proposed set of relationships, which can then be tested for validity". As such, the model has not yet evolved into a "statement of the relationships among theoretical propositions", but it does represent "a framework for thinking about [the] problem" (Wilson 1999, p.250). Hence, the model shows the association of principles, from a top-level perspective, whereas their application might depend on more complex considerations, such as functional requirements or on refinement through iterative design and user testing.

There are a small number of instances in which design criteria from HCI and 3D architecture have been theoretically combined in the digital space (Hong and Kim 2004). Both Hong and Kim (2004) and Hernandez Ibanez and Naya (2012) highlighted the relevance of the traditional architectural principles of *utilitas* (usefulness), *firmitas* (robustness) and *venustas* (beauty) as abstract principles by which any digital environment, whether 2D or 3D, can be evaluated architecturally. According to Hong and Kim (2004), *venustas* applies practically to visual design and aesthetics. The robustness (*firmitas*) of a website, they argue, can by evaluated by internal reliability, denoting the operational stability of websites. *Firmitas* is further denoted by external security criteria, representing the safety of websites from external threats. *Utilitas* indicates that websites should provide appropriate features for users to interact with the system and complete their intended activities (Hong and Kim

2004). Hevner and Chatterjee (2010) cite an early software engineering theorist, Mitch Kapor, who wrote that good software should be like a well-designed building, and exhibit the Virtruvian triad, of *firmness*, *commodity*, and *delight*. In his framework, a "firm" program should not have any bug that inhibits its function, a "commodious" program should be suitable for the purposes for which it was intended, and a "delightful" program is a pleasurable one to use (Hevner and Chatterjee 2010). Hernandez Ibanez and Naya (2012) also picked up the Vitruvian triad theme, citing three top-level principles, and then proposing a new criterion, "virtualitas" which would modify the other principles in the 3D context.

In our model, we propose that all of the criteria emerging from classical architecture and from HCI can be considered to be "aesthetically pleasing", "fit for purpose" or to "facilitate movement through the 3D space", corresponding to *venustas*, *utilitas*, and *firmitas*, respectively. We present a configuration of principles operating under this triad which builds on the early suggestion of Hong and Kim (2004), emanating as they do from the robustness and thoroughness of the literature review. Both Hong and Kim (2004) and Hernandez Ibanez and Naya (2012) present their concerns about the applicability of architectural criteria in the 3D space. Applicability is achieved in Hong and Kim (2004) through top-level, abstract application of the Vitruvian triad. Our approach furthers theirs by grounding itself in two separate disciplines, offering a more realist application of both architectural and HCI principles. In Hernandez Ibanez and Naya (2012) the proposition of a fourth principle, *virtualitas*, which describes the precise quality of the virtual system as modifier of Vitruvian design principles, is an insight which is built upon in our research by proposing a list of combined principles which can be investigated and evaluated through an experimental methodology, thus providing answers as to the relationships between principles and which ones are truly operative in the 3D user experience.

4.2 Process of Combining Criteria

The model proposes that the following principles constitute the aesthetic experience of a 3D digital library. As a result of the application of these principles, the 3D digital library is "aesthetically pleasing", a top-level criterion which corresponds to *venustas* (Vitruvius 1960).

Principles from classical architecture making a system aesthetically pleasing:

- Beauty – an overarching principle of all classical architecture
- Symmetry
- Proportionality

- Ornamentation
- Propriety
- Arrangement

Since “aesthetic appearance” is a key heuristic within HCI design, and yet so many of the above principles from architecture already constitute an aesthetic experience, we look to the associated metrics which we associated with HCI. In the HCI literature, aesthetic appearance relates to text and graphics. Since graphics in 3D digital environment dominate the user interface, forming a scenery or background, “scenery” is included in the list. The listed principles of aesthetic appearance from HCI are thus:

- Text
- Graphics
- Scenery

The second grouping of principles refers to what we might practically call “fit for purpose”. Broadly speaking, this corresponds to *utilitas*, but the translation of “usefulness”, because its association with HCI, gives less scope than “fit for purpose”, which can also incorporate architectural principles such as commodity. Apart from “commodity”, and the usability criterion of “effectiveness”, the majority attributes of a 3D digital library which is fit for purpose are in fact “usefulness” criteria from the HCI literature. The inclusion of “effectiveness” as a component of fitness for purpose comes because the discussion of the effectiveness of a 3D digital library is primarily in relation to its use as a resource that facilitates information goals.

The full list of principles making a 3D digital library fit for purpose is given below:

- Commodity
- Effectiveness
- Relevance
- Reliability
- Currency
- Credibility

The final grouping of principles concerns how the 3D digital library is designed to facilitate movement through the 3D space, as well as navigation where the interface presents 2D features such as list menus, for example. All of the listed features refer to the user's successful accomplishment of an in-world exploration task. All but one of the criteria are drawn from the usability literature, given the specific affordances of the digital space, but the architectural principle of wayfinding, which is mainly achieved through the placement of features that guide, also has applicability in the 3D space. The list of principles facilitating movement through the 3D space broadly corresponds to the third Vitruvian design consideration of "robustness". The principles are listed below:

- Efficiency
- Terminology
- Navigation
- Learnability
- Wayfinding

The groupings given above are not absolute; nor are criteria applicable in all circumstances, and the model may be refined over time. The criteria themselves came from an inductive process at the literature review stage and so may be open to discussion as to their interpretation and descriptive scope.

The model is offered as a useful resource for those seeking to understand the user experience in relation to design of 3D digital libraries, as it isolates successful design attributes of such environments. In later chapters, a methodology is offered that proposes to investigate the role and presence of HCI features through user testing, and of architectural features through qualitative data describing the user experience, matching measures and design features to user behaviour. The model may also be of use to developers and designers of 3D digital libraries since it brings together attributes from across disciplines, thus augmenting the scope of how design is considered in such environments.

The model is visualised in a way that groups the principles into a set of three broad applications broadly corresponding to the Vitruvian triad, and is itself representative of a 3D virtual environment. This option is taken in order to increase the comprehensibility of the model, with the principles associated with representative features in the environment, and also coheres with the overall philosophy of the research which assumes that the practical application of principles can correspond to a visual experience.

4.3 Model

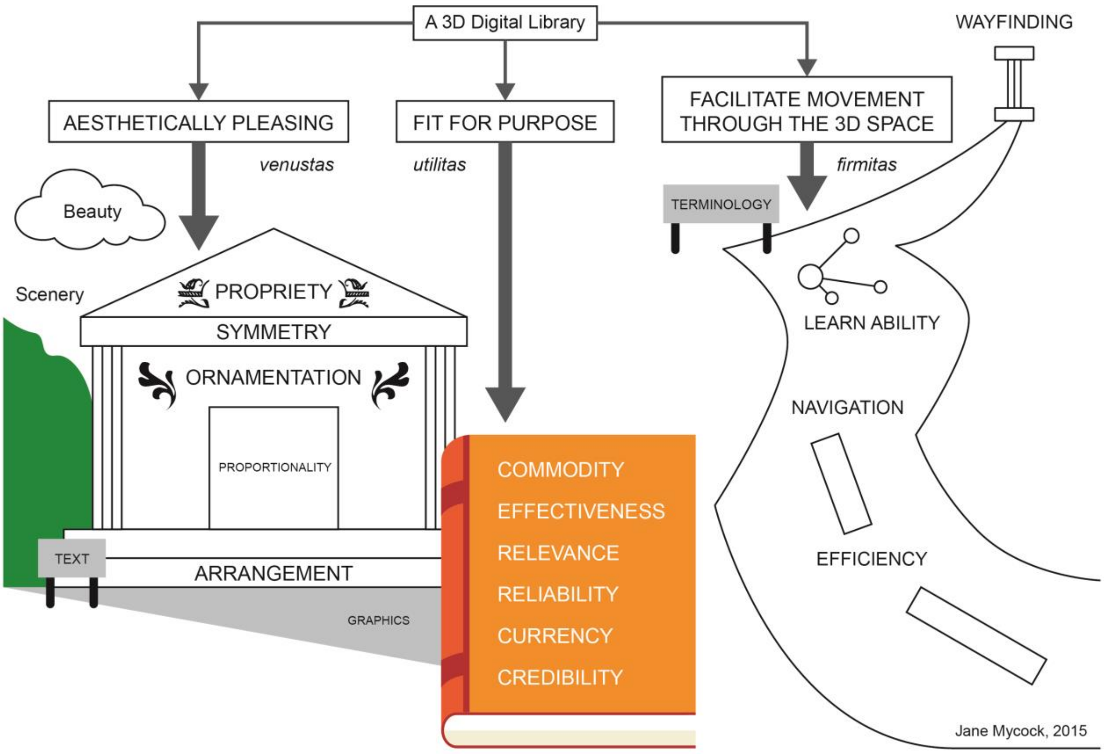

Fig. 5. Model showing the association of HCI and architectural principles for the design of 3D digital libraries.

4.4 Conclusion

The validation of a model of combined criteria has rested up to this point on the theoretical and inductive process of isolating principles from two separate disciplines which are hypothesised to have representative applicability in the 3D virtual world. It thus offers a unique contribution to the existing literature on heuristic approaches to 3D digital spaces. This chapter concludes the consideration of the design of 3D digital libraries from a purely theoretical perspective. The following chapter will consider user information behaviour, the primary theoretical lens through which we can consider user behaviour in relation to 3D digital libraries, and the purpose of that chapter is to build up a coherent theoretical framework before applying a testing methodology. The testing methodology bears the burden of examining the relationship between design and behaviour in existing examples of 3D digital libraries. It thus seeks to validate the model by mapping associations between principles and behaviour and will allow us to conclude to what extent the theoretical principles hitherto postulated are operative and measurable.

Chapter 5: User Information Behaviour Literature Review

5.1 Abstract and Methodological Approach

Purpose – The chapter reviews relevant literature embracing the fields of user information behaviour online, and information seeking as it pertains to curiosity. The literature review is relevant to understanding the user experience with the user group involved in testing the 3D digital libraries.

Methodological approach – Databases from Library and Information Sciences, especially digital library literature, Computer Science databases containing abstracts on HCI, and Psychology databases were consulted. The main databases searched were:

- LISA: Library and Information Science Abstracts (CSA) (ProQuest XML)
- ACM Digital Library
- Computer and Information Systems Abstracts (ProQuest)
- PsychINFO

The following search terms were used:

information seeking behavi*
and child or youth or young or adolescent
and online or internet

Information behavi$r*
and engagement
and child or youth or young or adolescent
and online or internet

Information behavi$r*
and curiosity
and child or youth or young or adolescent
and online or internet

Information seeking
and curiosity

Information seeking
and explorat*

Findings – As a result of these searches, themes of relevance to user behaviour in 3D digital libraries emerged. The first theme was the relevance of information seeking literature, where particular attention was paid to its focus on the notion of curiosity. The role of curiosity in the information search process was supported by wider literature (e.g. HCI, psychological and educational theories) concerning the notions of motivation and curiosity which was often referenced in the Information Seeking Behaviour (ISB) literature.

Practical implications – In researching 3D digital libraries, it is necessary to understand both the nature of the system and the nature of the user, making use of interdisciplinary insights to understand the human-computer interaction taking place. This chapter provides research insights to understand, primarily, the behaviour of the user, building up a picture from information seeking theory and supporting psychological and educational notions of the child user in the 3D virtual environment. Consequently, a list of thematic codes is provided at the end of the chapter. These concepts will be explored and their relationships with other codes from HCI and ISB explored at the time of analysis of the data collected in this study.

5.2 Introduction

A review of the information behaviour literature draws us in to look at information seeking in the learning context and especially to models considering the affective aspect of information seeking. The literature review discusses to what extent the notion of curiosity can be implicitly found in Wilson (1997) and Kuhlthau's (2004) ISB models. Wilson can be said to relate curiosity to motive but he also suggests a number of other variables from the interdisciplinary literature. Kuhlthau's (2004) theoretical framework is pinned to constructivist learning theory, but it also raises questions about the motivation driving students and whether this can be attributed to curiosity or to some other intrinsic or extrinsic factor. In search of the motivating factors, we then search more widely in the field of digital design and psychology for relevant supporting literature which supports the notion of motivation or the related concept of curiosity playing a role in information seeking. This process of more deeply embedding ourselves in the notion of "curiosity" and "motivation" allows us to better understand the explicit reference to these factors in Nahl's (2007) model of ISB and to understand the role of curiosity in providing the intentional impetus driving cognitive, knowledge construction and sensorimotor actions associated with Wilson's (1997) and Kuhlthau's (2004) models.

5.3 Information Behaviour Overview

According to Beheshti and Bilal (2014), "the field of human information behaviour can be understood as the ways and means by which people go about looking for information when faced with an information need, and the contextual factors to this process". Since "there are many instances in the study of information behaviour where researchers draw on ideas from other disciplines" (Shenton and Hay-Gibson 2011), interdisciplinary papers are sought across the information sciences, computer science and psychology. Results are purposefully sampled to provide a literature base with which to theoretically anchor the user experience with 3D digital libraries. Since the test group involves 13-15 year-olds from an English school, resources of either universal scope are considered, as are those specific to this particular age group and nationality. Where papers and books considering online or Internet activity is considered, resources written 2002-2014, and especially after 2006, are prioritised due to changes in the digital sphere which affect the currency of older material (following Shenton 2007).

It is important to clarify the use of "information behaviour" and "information seeking" which are interspersed throughout the chapter. Wilson (1999, p.263) specifies that information seeking behaviour is a sub-topic of information behaviour. However, in the context of the exploration of a 3D digital library, both information behaviour literature and information seeking literature may have salience. This is because in many cases, definitions of information seeking have tended to explain the phenomenon very much in terms of the pursuit of material, or to the retrieval of information, in response to a gap in knowledge, while information behaviour can extend to more browsing-like activities and the serendipitous encounter. The precise delineation varies across the literature. Case (2012) calls information seeking "a conscious effort to acquire information in response to a need or gap in your knowledge" and Krikelas (1983) considers information seeking to involve the undertaking fact-finding activities in order to satisfy perceived information needs. Others concur on the importance of the perceived need (Dervin *et al.* 1983, p.9; Shenton 2004, p.244; Shenton and Dixon 2003, p.8). While these definitions are useful, in the exploration of a 3D digital library, less active forms of information seeking might take place, calling on alternative definitions within the information seeking literature, or consideration of broader literature relating to information behaviour. Within the information seeking literature, there are thinkers who consider information seeking behaviour to be more generic: Erdelez (1999, p. 25) calls information seeking behaviour "a generic term for all types of information acquisition", and Kari (1998) argues that information seeking can also encompass the accidental discovery of information, as well as more purposeful behaviour. Krestel *et al.* (2011) hold that information seeking is compatible with the act of exploration, and not solely with finding specific facts.

This chapter takes into account the demographic specificity of the test subjects. Todd (2003) considers that children and adolescents are an understudied group in information behaviour literature considering the size and importance of this group. However, in the intervening years, the subject of child and adolescent information behaviour in the digital sphere has been addressed by numerous authors (Beheshti and Bilal 2014). Much of the child and adolescent literature focuses on a specific test group, and increasingly on type of device used, e.g.: toddlers' use of touchscreen devices (Agarwal 2014), young girls in information poor societies (Bilal and Jopeck 2014), and Maori secondary school students (Lilley 2014). Beheshti and Bilal (2014) call group types characterised by differences such as ethnicity, geographic location or other factors such as disability "special populations". Beheshti and Bilal (2014) also demarcate a third research emphasis, on "designing systems", which consider topics such as contextual variables, e.g. broadband access on children's information seeking, and interface design from the perspective of library catalogue design and information retrieval (Creel 2014). Following this conception, we can see that the testing volunteers involved in this research is a "special population" insofar as all participants are female and enrolled in a fee-paying school in England – a specific gender and typically socio-economic demarcation. Although it is not the main focus of this study, it is recognised that a limitation of this study is that this group will have their own characteristics. These may take place along socio-economic or gender lines. In a study of German secondary school children, Iske *et al*. (2008) found that general usage of the Internet in leisure time strongly correlated with educational background, with a higher-level parental educational background corresponding to more frequent Internet use. Gender differences are less clear since earlier studies showed divergences in Internet uptake (e.g. Tsai *et al.*2001; Large *et al.* 2002), but this may no longer be the case. In addition, the selection of 13-15 year olds is significant because it demarcates a developmental stage, and so research into distinct groups such as toddlers or the elderly is less applicable. Furthermore, the use of a 3D digital library as defined (accessed online, via a 2D terminal, and involving the dimensional characteristics discussed in the chapters on design) establishes a specific technology "type" or variable.

The technology type impacts upon information-seeking taking place therein. 3D digital libraries involve the curation of all materials within a self-contained virtual environment. This presents a different sort of environment to an information search "in the wild" (see Reynolds *et al.* 2013) which may involve a range of actors using a range of resources, including peers or parents. In descriptions of information seeking proceeding from library and information science, information seeking is conceived as spurred by a problem-solving orientation involving a range of resources. For example, Choo (2000, p.248) isolates key challenges for the information seeker: identifying possible sources, selecting those to be used, locating or making contact with them and interacting with the sources so as to obtain the desired information. In this research, at the 7-month interval after using the systems, the participants will be asked in focus groups about their information seeking activities *after* using the resource, whereby problem-solving approaches such as Choo's (2000) are very relevant, since the participants will have had to go through the stages of identifying, selecting, contacting and interacting with resources to satisfy any information needs. For participants at the 7-month interval, a problem-solving orientation is critical to their success (see Pitts 1994, p.251). However, when it comes to the focus groups taking place soon after exploration, we are dealing with an encounter where all information is contained within a system. Problem solving may take place within this context, in the weighing of which resources to explore, for example, but it is possible that other behaviours will be evident. For example, writing from a computer science perspective, Sharp *et al.* (2007) note instances where the user is not sure exactly what he or she is looking for and he or she may "browse through information, allowing it to guide [… the] attention to interesting or salient items" (Sharp *et al*. 2007). For this reason, both traditional information seeking literature, and considerations of behaviour from a wider computer sciences and cognitive perspective are discussed.

5.4 Approaches to Information Seeking Behaviour in the Learning Context

In this section we discuss ISB literature pertaining to the learning context. In particular we consider the models of ISB that have been proposed within a learning context.

Much of the ISB literature in the learning context considers specific, task-based searches, often imposed by the researcher (e.g. Marchionini 1995; Choo *et al.* 2000). The concept of learning is not key to all kinds of information seeking theory. In their paper introducing Shenton and Hay-Gibson's (2011) model, for example, they state that their model could encompass an event whereby a pupil would "merely copy and paste in order to complete a school assignment with the utmost expedition and, despite the aims of the teacher, no 'learning' as such is intended by the pupil". As Wilson (2000) states, "virtually all" studies (to the date of his writing in 2000) "are concerned not so much with human aspects of information use but with the use of information sources and systems".

However, Wilson (2000, p.51) notes a number of seminal studies since the 1980s have begun to shift the focus to user behaviour in information seeking. These studies, he notes, have been conducted using a switch from quantitative methods to qualitative methods. The key thinkers associated with qualitative studies into user behaviour who are noted by Wilson (2000) are Ellis (1987; Ellis *et al.* 1993; Ellis and Haugan 1997), Dervin (1983), Kuhlthau (2004) and Wilson (1981). In addition to those identified by Wilson (2000), Shenton and Hay-Gibson's iterative model of children's information seeking (2011), where information seeking is "shown to be an iterative process, with the individual often revisiting previous stages, frequently in response to difficulties", is also notable, while a study of information seeking with web interfaces, taking into account cognitive aspects was undertaken by Bilal *et al.* (2008).

Wilson (1981) initiated a developing information seeking model based on qualitative study of the user and their context which activated the process of information seeking behaviour. Wilson has since proposed a revised global model of information behaviour (1997) as well as one integrating problem solving aspects (Wilson 1999). The global model is more apt to this study, since the problem solving model (1999) perceives information seeking, searching and use "as associated with the different stages of a goal-directed problem-solving process, the stages being: problem recognition, problem definition, problem resolution, and (where needed) solution statement" (Wilson 2000). The global model (1997), on the other hand, does not require a specific goal direction or problem recognition, but considers the global influencers at the various stages of context of *information need*, *activating mechanism*, *intervening variables*, and *information seeking behaviour*, preceding *information processing and use* (Wilson 2000).

Dervin (1983) developed a "sense-making" approach to information seeking. This approach conceived information seeking as consisting of four constituent elements: a *situation* defining the context in which information needs arise, a *gap*, being the identification of a difference between the existing contextual situation and the desired situation of information acquisition, an *outcome*, being the consequences of this sense-making process, and a *bridge*, being the means by which the gap between situation and outcome is closed.

Ellis (1987; Ellis *et al.* 1993; Ellis and Haugan 1997) employed qualitative interviewing to identify common characteristics in the information behaviour of researchers, comprising: *starting*, whereby the user begins seeking information; *chaining*, being following footnotes or citations or citation indexes; *browsing*, being "semi-directed or semi-structured searching"; *differentiating*, or using this skill to filter information obtained; *monitoring*, or keeping up do date with current material;

extracting, or selectively identifying relevant information from a source; *verifying*, or checking the accuracy of information; and *ending*, which can be defined as “tying up loose ends” during a final search activity.

Kuhlthau (2004) advances a process-based model, which, she argues, is best applied where the focus is on a complex learning task involving stages of learning (Kuhlthau 2004). This approach ties in with the “concept of teaching library resources as evidence to be examined for shaping a topic rather than finding a quick answer to a question” (Kuhlthau 2004). The stages of the model are: *initiation*, *section*, *exploration*, *formulation*, *collection* and *presentation*.

Shenton and Hay-Gibson (2011) present a model based on a systems model. They describe a process not dissimilar to Dervin’s (1983) whereby an *external life situation* leading to *reflection*, or an *internal stimulus*, resulting in the identification of a *gap*, followed by stages of *action*, *delay*, and *undesired outcomes*. In comparison to Dervin’s (1983) model, Shenton and Hay-Gibson’s (2011) model revolves around the expectation that a user will frequently revisit previous stages, leading, it is hoped, to the *uptake of information* or *information capture.* Shenton and Hay-Gibson (2011) present a systems-based model which points towards the relevance of usability factors, especially barriers and complications such as “delays”, “unintended consequences” and “gaps”.

Bilal *et al.* (2008) present a model based on children’s information seeking in the International Children’s Digital Library (ICDL). The model shows users starting with an *information need*, followed by a process of *exploration* encompassing *recognising*, *browsing, differentiation*, and *reading*; and involving exploration steps such as *backtracking* and *navigating.*

In the history of ISB research, a number of thinkers have incorporated affect as a significant variable in information seeking. Savolainen (1995) incorporated the affective dimension as a significant variable in his everyday life information seeking (ELIS) model, and Solomon’s (1997) research in sense-making behaviour also deals with concepts of the affective dimension. Bilal’s (1998; 2002) work on the *Yahooligans!* search engine reported positive and negative emotions associated with information searching. Nahl (2004) starts from the position that affect influences cognition and focuses on the concept of motivation.

The process-based and affective approach to the information-seeking user is appropriate to this study, where the resources under discussion are highly interactive. Interactivity, according to Dresang (2005), refers to “dynamic, user-controlled, nonlinear, nonsequential, complex information behavior and representation" – hence, the user's behaviour is important to the study, since the system does not dictate a series of steps.

Of the models reviewed above, three in particular focus on the affective state of information seekers. Wilson's (1981) research found that information behaviour was prompted by the individual's "physiological, cognitive and affective needs" (Wilson 2000) and has been developed over the years to develop the intervening factors at each stage of the process (Wilson 1997). Kuhlthau's (2004) model associated each stage in the information seeking process (ISP) with certain feelings and specific activities. Bilal *et al.* (2008) attribute emotions to the start and finish of the ISP: *anxiety* and *uncertainty* at the start, and *certainty* and *satisfaction* at the end.

We considered two of these key models – Wilson (1997) and Kuhlthau (2004) – both heavily cited in the literature, in greater depth because of their especial focus to the affective aspects of the ISP *throughout* the process (Bilal *et al.* [2008] attribute affective aspects only to the start and close of the search). The affective aspect considered throughout the process is considered important because without a specific search task, the 3D digital library guides the user through design and it is therefore assumed to impact upon their affective state: the system itself can stimulate curiosity. Due to the pragmatic nature of the user study, which offers a snapshot of the learning process, the focus is on the concept of curiosity in such models rather than on learning theories pertaining to the learning process as a whole.

Wilson's (1997) model and Kuhlthau's (2004) model are now examined to discover if they mention curiosity, either implicitly or explicitly, and how terms are defined within the models.

5.4.1 Wilson's (1997) ISB model

Wilson's (1997) model of information behaviour is presented below.

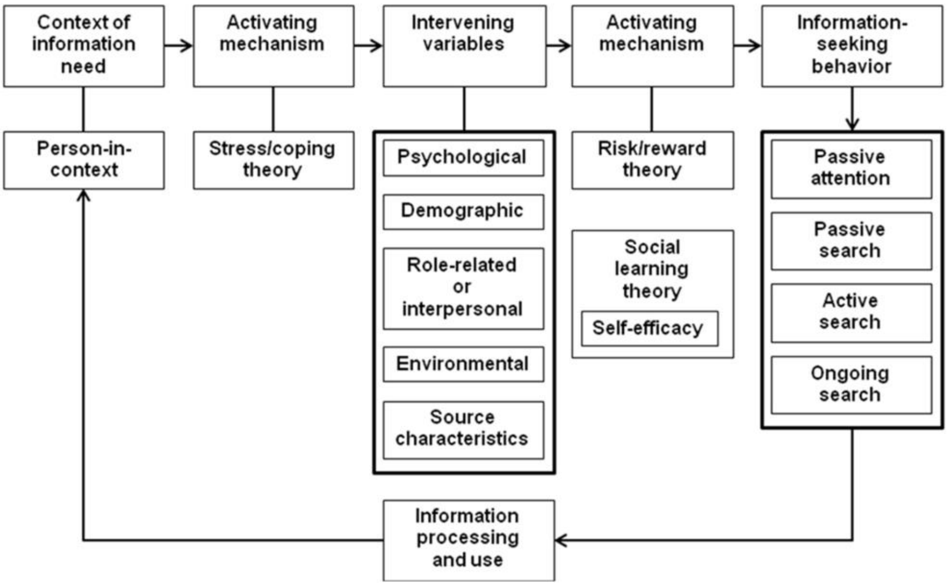

Fig. 6. "A revised general model of information behaviour" (Wilson 1997)

Wilson does not mention the notion of "curiosity" explicitly in his model. However, in drawing upon interdisciplinary intervening variables on the information behaviour model, Wilson (1997) uses concepts across "the study of personality in psychology; the study of consumer behaviour; innovation research; health communication studies; organizational decision-making; and information requirements in information systems design". Many of the theoretical perspectives cited touch implicitly, or occasionally explicitly, on the notion of curiosity.

To deconstruct Wilson's (1997) model from left to right, we can see how Wilson defines each term in the model. He begins with the "information need". Wilson maintains his 1981 reasoning (Wilson 1981) which holds that the concept is intractable, due to the subjective formulation of an information need, which is not directly accessible to an observer. However, Wilson (1997) then goes on to attribute "need" to the factor of a "motive". According to Wilson's new model (1997), motivation is necessary for a person to act on a need. He draws on Morgan and King (1971), who propose that needs emerge from three kinds of motives listed below:

> "Physiological motives (for example, hunger and thirst)
> Unlearned motives (including curiosity and sensory stimulation), and
> Social motives (the desire for affiliation, approval or status, or aggression)" (Wilson 1997, drawing on Morgan and King 1971).

According to Wilson (1997), citing Morgan and King (1971), an information need is attributed to a motive which may at the "unlearned" level be equated to curiosity. The motive is necessary for actually engaging in information behaviour: "if we assume that, for whatever reason, a person experiences an *information* need, there must be an attendant *motive* actually to engage in such behaviour" (Wilson 1997). In short, the information search process may be precipitated by curiosity, as being a sufficient attendant motive to progressing beyond a "need" to initiating information behaviour. Further attendant motives of relevance to a 3D digital library may be sensory stimulation, social motives arising from the classroom environment, and physiological factors are unlikely to play a part unless in a negative sense they influence a user to stop a search.

Wilson (1997) also considers gratification theory (Fiske 1990) in relation to the notion of motive. This theory suggests that people are active seekers of information to gratify their needs (Rubin 1986). Wilson (1997) also cites McQuail's (1972) "categories of gratification", which are listed below:

> "Diversion: escapism, emotional release
> Personal relationships: companionship, social utility
> Personal identify: comparison with life; reality exploration; value reinforcement" (Wilson 1997, drawing on McQuail 1972).

In this conception, motive is related to gratification which is in turn categorised as consisting of diversion (fun), or as having a basis in personal relationships or in exploration or construction of identity. Hence, that "needs" can be understood as driven by a "fundamental" motivation such as those listed by Wilson (1997), drawing on Morgan and King (1971) and McQuail (1972) posits "curiosity" and other elements of particular pertinence to a 3D digital library such as "diversion", not excluding the other factors as possible, variables, as key to the initiation of an information search process.

Wilson's (1997) research collates "intervening variables" under various headings:

"Personal characteristics

Emotional variables

Educational variables

Demographic variables

Social/interpersonal variables

Environmental variables

Economic variables

Source characteristics" (pp.556-667).

The main identifiers and effects of each variable, according to Wilson (1997) and the authors cited therein are given below:

- Personal characteristics mostly relate to people's interests, needs or existing attitudes (Wilson 1997). Rogers (1983) suggests that "individuals generally tend to expose themselves to ideas that are in accordance with their interests, needs or existing attitudes. We consciously or unconsciously avoid messages that are in conflict with our predispositions". In a self-directed information search, Johnson and Macrae (1994) noted that students tended to demonstrate cognitive avoidance of information not in keeping with interests, needs or existing values, whereas when information acquisition was controlled by the research "a reduction in their stereotype-based impression" was observed. Personal characteristics must also be at play when Wilson (2000, p.50) sees the incorporation of information "into the person's existing knowledge base" as central to information use.

- Emotional variables are briefly alluded to in Wilson (1997). He states that to speak of "emotional barriers" may be an alternative way of speaking about "blunting" – a notion in emotion/coping theory that can explain inaction at the initiation of an information search. It thereby seems that the main emotional factor cited by Wilson (1997) is "stress and coping theory" at the acting mechanism of an information seeking process. Wilson defines the acting mechanism as that which is a proximate cause of information seeking (Wilson 1997, p.554). Wilson (1997) cites Miller and Mangan (1983) who notes that "one key situational property that has consistently been found to affect stress is whether the individual has maximal information (predictability) or minimum information (unpredictability) about the event and its effects". Degree of predictability in the information seeking task would therefore be an identifier indicating level of stress at the outset of the search. Stress is in turn related to coping (Wilson 1997, p.554). Kleiber *et al.* (1995) stated that two types of "coping", labelled "emotion-focussed" and "problem-focussed" (Folkman 1984) have different instantiations: problem-focussed coping is involved when an effort to change the nature of an encounter in the environment takes place, whereas emotion-focussed coping "involves cognitive activities that do not alter the relationship with the environment but do alter the way in which the person-environment is perceived". Coping with a stressor will suggest various states as a result of "intolerance of uncertainty and intolerance of arousal" at the information seeking initiation. Wilson (1997) suggests that an understanding of stress/coping is relevant to understanding the information-seeking process. While he explicitly identified "curiosity" as a factor of "motive" there is also a relationship between motivation and stress/coping insofar as either factor or both in consort may be at play at the initiation of a search. Wilson (1997) describes the role of stress/coping in the context of seeking health information, where "even in critical circumstances when the gaps in the knowledge are evident, people do not always seek medical information" (Wilson 1997), citing van Zuuren and Wolfs (1991) who pointed out that information which could help solve a problem could be perceived as threatening in itself. Stress/coping is effectively added to Wilson's (1981) conception of "intervening variables" in information seeking, where he lists "personal barriers, social or role-related barriers, and environmental barriers". While stress/coping is posited by Wilson (1997) as an activating mechanism, and the other intervening variables at the next stage in the model, their precise ordering is likely complex. What Wilson's model reveals is that a number of variables, including the stress/coping variable may influence ISB.

- Educational variables can result in "advantages in acquiring and processing information" as cited in Ippolito and Mathios (1990). According to Wilson (1997), following Ippolito and Mathios (1990) the main identifiers of such a variable in operation are "GRADE, an educational measure; INCOME, (…) the total household income; and MHEAD, signifying whether there were two adults in the household". The main effect of combined advantages in this variable is an advantage in the ability to "incorporate" new information into behaviour (Ippolito and Mathios 1990). Related to this educational variable, calculated with reference to a scale, is the more subjective measure of a person's perception of their own knowledge. According to Radecki and Jaccard (1995), "personal perceptions of knowledge influence decision-making and behaviour to the extent that people may seek less information on topic they feel knowledgeable". Perceived importance of the topic also led to higher estimations of knowledge in Radecki and Jaccard's (1995) study. According to Wilson (1997), perceived knowledge may have more weight as a central construct in the analysis of ISB than actual knowledge.

- Demographic variables cited by Wilson (1997) include age and sex. However, the studies cited by Wilson (1997) are specific to health information provision and searches and are not generalizable. However, the commonly cited sources in the field throw light on the influence that age may have on information seeking in an adolescent group. The World Health Organisation states that adolescence starts at age 10 and ends at 19. Poole and Peyton (2013) suggest that early adolescence takes place roughly from ages 10-14 and late adolescence from roughly 15-19. During early adolescence, the age of most participants (mostly 13-14 with a small number of outliers aged 12 or 15) cognitive development takes place, with characteristics of this age group including deferring to group opinion, sensation seeking and risk-taking behaviours (Dahl 2004). Intellectual developments with this age group include considering hypothetical questions, reflecting on how choices might impact the future and recognising other points of view to their own (Mack *et al.* 2009). Literature citing the effects of age or gender on information seeking, especially on the notion of curiosity, with generalizable results is scanty.

- Social/interpersonal variables include cultural differences (where in the broadest sense, culture can also extend to workplace or educational culture). Wilson (1997) used Hofstede's (1980) four tested dimensions of how cultures might differ: in *power distance* (i.e. acceptance of unequal distribution of power in organisations), *uncertainty avoidance* (the extent to which a society feels threatened by and thus avoids uncertain situations), *individualism-collectivism*, and *masculinity-femininity*. However, Wilson (1997) cites no studies indicating the effect of cultural differences on information seeking. These are merely hypothesises: e.g. where high *power distance* exists, information exchange is likely to be lower.

- Environmental (or situational) variables (Wilson 1997) include time limitation which constricts information exchanges (Wilson 1997; Cameron *et al.* 1994).

- Wilson (1997, p.559) summarises economic issues relating to ISB as falling into two categories: "direct economic costs, and the value of time", which may affect effort spent in searching (Stigler 1961), although other writers such as Jacoby *et al.* (1978) state that wage value of time is not the only factor, since people may search for other reasons such as simple enjoyment (an implied "motive" impinging on the notion of curiosity).

- "Source characteristics" in Wilson (1997) refer to two factors which are strictly characteristic of the source: access and credibility. According to Wilson (1997) "a fundamental requirement for information-seeking is that some source of information should be accessible. The lack of an easily accessible source may inhibit information-seeking altogether, or may impose higher costs than the enquirer is prepared to pay". Wilson's (1997) definition of credibility coincides with the definitions advanced in usefulness research (a companion to usability research). Wilson's citations of Kotler (1991) and Lord and Putrevu (1993) indicate an understanding that perception of credibility is also a subjective factor.

In considering risk/reward theory as the provenance of other activating mechanisms to the ISP, Wilson (1997) cited Settle and Alreck's (1989) fivefold components of perceived risk. These are:

> "*performance risk* – concerning the probability of a product performing to an accepted standard;
>
> *Financial risk* – is the product affordable, or should a cheaper product be found?
>
> *Physical risk* – is the product hazardous to the individual or his property?
>
> *Social risk* – will the product impress friends and colleagues? And
>
> *Ego risk* - will the product improve the person's state of happiness?" (Wilson 1997, citing Settle and Alreck 1989)

Wilson (1997) cites Aaker *et al.* (1992) who suggest that these may have an effect on information search insofar that more active searching is likely to occur when the risk associated with a product is high. Wilson (1997) cites an example of information searches in special libraries in relation to patent or legal information, where exhaustive searches are common and the risk of failure may be high.

Wilson (1997) cites "self-efficacy" as a sub-topic within social learning theory. Cited by Wilson (1997), Bandura (1977) defines self-efficacy as follows: "an outcome expectancy is defined as a person's estimate that a given behaviour will lead to certain outcomes. An efficacy expectation is the conviction that one can successfully execute the behaviour required to produce the outcomes. Outcome and efficacy expectations are differentiated because individuals can believe that a particular course of action will produce certain outcomes, but if they entertain serious doubts about whether then can perform the necessary activities such information does not influence their behaviour". According to Bandura (1977), the extent to which a person feels a sense of self-efficacy can affect whether they will try to cope with given situations, and Wilson (1997) argues that this can be applied as a general determinant of ISB. Subjective doubt about an individual's capacity to use a resource or conduct a search may result in their failure to use the resource, states Wilson (1997).

In his 1997 model, Wilson lists four types of ISB. These are defined as follows:

> Passive attention – e.g. listening to the radio or watching television programmes, where information acquisition may take place without intentional seeking;
>
> Passive search – occasions when one type of search results in the acquisition of information that happens to be relevant to the individual;
>
> Active search – where an individual actively seeks out information;
>
> Ongoing search – where an active search has set out a basic framework of knowledge but where occasional continuing search is carried out to expand one's framework (Wilson 1997).

A key factor attributed to influencing the type of search is presentation format (Wilson 1997). He cites Bettman and Kakkar (1977), who state that "the strategies used to acquire information are *strongly* affected by the structure of the information presented. In effect, consumers process information in these studies in the form it is given. Acquisition strategies are totally adapted to the task environment".

Wilson's (1997) citations are supported by Heinstrom's (2006) assertion that at a physiological level, all information processing depends on attention (Heinstrom 2006). Heinstrom goes on to write: "Whether found through deliberate searching or accidental discovery any encountered information piece must be recognized for its potential cognitive or affective value in order for it to be chosen from competing stimuli" (2006). The form of presentation and its influence on attention could therefore be hypothesised to influence which type of ISB takes place. The cognitive process described by Heinstrom is related to motivation, which both "fuels both the initial receptivity and guides the continued search and information analysis" (Heinstrom 2006).

5.4.2 Kuhlthau's (2004) ISB model

Kuhlthau's (2004) model of the information search process is presented below. According to Kuhlthau (2004), the "model of the information search process incorporates three realms: the affective (feelings), the cognitive (thoughts), and the physical (actions) common to each stage. In turn, tables are reproduced which further break down each suggested stage of the ISP model into attributes comprising "thoughts", "feelings", "actions", "strategies" and "mood". This model is considered here because of its emphasis on these affective aspects. The model and associated tables are annotated with underlining to distinguish concepts with a possible connection to curiosity or terms to be investigated and explained.

Model of the Information Search Process

	Initiation	Selection	Exploration	Formulation	Collection	Presentation	Assessment
Feelings (Affective)	Uncertainty	Optimism	Confusion Frustration Doubt	Clarity	Sense of direction / Confidence	Satisfaction or Disappointment	Sense of accomplish-ment
Thoughts (Cognitive)	vague			focused	increased	interest	Increased self-awareness
Actions (Physical)	seeking	relevant Exploring	information	seeking	pertinent Documenting	information	

Fig. 7: Kuhlthau's (2004) model of the Information Search Process (p.45)

Table 2: “First Stage of the Search Process – Task Initiation” (Kuhlthau 2004, p.44).

TASK	THOUGHTS	FEELINGS	ACTIONS	STRATEGIES	MOOD
Stage 1 – Task Initiation					
To prepare for the decision of selecting a topic	Contemplating assignment Comprehending task Relating prior experience and learning Considering possible topics	Apprehension at work ahead Uncertainty	Talking with others Browsing library collection	Brainstorming Discussing Contemplating possible topics Tolerating uncertainty	Primarily invitational

Table 3: “Second Stage of the Search Process – Topic Selection” (Kuhlthau 2004, p.46).

TASK	THOUGHTS	FEELINGS	ACTIONS	STRATEGIES	MOOD
Stage 2 – Topic Selection					
To decide on topic for research	Weighing topics against criteria of personal interest, project requirements, information available, and time allotted Predicting outcome of possible choices Choosing topic with potential success	Confusion Sometimes anxiety Brief elation after selection Anticipation of prospective task	Consulting with informational mediators Making preliminary search of library Using reference collection	Discussing possible topics Predicting outcome of choices Using general sources for overview of possible topics	Primarily indicative

Table 4: “Third Stage of the Search Process – Prefocus Exploration” (Kuhlthau 2004, p.47).

TASK	**THOUGHTS**	**FEELINGS**	**ACTIONS**	**STRATEGIES**	**MOOD**
Stage 3 – Prefocus Exploration					
To investigate information with the intent of finding a focus	Becoming informed about general topic Seeking focus on information on general topic Identifying several possible focuses Inability to express precise information needed	Confusion Doubt Sometimes threat Uncertainty	Locating relevant information Reading to become informed Taking notes on facts and ideas Making bibliographic citations	Reading to learn about topic Tolerating inconsistency and incompatibility of information encountered Intentionally seeking possible focuses Listing descriptors	Primarily invitational

Table 5: “Fourth Stage of the Search Process – Focus Formulation” (Kuhlthau 2004, p.48).

TASK	**THOUGHTS**	**FEELINGS**	**ACTIONS**	**STRATEGIES**	**MOOD**
Stage 4 – Focus Formulation					
To formulate a focus from the information encountered	Predicting outcome of possible foci using criteria of personal interest, requirements of assignment, availability of materials, and time allotted Identifying ideas in information from which to formulate focus Sometimes characterized by a sudden moment of insight	Optimism Confidence in ability to complete task	Reading notes for themes	Making a survey of notes Listing possible foci Choosing a particular focus while discarding others Combining several themes to form one focus	Primarily indicative

Table 6: “Fifth Stage of the Search Process – Information Collection” (Kuhlthau 2004, p.49).

TASK	**THOUGHTS**	**FEELINGS**	**ACTIONS**	**STRATEGIES**	**MOOD**
Stage 5 – Information Collection					
To gather information that defines, extends, and supports the focus	Seeking information to support focus Defining and extending focus through information Gathering pertinent information Organizing information in nodes	Realization of extensive work to be done Confidence in ability to complete task Increased interest	Using library to collect pertinent information Requesting specific sources from librarian Taking detailed notes with bibliographic citations	Using descriptors to search out pertinent information Making comprehensive search of various types of materials, i.e., reference, periodicals, nonfiction, and biography Using indexes Requesting assistance of librarian	Combination of indicative and invitational

Table 7: “Sixth Stage of the Search Process – Search Closure” (Kuhlthau 2004, p.50).

TASK	THOUGHTS	FEELINGS	ACTIONS	STRATEGIES	MOOD
Stage 6 – Search Closure					
To conclude search for information	Identifying need for any additional information Considering time limit Diminishing relevance Increasing redundancy Exhausting resources	Sense of relief Sometimes satisfaction Sometimes disappointment	Rechecking sources for information initially overlooked Confirming information and bibliographic citations	Returning to library to make summary search Keeping books until completion of writing to recheck information	Indicative

Kuhlthau’s ISP model was validated by a study conducted by the author and published in 2004. This study verified the process, whereby college-bound students in the USA were revealed as engaging in a cognitive process where their feelings of confidence increased. However, there were some limitations to the study, such as the insufficient collection of data which would have allowed a study of lower-achieving students. As a result, the model itself can be said to offer an interpretive snapshot of the circumstances of an ISP but its results do not necessarily attain to universal validity. Its consideration alongside Wilson’s (1997) model offer additional balance in consideration of the affective component of information seeking.

In in the next few paragraphs, we will look at whether Kuhlthau (2004) talks about curiosity, either implicitly or explicitly, in her ISP model or accompanying (2004) writing. We will consider how she defines relevant terms, and whether any attributed factors are given or relationships to other notions or terms are given.

- The “initiation” stage is marked by uncertainty and apprehension in affective feelings, vagueness in cognitive thoughts associating with comprehending the task ahead and generating new ideas and associations, and seeking activities.

- The “topic selection” stage is marked by affective optimism, ongoing vagueness in cognitive thoughts – including confusion, sometimes anxiety, brief elation after selection, and anticipation – and the selection of resources.

- The “exploration” stage, occurring when information seeking is ongoing, and the cognitive state is still described as “vague”, comprises affective feelings such as “confusion”, “doubt”, sometimes “threat” and “uncertainty”.

- At the “formulation” stage of information seeking, the cognitive state becomes focussed, and the affective state comprises “optimism” and “confidence” in ability to complete the task.

- At the “collection” stage, cognitive focus is increased, and documenting occurs, with affective state being one of “realization of extensive work to be done”, “confidence” in ability to complete the task, and “increased interest”.

- At the “search closure” stage, affective states include a “sense of relief”, and, depending on objective and subjective success, sometimes a feeling of “satisfaction” and sometimes a feeling of “disappointment”.

At no point does this model explicitly consider curiosity, but what is does do is present a notion of learning, where feelings of satisfaction increase as findings increase and these findings are integrated into the student’s existing knowledge base. The challenge starts from a state of relative unknowing, which is associated with affective uncertainty and associated “negative” affective states, and as information is found as a result of a range of information seeking activities, positive feelings start to occur.

The model which shows a broad process from uncertainty and anxiety to increased certainty and satisfaction is influenced by the constructivist approach to learning which underpins the model. Kuhlthau (1999, 2004), as did predecessor Dervin (1983), draws on constructivist learning theory to understand information seeking respectively as a “constructing” activity (Dervin 1983, p.5) and as involving a protagonist involved in the “personal creating of sense” (Kuhlthau 1999, p.15). Kuhlthau

(1992) draws especially on the theoretical frameworks of Dewey (1933), Kelly (1963) and Bruner (1973). This approach was useful to Kuhlthau (1992) because of its emphasis on information seeking as problem solving and its focus on cognitive processes such as the production of hypotheses.

Kuhlthau's model is related to prior schemata developed by Dewey (1933), who described reflective thinking as occurring in five phases: suggestion, intellectualisation, guiding idea of hypothesis, reasoning, and testing by action (pp.106-114). Kuhlthau (1992) argues that this framework can be extrapolated to in information-seeking context where sense-making and construction of knowledge occurs. Dewey's process, as mediated by Kuhlthau (1992) describes an initial state of incomplete knowledge which causes confusion and uncertainty, after which, at the intellectualisation stage, the problem is conceptualised. The guiding idea represents the interpretation of the initial suggestion which is used to initiate and guide the collection of research material. In Kuhlthau's (1992) words, a "careful survey incorporating examination, inspection, exploration and analysis is made to define and clarify the problem at hand" then takes place. "Acts of searching, hunting and inquiring to find information characterise this phase" (Kuhlthau 1992). In the fourth phase, ideas are elaborated through reasoning, as facts emerge. At the fifth phase, the learner takes a stand on the tentative hypothesis with the aim of resolving doubts (Kuhlthau 1992), either involving action or thought. The process as summarised thereby relates a problem-solving approach and one which is guided by an information need. Curiosity, as it is implied, is therefore driven by the "need to know". Kuhlthau (1992) also draws on Bruner (1973), whose "Phases of Interpretation" "corroborate and elaborate the active part the individual plays in the constructive processes of both Dewey and Kelly", according to Kuhlthau (1992). Bruner emphasises the act of interpreting as central to knowledge construction, since merely gathering information is not sufficient (1973, p.53). Bruner describes a process involving the encounter with new information, a second phase involving recognising patterns, a third phase involving making inferences by connecting categories, a fourth phase including the making of predictions and a final phase including creating "products of the mind" (Bruner 1973). This process is similar to Dewey's approach.

Kelly (1963) described the process of forming new knowledge constructs as taking place through a series of psychological stages. He emphasised the disruptive impact of new information in the search process related to reflective thinking, with a resultant heightened sense of uncertainty, especially at the early stages of construction. Kelly's (1963) approach is characterised by the experience of new information of ideas that cannot be fitted into existing knowledge and hence his theory of construction rests upon the notion that new learning is in some way disruptive in order to be generative. In analysing whether curiosity is said to play any part in this process, if any, it is uncertain whether negative experiences can be said to drive curiosity, and the role of curiosity may differ depending on whether the task is imposed from without and has a degree of compulsion, or whether learners will tolerate the disruption of new knowledge and concomitant uncertainty in a freely-chosen circumstance. This raises the question of whether curiosity arises as a facet of the desire or need to know and is therefore associated with the feelings of uncertainty and discomfort found in these constructivist thinkers, or whether it precedes the need to know and makes the search more pleasant as a result.

Kuhlthau's ISP was the starting point of studies (2004) where students undertook a compulsory research project in school and choose the topic themselves. In this task, the initial driver of the task may be that the project is compulsory and the students are compelled to find information in order to succeed in the task. The fact that data was reduced for the lower-achievers, who did not engage in the task, implies that the successful group were driven to engage in the task despite their negative feelings, while the process broke down for the lower achievers, although the lack of data cannot explain whether this was due to affective factors, cognitive factors, or a combination of the two. In the model, positive feelings are increased by the satisfaction of finding and engaging with information to form coherent knowledge.

In conclusion to this section about Kuhlthau's (1993) model, there is some evidence of ideas of curiosity propelling the constructivist approach to learning which underpins her model, which leans heavily on cognitive and affective aspects of an ISP. However, the task described, to which the model is related, may not reflect the experience of browsing a 3D digital library as it is conceived in the testing methodology of this study since it may not be underpinned by the same extrinsic task or by the same cognitive motivators. Furthermore, it is not clear in any of the thinkers cited, whether curiosity equates to the process of feeling uncertain and going ahead with an information seeking or knowledge construction task, or whether it is a "third" factor which influences the search initiation or makes it more pleasant.

In addition, the design of a 3D digital library may in many ways influence or constrain the task as it is experienced. Facer and Sandford (2010) state that the type of learning in virtual environments depends on their features and whether they focus more on a "personalised, learner-centred mode" or are more didactic in their transmission of information. Many resources depend on "knowledge transfer strategies that have centred on textually-based engagements with learners and dialogic methods of interaction" (de Freitas *et al.* 2010), and are therefore more communicative than constructivist. Gaming environments are often associated with more behaviourist approaches (see

Kickmeier-Rust *et al.* 2007, following Malone 1981; Prensky 2001), while virtual learning environments such as *Second Life* are often associated with a more bottom-up constructivist approach (see Bronack *et al.* 2006). Other studies focus on more psychological concepts, for example negotiating life transitions (Devlin *et al*. 2013), interest-induction (Brophy 1986), attention focussing, relevance, confidence building and satisfaction (Keller 1983), the learner's perceived control and competence (Weisz and Cameron 1985), and interest (Schiefele 1991).

5.5 Supporting Literature Referencing Curiosity and Motivation

Kuhlthau's (2004) and Wilson's (1997) models are remarkable in the importance of the notion of uncertainty, which is elicited due to a lack of understanding and initiates the search behaviour. The emphasis on uncertainty and anxiety as drivers of search behaviour is also found in other ISB conceptions (Kuhlthau 1993; Wang and Tenopir 1998; Wilson *et al.* 2002). However, positive emotions such as motivation or curiosity might also play their part in ISB. In compulsory education, motivation "needs to be recognized and enhanced as the contribution or lack thereof influences the quality of learning" (Heinstrom 2006). Zillmann (1988) points out that searching behaviour may be used to prolong positive emotions that are occurring. We now move to supporting literature which references the notions of curiosity and motivation. This part of the review focussed most centrally on research in library and information science, but additional searching was conducted in related fields implicating these emotions, such as HCI and psychology, where they were cited in Library and Information Science literature.

The wider literature can lend more scope to Wilson's (1997) analysis of motive, by considering the notion of motivation. The literature points to motivation as a key cognitive factor in the successful educational experience. In compulsory education, motivation "needs to be recognized and enhanced as the contribution or lack thereof influences the quality of learning" (Heinstrom 2006). Motivation is a factor which is crucial to the success of online learning environments (Bekele 2010; Jones and Issroff 2007). Motivated learners achieve other measures in learning, such as demonstrating deep approaches to learning, as well as demonstrating enhanced performance, persistence and creativity (Schunk *et al.* 2008).

Motivation depends on both intrinsic and extrinsic factors (Corno and Rohrkemper 1985; Deci and Ryan 1985). Motivation can depend on intrinsic factors such as self-efficacy (Schunk 1991), perceived ability (McIver *et al.* 1991), or self-concept (Wigfield and Karpathian 1991). Extrinsic factors are also relevant and educational research has focussed on the behaviours that a teacher can adopt to encourage motivation (Skinner and Belmont 1993), such as guidance, provision of choice, curiosity-induction and interest-induction (Brophy 1986), or attention focussing, relevance, confidence building and satisfaction (Keller 1983). These behaviours can increase the learner's perceived control and competence (Weisz and Cameron 1985), and interest (Schiefele 1991).

Curiosity, in particular, is closely related to motivation (Brophy 1986) and the promotion of curiosity is closely linked to the type of learning provision, rather than to complex intrapersonal self-esteem. Curiosity is effectively "manipulated" using design: it is often employed in design and storytelling contexts by the use of various factors or design principles which are known to evoke curiosity. Cialdini (2001) lists a large number of real world examples from these sectors. Tieben *et al.* (2011) list some of the "pivotal elements of curiosity" as "surprise" and "ambiguity", and also list related things that evoke curiosity, such as "novelty". Garris et al. (2002) showed that various factors can evoke curiosity: "incongruity of information", "complexity", "novelty", "surprise", "violation of expectations", "incompatibility between ideas", "inability to predict the future", and incomplete or inconsistent information. Zheng *et al.* (2007) have worked on "surprise", while Gaver *et al.* (2003) considered the role of ambiguity in design. Exploration and discovery are also isolated as key factors in evoking curiosity in Korhonen *et al.*'s (2009) work. Given the overlaps with storytelling and the role of a 3D environment in bringing about instances of surprise and ambiguity it is also no surprise that curiosity is a feature in game design (Garris *et al.* 2002; Yee 2007).

Curiosity is evoked by certain factors; other thinkers have sought to define its nature. Curiosity is defined as a principle related to knowledge and information: Tieben *et al.* (2011) as "the strong intrinsic desire we living beings have to know or learn something". When design evokes curiosity, it can have a direct outcome in exploratory behaviour (Tieben *et al.* 2011). Following this logic, if design evokes curiosity and also has information content, it can result not only in exploratory behaviour but also in knowledge and learning. Knowing and learning require some definition, however. Berlyne (1960, 1967, 1971) defined two dimensions of curiosity: "sensory curiosity" such as novel sensations and stimuli, and "cognitive curiosity", the desire for more knowledge. In the HCI literature, *learning* can be considered in terms of "(i) how to use a computer-based application or (ii) using a computer-based application to understand a given topic" (Sharp *et al.* 2007). Design of 3D systems can evoke sensory curiosity but it is in their population with cultural content that they have the potential to inspire cognitive curiosity. Kashdan *et al.* (2004) built on Berlyne's (1960) theory by defining "diversive curiosity", seeking out varied sources of novelty and challenge, and "specific curiosity", seeking depth within a particular activity. Where the user is not sure exactly what he or she is looking for, he or she may "browse through information, allowing it to guide [… the] attention to interesting or salient items" (Sharp *et al*. 2007).

Some attempts have been made to model the process of curiosity. Loewenstein's information-gap theory which described curiosity in terms of primitive needs to make sense of the environment around us (1994). Tieben *et al.* (2011) advanced a model which visualised the curiosity process as a series of events named "encountering", "exploring", "discovering" and "adjusting", precipitated by circumstances such as "novelty", "uncertainty" and "conflict", and driven by the cognitive process of uncovering ("exposing") and interpreting new information. This model is useful because it describes an explorative process. Using Berlyne's insights, it is possible to see this process as having both cognitive and sensory dimensions in a 3D digital environment populated by cultural artefacts. For this reason, as well as drawing on information seeking literature, it is apt that a 3D digital library take into account theories from psychology and gaming which can impact on the understanding of exploration of information in the 3D environment.

The notion of curiosity is also relevant in an interdisciplinary context: for example, in the field of digital design. Beyond the disciplinary field of information-seeking theories, HCI, especially in its fields of systems design and games design, often adopts psychological theories of curiosity and engagement to influence design decisions (Garris *et al.* 2002; Gaver *et al.* 2003; Van der Vorst 2007; Yee 2007; Zheng *et al.* 2007; Korhonen *et al.* 2009). Curiosity is closely related to interest, an affective state that helps to motivate the desire to learn and explore (Silvia 2006, 2008). Silva (2008) calls interest "the curious emotion". Emotions are also an integral part of user experience and their measurement consequently becomes central in the empirical research conducted in the field of user experience (Agarwal and Meyer, 2009).

In addition to curiosity, "enjoyment", as noted in Wilson's (1997) paper may also be an important element of motive. This is particularly relevant in this research, since computers are increasingly seen as "interactive systems as a medium for emotions, sociability and pleasure" (De Angeli *et al.* 2006). This observation is perhaps most pronounced in the gaming world. In computer games the balance between pleasure and usability differs from some user interfaces with the "principle of least effort" not necessarily the first priority for users (Sharp *et al.* 2007). Many gamers enjoy games which are not easy, and which contravene usability goals: for example, "[b]anging a plastic hammer to hit a virtual nail represented on the computer screen, compared with using a more efficient way to do the same thing, e.g. selecting an option using command keys, may require more effort and be more error-prone but can result in a much more enjoyable and fun experience" (Sharp *et al*. 2007). Elements that combine to make a user experience more "fun" and enjoyable might include play, interactivity, control, narrative and flow, according to Sharp *et al*. (2007).

As Wilson's (1997) research suggests, there are many other intervening variables to the ISP to be examined. This is corroborated by the wider literature search that indicates that in online and Internet environments, certain problematic aspects may intervene in the information seeking process. Other than finding satisfactory information, Agosto (2002b, p.213) finds that "the onset of physical discomfort, the onset of boredom, time limit expiration, and information snowballing" are the reason for finishing searching activities. Physical discomfort can relate to the computer situation, such as looking at a screen; the onset of boredom by come from not finding a site engaging or excessive loading times (Shenton 2004, p.193; Large and Beheshti 2000, p.1077; Fidel *et al*. 1999, p.31; Kafai and Bates 1997), while time limit expiration may depend on a number of access limits. "Information snowballing" is when the perception of too much information begins to overwhelm the user, causing frustration (Shenton 2004, p.193) and anxiety (Agosto 2002a, p.22).

There are also potentially interesting implications for learning when 3D exploration helps us enter into an effectively "3-dimensional ontology" (Frankl 1988) which significantly broadens the potential of direct encounters with context and relationships, bringing information back into the Euclidian space (Fingerhut 2015). Sharp *et al*. (2007) find that design interfaces can influence learning by utilising: "design interfaces that encourage exploration", "design interfaces that constrain and guide users to select appropriate actions when initially learning" and by making use of "dynamic[…] link(age of) concrete representations and abstract concepts to facilitate the learning of complex material". Carroll (1990) observed that computer-based skills learners find it hard to learn using manuals and prefer to "learn through doing". Sharp *et al*. (2007) argue that this option supports "active learning by supporting exploratory interaction". The specific design of 3D virtual environments may influence information-seeking outcomes. Speaking of video games, Gee (2003) notes that exploration of the environment can encourage researchers and learners to reconceive learning goals. Additionally, in a case study of two 3D virtual environments for courses in business computing and 3D modelling, Dickey (2005) argued that contextual elements such as a "first person symbolic perspective" and 3D space increase learners' sense of presence. This has the benefit of providing a "visual narrative of the course content" (Dickey 2005, p.444).

5.5.1 Nahl's (2007) ISB Model

It has been noted that Wilson's (1997) and Kuhlthau's (2004) models raise important questions about the role of motivation and curiosity. These notions were explored in the section immediately prior to this one. Now it serves us to consider another information seeking model which does lend more explicit attention to affect, to see whether this "affect" can be broadly conceptualised as the curiosity or motivation that drive the cognitive and sense-making processes in Wilson's (1997) and

Kuhlthau's (2004) models. We are not alone in considering Wilson's (1997) and Kuhlthau's (2004) models to be primarily cognitive: Fisher and Landry (2007) note that theories and models such as Dervin's sensemaking (1983), Kuhlthau's information search process, and Wilson's information need and seeking model (1999) are "ironically" frameworks "focussed primarily on cognition" (according to Fisher and Landry 2007). They go on to say that while these three models were "instrumental in the identification and development of 'affect' as a concept for understanding IB", they were "known at the time for their emphasis on users' cognitive stages" (Fisher and Landry 2007). Their conclusion and the findings of this literature review suggest that it is now apt to consider an affective information seeking model which incorporates practices that can be associated with curiosity, in order to plug the motivational gaps which are not explained in either Wilson (1997) or Kuhlthau (2004).

The literature review uncovered one such model which is well-cited in the literature (e.g. Farmer 2007). Nahl (2001; 2007) proposes an information seeking model which takes into account affective aspects, which is visualised below.

This model is accompanied by a table which gives additional actions to the terms used. Many of these terms reflect information search or information use practices of either a sensorimotor or cognitive nature (see Steps 1-2; Steps 5-6). These approaches are familiar as aspects of both the information search process and the construction of knowledge outlined in other models and theories discussed above.

What is of most interest from the perspective of curiosity in Nahl's (2001) model, is the focus on the affective aspects of information seeking. In particular, those practices which inform an intention (at Step 4) can be implicitly associated most closely with curiosity or the related notion of motivation. The focus of many of the listed practices is on the movement of what might traditionally be called the "will" towards further searching. Words such as "intending or wanting to" and "striving or persisting" match the notions of motivation and curiosity discussed in the review. The "intending practice" (Nahl 2001) may represent the mediating role of curiosity which can insert itself into previously discussed models of information seeking.

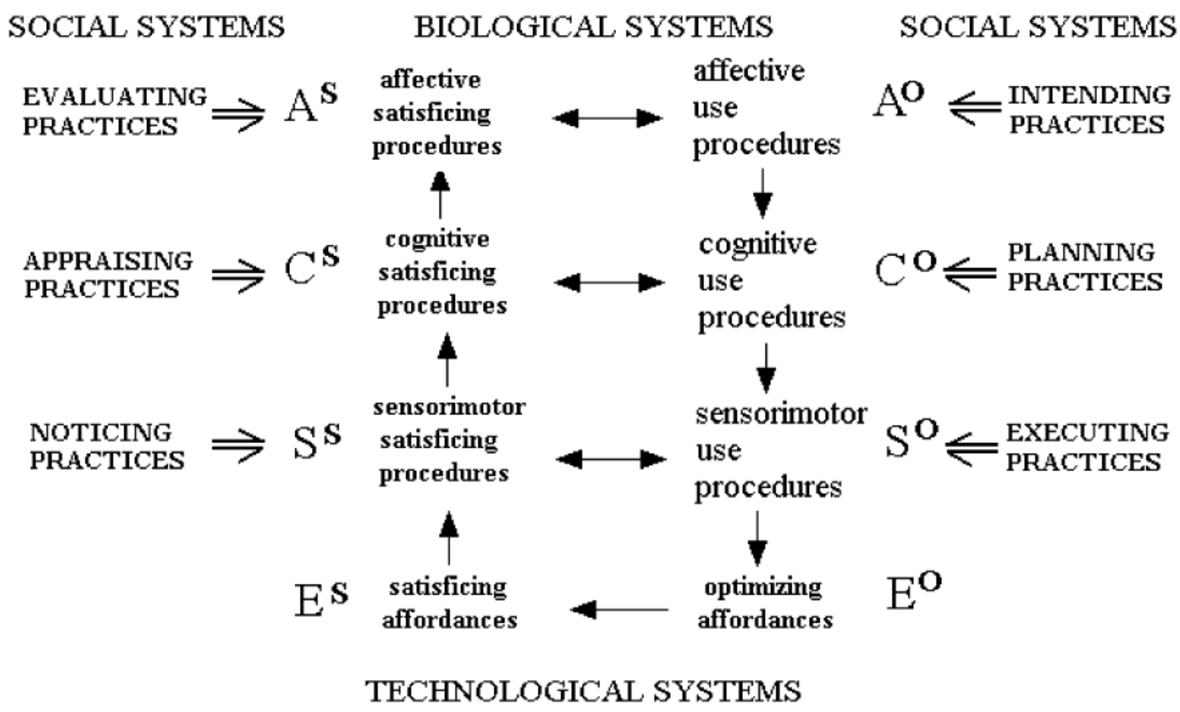

Fig. 8. "Social-Biological Information Technology" (Nahl 2007).

Table 8. "Additional Terms Referring to the Social Group Practices" (Nahl 2007).

Step 1 **Noticing Practices (by performing sensorimotor satisficing procedures)**	**Step 2** **Appraising Practices (by performing cognitive satisficing procedures)**	**Step 3** **Evaluating Practices (by performing affective satisficing procedures)**
Identifying Ignoring Locating Perceiving Recognizing Sensing Attending Orienting Etc.	Interpreting or categorizing Justifying or giving reasons Attributing cause Comparing or limiting Explaining or listing Etc.	Value-attaching or rating Applying reference norms Prioritizing or ranking Accepting vs. avoiding Feeling satisfied vs. not consummating or filling a need Feeling attracted or interested vs. not Etc.
Step 6 **Performing Practices (by performing sensorimotor optimizing procedures)**	**Step 5** **Planning Practices (by performing cognitive optimizing procedures)**	**Step 4** **Intending Practices (by performing affective optimizing procedures)**
Performing or acting Keyboarding or texting Verbalizing or languaging Inspecting or reading Purchasing or waiting Clicking or moving the mouse Etc.	Predicting or problem-solving Designing or scheduling Inventing or extending Imagining or picturing Managing or setting objectives Etc.	Purpose or goal-setting Regulating or directing Striving or persisting Intending or wanting to Engaging or making use of Implementing or adopting Looking for or searching Etc.

Nahl (2007) posits the "motivating intention", also called the "task completion motivation" (Nahl 2007, p.15) as key to the information seeking process. The motivated intention is the intention to search for something, and is thus linked to the notion of motivation and curiosity. According to Nahl (2007) intending practices may include "purpose or goal-setting, regulating or direction, striving or persisting, intending or wanting to, engaging or making use of, implementing or adopting, and looking for or searching".

Dervin and Reinhard (2007) conducted a user study informed by sensemaking methodology (Dervin 1983), and cited a number of intervening aspects affecting the motivated intention. These include demographic aspects such as gender (Knobloch-Westerwick and Alter 2006; Shamo 2001) and experience levels with steps taken in the searching process (McCreadie 1998; Nahl 1998a; Wang and Tenopir 1998; Wilson *et al.* 2002), as well as an individual's general interests, lifestyles and motivational states (Kracker and Wang 2002; Nahl 2005; Nahl-Jakobovits and Jakobovits 1985).

In Fisher and Landry's (2007) study of stay-at-home mothers' ISB, also studied through an affective lens, it was found that "empowerment was a significant affective aspect of the information process", encompassing aspects such as "the ability to affect decision-making, the confidence to find something out for oneself, and the ability to provide information to others". Hence, empowerment, relating to one or a combination of these aspects, may also have a role as an intervening aspect of motivation.

We suggest that the state of motivation associating with "striving or persisting" (Nahl 2001) may intervene where "uncertainty" plays a role in the information search process (e.g. Kuhlthau 2004). Nahl introduced the concept of "affective load", which is defined as uncertainty multiplied by time-pressure. If affective load is too high, users will end their task, but the more users are able to manage uncertainty, the more they can reduce their affective load (McKechnie *et al.* 2007). Nahl (2001) also cites self-efficacy as an affective issue of particular importance in information seeking. The role of self-efficacy is corroborated by other research into computer use: Collins and Veal (2004) found that students' perceptions of their own information skills affected their level of anxiety towards internet use, and Kurbanoglu (2003) reported an association between literary self-efficacy and computer use.

5.6 Conclusion

The chapter identifies ISB models focussing on the affective aspect of information seeking, with a focus on Wilson (1997), Kuhlthau (2004), and Nahl (2007) as models which can be used to analyse user behaviour with a 3D digital library. This completes the literature review, as literature relevant to both design criteria and to user behaviour has been reviewed. The research aims and questions can be considered by analysing both factors in relation to the use of a selection of 3D digital library in a user testing context. Nahl's (2007) model, although less often cited than Wilson's (1997) and Kuhlthau's (2004), provides a missing link in their process-based models by providing a greater insight into the factors of motivation and curiosity which drive perseverance and information seeking actions. These factors are also supported and augmented in scope by supporting literature cited in the chapter.

A list of concepts drawn from the chapter were drawn up and summarised in a series of tables. Citations for each code and any relevant component descriptions were given, as were any clear relationships with other themes found in the literature. The resulting table provides an analytical framework which suggests codes through which analysis might take place.

Table 9. Search behaviours identified in the ISB literature review.

Part A: searching

Thematic code	**Origin**	**Components**	**Relationships**
Passive attention	Wilson (1997); Kari (1998)	Listening or watching activities where information acquisition may take place without intentional seeking (Wilson 1997)	
Passive search	Wilson (1997)	One type of search results in the acquisition of information that happens to be relevant to the individual (Wilson 1997)	
Active search	Wilson (1997)	Individual actively seeks out information (Wilson 1997)	
Ongoing search	Wilson (1997)	An active search has set out a basic framework of knowledge but where occasional continuing search is carried out to expand one's framework (Wilson 1997)	
Browsing	Sharp *et al.* (2007); Ellis *et al.* (1993); Ellis and Haugan (1997); Bilal *et al.* (2008)	The user is not sure exactly what he or she is looking for and he or she may "browse through information, allowing it to guide [… the] attention to interesting or salient items" (Sharp *et al*. 2007)	
Iterative process / backtracking	Shenton and Hay-Gibson (2011); Bilal *et al.* (2008)	The individual revisits previous stages, frequently in response to difficulties (Shenton and Hay-Gibson (2011)	

Part B: Cognitive steps in information seeking

Thematic code	**Origin**	**Components**	**Relationships**
Identifying possible sources	Choo (2000)		
Selecting resources to be used / differentiation / filtering	Choo (2000); Ellis *et al.* (1993); Ellis and Haugan (1997); Bilal *et al.* (2008)		
Locating or making contact with sources	Choo (2000)		
Interacting with resources to find desired information. Reading	Choo (2000); Bilal *et al.* (2008)		
Problem-solving	Wilson (1999)	Problem recognition, problem definition, problem resolution, and (where needed) solution statement" (Wilson 2000)	
Incorporation of information into person's existing knowledge base	Wilson (2000)		
Sense- making / knowledge construction	Kuhlthau (1999); Dervin (1983)	Information need. A gap identified between existing situation and new information. A bridge created between existing situation and new information (Dervin 1983)	
Encountering	Tieben *et al.* (2011); Bruner (1973).		
Exploring	Tieben *et al.* (2011); Korhonen *et al.* (2009)	Recognising patterns. Making inferences by connecting patterns Making predictions (Bruner 1973).	Precipitates further curiosity
Discovering	Tieben *et al.* (2011); Korhonen *et al.* (2009)	Recognising patterns. Making inferences by connecting patterns Making predictions (Bruner 1973).	Precipitates further curiosity
Adjusting	Tieben *et al.* (2011)	Creating products of the mind (Bruner 1973).	
Sensory curiosity	Berlyne (1960, 1967, 1971)	Curiosity for novel sensations and stimuli	

Cognitive curiosity	Berlyne (1960, 1967, 1971)	Desire for more knowledge	
Collection	Kuhlthau (2004)		Relates to increased "interest". "Confidence" in ability to complete task
Initiation	Kuhlthau (2004). Bilal *et al.* (2008)	Uncertainty and apprehension, vagueness in cognitive thoughts associating with comprehending the task ahead and generating new ideas and associations, seeking activities. (Kuhlthau 2004)	
Topic selection	Kuhlthau (2004)	Affective optimism, vagueness in cognitive thoughts – including confusion, sometimes anxiety, brief elation after selection, and anticipation – and the selection of resources.	
Formulation	Kuhlthau (2004)	Cognitive state becomes focussed, and the affective state comprises "optimism" and "confidence" in ability to complete the task.	

Part C: Factors influencing motivation

The central concept in motivation is posited as the "motivating intention" (Nahl 2007), and its attendant components. According to Nahl (2007), motivating intention involves purpose or goal setting, regulation or directing, striving or persisting, intending or "wanting to", engaging or making use of, implementing or adopting, and looking for or searching. Elsewhere in the literature, a number of factors mitigate against motivation or motivated intention.

Concept	**Origin**	**Components**	**Related to**
Motivating intention	Nahl (2007)	Purpose or goal setting. Regulation or directing. Striving or persisting. Intending or "wanting to". Engaging or making use of. Implementing or adopting. Looking for or searching.	Mitigating factors below
Curiosity	Morgan and King (1971)		Unlearned factor in motivation
Empowerment, control and competence Self-efficacy Perceived ability Self-concept	Fisher and Landry (2007); Weisz and Cameron (1985) Schunk (1991); Wilson (1997); Bandura (1977); McIver *et al.* (1991) Wigfield and Karpathian (1991)	Affect decision making Confidence to find something out for oneself. Ability to provide information to others.	Affects motivating intention
Social motives	Wilson (1997)	The desire for affiliation, approval or status, or aggression (Morgan and King 1971)	Affects motivating intention
Experience level with steps involved in search	McCreadie (1998); Nahl (1998); Wang and Tenopir (1998); Wilson *et al.* (2002)		Affects motivating intention
Individual's general interests, lifestyles and motivational states	Kracker and Wang (2002); Nahl (2005); Nahl-Jakobovits and Jakobovits (1985); Johnson and Macrae (1994); Wilson (1997)		Affects motivating intention. Interests can be increased by "Teacher's behaviours"
Enjoyment	Wilson (1997)		Affects motivating intention May prolong searching behaviour (Zillmann 1988)
Teacher's behaviours (by extension: system attributes)	Skinner and Belmont (1993)	Guidance, provision of choice, curiosity-induction and interest-induction (Brophy 1986)	Increased control and competence (Weisz and Cameron 1985), and interest (Schiefele 1991)
Teacher's behaviours (by extension: system attributes)	Skinner and Belmont (1993)	Attention focussing, relevance, confidence building and satisfaction	Increased control and competence (Weisz and Cameron 1985), and

		(Keller 1983)	interest (Schiefele 1991)
Attention	Heinstrom (2006)		Affects motivating intention
Perceived information need	Case (2012); Krikelas (1983); Dervin (1983); Shenton (2004); Shenton and Dixon, (2003); Wilson (1997); Bilal *et al.* (2008)		Affects motivating intention
Cultural context	Wilson (1997)	Characteristics of environment: degree of: power distance Uncertainty avoidance Individualism-collectivism Masculinity-femininity(Hofstede 1980) Gender (Knobloch-Westerwick and Alter 2006; Shamo 2001)	Affects motivating intention
Educational variables	Wilson (1997)	"GRADE, an educational measure; INCOME, (…) the total household income; and MHEAD, signifying whether there were two adults in the household" (Ippolito and Mathios 1990)	Affects motivating intention
Emotional barriers / "blunting"	Wilson (1997)		Can explain inaction at the initiation of an information search.
Gratification	Wilson (1997)	Diversion: escapism, emotional release (McQuail 1972)	Affects motivating intention
Gratification	Wilson (1997)	Personal identity: comparison with life; reality exploration; value reinforcement (McQuail 1972)	Affects motivating intention
Credibility	Wilson (1997)		Influences decision to use
Degree of risk involved in search	Wilson (1997); Aaker *et al.* (1992)		More active searching occurs with higher risk (Aaker *et al.* 1992)

Accessibility	Wilson (1997)		Lack of accessibility inhibits information seeking
Economic costs	Wilson (1997)	Direct economic costs, the value of time (Wilson 1997)	May affect effort spent in searching (Stigler 1961)
Perception of knowledge	Radecki and Jaccard (1995)		People may seek less information on topic about which they feel knowledgeable

Part D: Factors precipitating curiosity

Thematic code	**Origin**	**Components**	**Relationships**
Interest	(Silvia 2006, 2008)		Precipitates curiosity
Novelty	Tieben *et al.* (2011) Garris *et al.* (2002)		Precipitates curiosity
Uncertainty	Tieben *et al.* (2011) Kuhlthau (2004)	Incongruity of information Complexity Violation of expectations Inability to predict the future. (Garris *et al.* 2002) Ambiguity (Gaver *et al.* 2003)	Precipitates curiosity Steps to resolve negative emotions
Conflict	Tieben *et al.* (2011)	Incompatibility between ideas. (Garris *et al.* 2002)	Precipitates curiosity
Exposing and interpreting new information	Tieben *et al.* (2011)		Precipitates curiosity
Surprise	Garris *et al.* (2002); Zheng *et al*. (2007)		Precipitates curiosity

Part E: Factors influencing ceasing information seeking

Thematic code	**Origin**	**Components**	**Relationships**
Physical discomfort	Agosto (2002b)	E.g. looking at the screen	Stopping information seeking
Boredom	Agosto (2002b)	Not finding site engaging Excessive loading times Shenton (2004); Large and Beheshti (2000);, Fidel *et al*. (1999); Kafai and Bates (1997)	Stopping information seeking
Time limit expiration	Agosto (2002b, p.213); Wilson (1997); Cameron *et al.* (1994).		Stopping information seeking
Information snowballing	Agosto (2002b, p.213)		Stopping information seeking
Search closure	Kuhlthau (2004); Bilal *et al.* (2008)	Sense of relief. Feeling of satisfaction or disappointment. (Kuhlthau 2004).	Stopping information seeking.

Part F: Source characteristics

Thematic code	**Origin**	**Components**	**Relationships**
Interfaces constrain and guide users	Sharp *et al.* (2007)		Supports exploratory interaction and hence active learning
Dynamic linkage of concrete representations and abstract concepts	Sharp *et al.* (2007)		Supports exploratory interaction and hence active learning
Presentation format	Wilson (1997); Bettman and Kakkar (1977)		Influences acquisition strategies (Bettman and Kakkar 1977)
First person symbolic presence	Dickey (2005)	Taking part in visual narrative of content	Increases sense of presence
Play, interactivity, control, narrative and flow	Sharp *et al*. (2007)		Enjoyment
Cognitive or affective value of stimulus	Heinstrom (2006)		Attention

This concludes the literature reviews into the three main theoretical frameworks informing the study of design and behaviour with 3D digital libraries. As a result we have a design framework based on both HCI and architectural principles, and thematic codes for exploring data related to user behaviour. The aim is to apply these theoretical frameworks to analysis, following the application of an appropriate methodology designed to explore user behaviour in relation to design. Prior to the demarcation of a methodology, it is apt to review emergent examples of 3D digital libraries according to baseline source characteristics which precedes selection of resources for experimentation, and this is the subject of Chapter 6.

Chapter 6: Emergent Examples of 3D Digital Libraries Review

6.1 Abstract and Methodological Approach

Purpose – The chapter depicts the landscape of resources conforming to the research definition of "3D digital library" accurate to the end of 2013.

Methodological approach – An empirical search for examples was conducted using the description of a 3D digital library from "1.1 Terminology" in this research. The search made use of the Google search engine, following the rationale that a search engine was the most appropriate location to seek relevant examples. The search was methodological, based on search word criteria, while some resources were noted at other stages in the literature review as a result of citations in the literature and were cited alongside those located using the empirical search methodology.

The search engine Google.com was used. Google.com was the leading search engine at the time of writing. Search terms were used without speech marks or other Boolean features. The top fifty results from the main body of results was explored and yielded either links to resources or literature referencing relevant resources. The results were checked up to the date of 15th December 2013. Resources with ascertainable publication dates from 2003 to 2013 were selected. Only resources available in the English language were sought. This resulted in a final list of resources which were potentially suitable sites for experimentation.

There is a lack of semantic or standardised vocabulary for the kind of resource sought, which may be because we are dealing with an emergent field with projects coming from both academic and commercial authors, with different disciplinary backgrounds. The search terms used were selected to cover digital and museum, library and archive vocabulary that could be representative of 3D digital libraries. Search terms were also verified by searching to see if they yielded relevant results with variations in vocabulary or terminology refined as more relevant results were located.

The search terms used were as follows:

- 3D virtual learning environment*
- 3D VLE
- Learning virtual world*
- Virtual learning world*
- 3D digital library*
- Digital library* virtual learning environment*

- 3D library*
- 3D digital museum*
- 3D museum*
- 3D digital archive*
- 3D archive*
- Digital heritage virtual environment*
- 3D digital heritage
- Cultural virtual environment*
- 3D learning game*

Findings – A list of 3D digital libraries extant to 15th December 2013 was compiled. In addition, related types of resources, though not conforming to the sought-after parameters of a 3D digital library, were located in the literature, and given the overlaps and contextual value of these resources, they were also documented.

Practical implications – The list of resources provides a comprehensive guide to 3D digital libraries to the end of 2013, providing a context for the research, and also suggesting resources which could be used in the subsequent experimental methodology to explore the relationship between design and behaviour in 3D digital libraries.

Limitations – As a limitation, the aspects comprising a 3D digital library may be open to debate, with different categories yielding different search results. This limitation is held against the pragmatic need for new definitions in an emergent field. The choice of search terms was challenging given the emergent nature of the field and the employment of digital vocabulary and vocabulary across the cultural sectors that can be applied to 3D digital libraries. A variety of search terms was employed to allow for variations in descriptive vocabulary but the results may not be exhaustive.

6.2 Definitions

We followed the definition used throughout the research and restated here, whereby the term "3D digital library" is used to indicate digital virtual environments involving the 2D transmission of 3D visuals with content representing the collections of a cultural or knowledge-economy institution. 3D digital libraries allow the user to interact with the objects placed within them, and to navigate in 3D around the 3D system in a walkthrough environment. Pathways through the environment may be given as options but the user has some choice as to where to walk and what to look at.

6.3 Related Types

Before presenting the results of the empirical search for emergent 3D digital libraries, we present related types of resources which surround the emergence of the archetypal 3D digital library. These serve to better situate the emergent genre of “3D digital library” within related paradigms and digital developments. The development of related types of 3D online resources for learning and culture is well documented by the 2014 book *3D Research Challenges in Cultural Heritage: A Roadmap in Digital Heritage Preservation* (Ioannides and Quak 2014). Chapters in the book focus on 3D object scanning, the challenges of curating large datasets, the use of scanning for archaeology contexts, and data preservation and reuse.

6.3.1 Large-Scale Digital Documentation

Digital documentation and visualisation is the effort to create scanned images of heritage sites, usually to a high degree of accuracy and specification.

A recent digital documentation initiative was the CyArk 500 Challenge (CyArk 2013), which aims to scan and digitally document 500 world heritage sites. A local project in Scotland is the Scottish Ten project under a collaborative title between the Digital Design Studio and Historic Scotland: “The centre for Digital documentation and Visualisation”. The aim is to digitally document five world heritage sites in Scotland along with five international sites, using “high-speed terrestrial and hand scanning systems, aerial LIDAR and photogrammetry” (Watterson *et al*. 2012). One example of high accuracy digital documentation is the Digital Bayon Temple (Ikeuchi *et al.* 2007). High quality digital scanning equipment was used to create an accurate image of the structure. This approach was taken because of the preservation concerns of the temple, which is deteriorating with the encroachment of the rainforest. The project also advanced research into the Temple: for example, an image which was only capturable by robots because of its obscure position allowed researchers to connect the Temple’s imagery with developments in Buddhist theology (Ikeuchi *et al.* 2007).

6.3.2 3D Scanning or Rendering of Museum Objects

A further category involves using 3D technology to digitise existing collections, or to literally translate a physical museum to a digital medium, usually to make them available online. One notable programme of 3D digitisation is taking place at the Smithsonian Institute (Metallo and Rossi 2012).

A similar, related initiative involves creating rendered objects in 3D, as an adjunct to digitally documenting them. This is advantageous in the example of extinct species, where digital scanning is not possible, but where effective rendering in 3D can enhance the user experience. One example of this is the Natural History Museum’s online exhibition “Dinosaurs in 3D” (Natural History Museum 2013).

A number of museums around the world now offer virtual tours as a way of seeing the collections. One example of this type is the Virtual Sighet Museum, which commemorates the victims of Communism and the Resistance in Romania (Civic Academy 2009).

6.3.3 3D Games and Cityscapes

This category includes games and other exploratory environments in which designers have sculpted photo-realistic buildings, representing speculated real environments or fantasy environments sculpted. This kind of computer-generated imagery makes use of software such as Blender, or architectural packages for computer-aided design (CAD) (cf. Jones 2012; Beier 2000; Jung *et al.* 2002).

In the majority of cases examples were designed primarily for entertainment, such as computer games, or as digital architectural renderings, such as the speculative work of architects producing renderings of what a completed building will look like or feel like to walk around to clients. Although these resources contained some information – computer games often contain contextual information about, for example, ancient worlds, and architectural CAD creations contain information about the proposed structure – they were not primarily designed or tailored to the embedding of resources.

Some best-selling gaming examples from the five year window of 2008-2013 include: *Call of Duty: World at War* (Activision 2008), *Call of Duty: Modern Warfare 2* (Activision 2009), *Uncharted 2: Among Thieves* (Playstation 3 2009), *Halo 3: ODST* (Microsoft Game Studios 2009), *Call of Duty: Black Ops* (2010), *StarCraft II: Wings of Liberty* (2010), *Kinnect Adventures* (Microsoft Game Studios 2010), *Halo: Reach* (Microsoft Game Studios 2010), *Call of Duty: Modern Warfare 3* (Activision 2011), *Battlefield 3* (Electronic Arts 2011), *The Elder Scrolls: Skyrim* (Bethesda Game Studios 2011), *Uncharted 3: Drake’s Deception* (Sony Computer Entertainment 2011), *Halo 4* (Microsoft Game Studios 2012), *Call of Duty: Black Ops 2* (Activision 2012), *Animal Crossing: New Leaf* (Japan 2012; North America, Europe and Australia 2013), *Luigi's Mansion: Dark Moon* (2013). The majority of these are action or shooter games, as might be predicted, since the experience of wayfaring through a city is conducive to war-like narratives. *Assassin’s Creed 2* (2009) is notable for its detailed renderings of historical environments.

6.3.4 2-Dimensional Innovations

Although not 3-dimensional, we uncovered a further category which is of interest to our research because it comprises a step "beyond the library catalogue". These are visual developments of library catalogues to use representational images rather than relying on metadata for each item.

One such example is the Bohemian Bookshelf (Thudt *et al.* 2012), a flat-screen digital library installation which is designed to support open-ended exploration and serendipitous discoveries of the book collections (serendipity is conceived of as having a fuller extent than its coincidence-weighted definition in the Oxford English Dictionary). Thudt *et al.* (2012) identify "knowledge", "open-mindedness", "perseverance" and the influence of "other people and systems" as factors influencing the serendipitous encounter with a suitable resource in a library or museum environment. They hypothesised that the Bohemian Bookshelf installation would promote serendipitous encounters by promoting different perspectives on the library catalogue, such as cover design and time covered, providing multiple visual access points based on such different perspectives (Thudt *et al.* 2012). In their study with the resource, interviews revealed that users enjoyed the "playful exploration" of resources, finding using the installation like "browsing, but more satisfying", and promoting "curiosity" (Thudt *et al.* 2012), and thus, many comments, although unprompted, pointed towards the "serendipity" hypothesis. The installation was also successful in highlighting adjacencies, as it facilitated the appreciation of connecting factors between resources that are not highlighted in the Online Public Access Catalogue (OPAC), creating an experience more akin to browsing an information shelf (Thudt *et al.* 2012). The Bohemian Bookshelf suggests that a trajectory based on promoting the "serendipitous encounter" and promoting curiosity is a realistic one to pursue when choosing to design digital libraries by visualising information in ways beyond the OPAC. The research suggests that such visualisations promote rewarding brief and in-depth explorations of library resources, which are especially suited to thematic collections of information.

A further example is the ViziQuest user interface, which is a visual, browser-based way of displaying collections without the requirement of textual input. The user is presented with a central image, surrounded by thematically related images (Poole and Payne 2012). In this case too, one of the key elements of the user experience is "virtual serendipity" (Poole and Payne 2012). ViziQuest has been used to display the collections of the Fitzwilliam Museum, Cambridge. Textual descriptions were also added to the resource as an optional feature for users wishing to explore the objects in this way (Poole and Payne 2012). Further multimedia features were added to the concept in a resource developed in collaboration with the Polar Museum in Cambridge (Poole and Payne 2012). ViziPlay is a variant on ViziQuest that was developed to enhance the learning experience. An application for schoolchildren was developed which encourages them to select items from the Polar Museum's digitised collections to use as props in a storytelling exercise (Poole and Payne 2012).

A second example is in the transformative potential of digital initiatives undertaken by library special collections departments, where the amplification in understanding from the book as a source of information to the book as object itself is most pronounced. One rare books blog aiming to engage people "beyond the catalogue" illustrates its approach by juxtaposing two pictures: rare books on a cataloguer's desk and a bibliographic record, and explaining that the two are not equivalent (Palmieri and Green 2012). The encounter with a book is brought into an online space in a way that a catalogue entry acting as a surrogate cannot usually allow.

6.3.5 Enhancing the Built Environment with Augmented Reality

There are emergent projects in cultural heritage, which are aimed at fostering a deeper participation, using virtual worlds and augmented reality technology. For example, at the University of Tokyo, Katsushi Ikeuchi's work in e-heritage involved the scientific visualisation of major sites in Cambodia, Italy and Japan. This involved both "e-monumentalising" existing structures, such as the Bayon Temple, and using mixed reality technologies, such as augmented reality, to create "Virtual Asukakyo", whereby visitors can see the older version of Asukakyo overlaid over the modern-day ruins, as well as see historical battles re-enacted in augmented reality (Ikeuchi *et al.* 2007).

In physical environments, it is possible to embed sensor technologies to detect the location of visitors. These environments can be configured to provide digital information on a device depending on the visitors' location within the physical environment. Further actions, such as changing the lighting in the room, can also be performed. Electronic tourist guides can be developed for mobile devices to provide information about places to visit when a user wanders through an unfamiliar place (Cheverst *et al*. 2000). Physical environments can be designed to incorporate features of a 3D virtual learning environment (VLE). For example, the *Ambient Wood* was designed as an outdoor learning experience with the aim of enhancing the ordinary experience of a physical woodland with digital information (Rogers *et al*. 2005). Augmented reality can be used to add a digital geocaching element to exploration of the countryside, as in the *Cateran Trail GeoTour* (Forestry Commission Scotland 2013) developed to enhance a popular hike in Perthshire, Scotland.

6.3.6 Historical Examples

In the 1990s, examples of mechanisms for visualising information in digital libraries became established research theme (Allen 1998). The early examples coincided with the work of Andrews (1995), Hearst (1995) and Wise *et al.* (1995) on visualisation in the digital sphere, all of which advocated for an interaction with texts that more closely resembled perceptions and actions in the physical world. The creation of these examples is based on the idea that “spatial Metaphors applied to virtual libraries encourage user investigation” (Cubaud *et al.* 1998). *Bookhouse* (Pejtersen 1989) was a 1986 system which employed direct manipulation as the user navigated a visual metaphor of a fiction library. Pejtersten built upon her earlier research which typologised user-librarian search interactions, by constructing the system to allow “analytical search”, “search by analogy” and “browsing” (Pejtersen 1979). Pejstersten’s stated aim was to improve the user experience, which encompassed effective information retrieval, by using spatial arrangement over more abstract data presentation. The direct metaphor replaced list indexes and thereby allowed the user to “wander round town” (Pejtersen 1989), and supported “intuitive” discoveries (Pejtersen 1989). It is interesting how later OPACs, in contrast, tend to support the specific retrieval of a book, and although built upon more complex databases, still use elements of list indexes to deliver results. This earlier experiment in direct manipulation of a visual metaphor was instead designed to more effectively support the information seeking experiences which prior research (Pejtersen 1979) had established.

Web Forager (Card *et al.* 1996) was an early attempt to simplify information retrieval and to make the World Wide Web more intelligible. It provided an alternative interface for encountering the information found on the World Wide Web, by representing a desktop workspace using 3D graphics. In *Web Forager*, the fact that the web books were themselves the main elements involved employing a metaphor. In this case, that metaphor was reminiscent of the experience of browsing library shelves, which provided a concrete, rather than abstract way of bypassing the standard catalogue entry as a substitute for the book.

Early examples of visualisation in digital libraries employed Virtual Reality Modeling Language (VRML) to create 3D interfaces. Important projects in the late 1990s included the VIBE project at Pittsburgh (Korfhage and Olsen 1995) and the Envision project at Virginia Tech (Nowell *et al.* 1996). Cubauld *et al.* (1998) used VRML to create an interface for a digital collection of rare books at Conservatoire National des Arts & Métiers (CNAM). This included a hemispherical visualization device to immerse the reader into 3D representations of the collections (Almeida *et al.* 2006). Fox *et al.* (1997) describe a 3D interface for browsing a US-wide repository of theses.

Several early efforts of digital library designers to broach the 3D divide produced 3D representations of actual library shelves (cf. Korfhage and Olsen 1995; Nowell *et al*. 1996; Fox *et al.* 1997; Cubauld *et al.* 1998; Almeida *et al*. 2006; Das Neves and Fox 2000), with one example going so far in its literalism as to recreate the dust on books (Rauber and Bina 1999). Many of these libraries will be of interest to the research. However, it is suggested that interfaces need not mimic built libraries, especially as 3D virtual worlds now include a wide range of fantasy environments, historical cityscapes and reconstructions of built heritage. It is conceivable that library collections could be embedded within such environments. A degree of creativity is expected if such an action is to be taken, because digital representations of actual library shelves are tied more closely, conceptually, to actual library bibliography. In the era of the Semantic Web, the interface can be linked to the "implicit" bibliographic record in a creative way, selecting the arrangement of attributes in three dimensions to support the user context (Dunsire 2009). As an alternative, an architectural landscape could be used (e.g. an historical structure, a cityscape, vernacular buildings and interiors) and convey a particular meaning (e.g. an historical period or area of study) to support the user's understanding and encounter with resources. Christoffel and Schmitt (2002) point out that a gap exists between digital library interfaces that employ real-world metaphors (e.g. Cubaud *et al.*2001) and the game industry, with its virtual reality games. This is an area in which libraries could still be seen to lag behind, and more recent examples of 3D digital library design have continued to be a part of the real-world metaphor hermeneutic (cf. Birmingham City Council 2013; Chow *et al.* 2010). This lack of abstraction may be, in part, because digital libraries lack a natural spatial organisation that would normally be evident on bookshelves.

Compared to literature relating to early experiments in 3D real-world library metaphors, literature relating to incorporating select aspects of digital gaming is more limited. In a literature review, Robertson (2008) notes "a variety of commercial applications, including information retrieval systems, file management systems, and desktops, that deliberate or not incorporate aspects of digital gaming, primarily three-dimensionality, in their user interface designs". Arguably, the impetus to use more divergent 3D environments for digital library collections is hastened by the engagement of organisations with close ties to libraries, from the cultural sector, in 3D digitisation and reconstruction projects, for the sake of widened access, digital preservation or furthering humanities research. In recent digital libraries conferences, we see emergent projects in cultural heritage, which are aimed at fostering a deeper participation, using virtual worlds and augmented reality technology (Deligiannidis and Jacob 2005; Ikeuchi *et al.* 2007; Dassault Systèmes 2012a; Dassault Systèmes 2012b; Digital Design Studio 2012; Watterson *et al*. 2012).

6.4 Findings

We now consider the findings conforming to the definition of a "3D digital library", with a preliminary summary of their commonalities.

All of the resources listed are or were accessible to the general public via digital media (e.g. online or through the sale of software). As "open source" resources, they are generally accessed from any device capable of running the software rather than solely at one location (e.g. a museum installation), and are accessible to a monolingual English speaker. All of the resources identified were intended to work on desktop setups, a setup common to most users (Sousa Santos *et al.* 2009), but increasingly more solutions are designed to work effectively on handheld devices whose uptake is in a period of growth (Ofcom 2013).

Some findings closely resembled cultural examples in the real world, while others made use of fictional environments, while others still combined elements of realism and fantasy. The reason for this decision was that all environments, whether realist or not, were characterised by a dimensionality which was suited to architectural analysis.

Resources represented a range of spatial interactivity. Some allowed the user to move freely around the environment, while others restricted movement to the ability to move between rooms. Some offered panoramic views from a static position or with the ability to hone in on resources. Object-level resources allowed the user to undertake an "object panorama" of the object and view it from all angles. All of the resources allowed some degree of interactivity, so that by the user's agency, the environment or objects could be manipulated.

Most of the resources were designed and developed by interdisciplinary groups involving actors such as developers, subject specialists, and educators. None of the resources identified specified that they were designed in strict accordance with the curriculum requirements for a specific subject.

Each resource is briefly discussed in relation to its content, intended audience if any, design traits (e.g. graphics, interactivity, etc.), and availability.

6.4.1 Findings Using Search Terms

Virtual Trillium Trail

The Virtual Trillium Trail (Virtual Field Trips 2009) was an immersive learning simulation and virtual environment of a real world field trip to a North American, deciduous forest and wildflower reserve. The content contained 3D object representations developed with the conservation society Audubon Society of Western PA. The Trail website states that the Virtual Trillium Trail is based on the fourth grade science and ecology curriculum in the USA. The site claims that the resource is also suitable for the second to seventh US grades. This would place the ideal age group for the resource at 9-10, with the wider range of users aged 7-13. The website suggests the following learning scenarios: 1) the teacher acts as guide while the virtual world is projected onto a screen, 2) the software is installed in a PC computer lab where the students can explore independently. Exploration can be free and open, or teachers can provide students with a map and assign a treasure hunt to find facts and concepts. The website also suggest that the resource can be used before or after a real world field trip (Virtual Field Trips 2009).

The system interface design is characterised by an immersive virtual world using rich CGI rendering of a wildlife habitat. The wildlife is populated by “objects” within the ecosystem, such as wildflowers, as well as by information boards (as shown, below) located beside key objects. Exploration is free within bounded zones and is achieved by moving the cursor through the environment. Animal avatars (such as a deer, a bird of prey) can be moved following the cursor movements. The cursor allows panoramic views of objects but at various points in the system the user is restricted to either ground-level or above-canopy exploration. The rich rendering has a slight compromising effect on the naturalistic flow of the resource but this appears to have been compensated for by the decision to lend richer rendering to key highlighted parts of the system and to use more impressionistic background rendering.

At the time of writing (December 2013), this resource was recorded as unavailable to purchase. This may be due to financial or proprietary factors.

Smithsonian Latino Virtual Museum in *Second Life*

The Smithsonian Latino Virtual Museum (Smithsonian Latino Virtual Museum 2011) is a cross-platform initiative by the Smithsonian Museum which aims to increase educational awareness of Latino culture. The Museum’s presence in the *Second Life* virtual world was of interest to us, since this is a walkthrough environment.

No specific audience was indicated in the accompanying literature. The Smithsonian Latino Virtual Museum appears to be aimed at all *Second Life* users with an interest in the topic.

Design traits cannot be effectively discerned since, at the time of writing (December 2013), this resource could no longer be accessed on *Second Life*. However, the resource uses features typical of *Second Life*, whereby the user selects and creates their own personal avatar whose use extends to all areas of the virtual world. The Smithsonian Museum acquires proprietary rights over an area of virtual space in Second Life, and designers are then able to build objects using the tools offered by OpenSim technology. This results in rendered objects, architectural structures, exhibitions and embedded 2D and multimedia resources providing a virtual museum experience for the visitor.

Great Buildings

Great Buildings (Architecture Week 1999-2012) is a website containing 3D walkthrough examples of built-world architectural masterpieces.

The main purpose of the resource appears to be to facilitate the study of architectural masterpieces by providing walkthrough models that can be explored. Although no user group is specified, the resource is a product of a professional architectural magazine, so it can be surmised that the resource is aimed at adult professional architects or adults with an interest in architecture. The buildings as objects offer a panoramic user experience but they do not contain elements that can be manipulated.

At the time of writing (December 2013), the resource was working but on verification of the link in March 2014, the resource link was broken.

Giza3D

Giza3D (Dassault Systèmes 2012a) is a richly detailed walkthrough virtual world showing the Giza necropolis in Egypt, in its iterations over several centuries. The visuals are designed using CGI technology and feature archival documents and museum objects in their situational context. The objects can be explored in-world and through links to 2D digitised archives. Use is made of avatar guides. The user can walk freely around the environment.

The Giza3D project was designed by Dassault Systèmes in partnership with the Museum of Fine Arts, Boston, and Harvard University. Dassault Systèmes has a history of 3D visualisation, while the Museum of Fine Arts, Boston, and Harvard University were seeking to make better use of the Giza Archives, a digitised archive of the outputs of the archaeologist Reisner, through historical reconstruction and placing items within their context. It is therefore another example of subject experts and technical experts partnering to achieve 3D visualisations in cultural heritage. This collaboration resulted in accuracy, since the evidence (archived photographs of digs, drawings, plans and notes) could be used to reconstruct the original appearances of archaeological finds either in ancient times or at the time they were discovered during 20th century digs.

According to Dassault Systèmes (2012a), Giza3D has two main aims: preservation and access. Preservation is important because the real-world monuments are vulnerable due to weather erosion and human encroachment on the site, while access is important because many people cannot visit Giza and cannot access all areas if they do. Another clear advantage of the Giza3D project is the sheer size of the physical site of the pyramids at Giza and the difficulties that would have existed in mentally visualising the location and context of mapped archaeological finds on the site. Dassault Systèmes (2012a) suggests Giza3D's role in teaching and research, especially in archaeology. In addition, they argue, the interactivity of Giza3D is such that it can be approached by "wanderers" with minimal subject expertise, since delving deeper into objects and archives is optional.

Giza3D can be accessed via an Internet portal. At Harvard University and in public displays, it has been projected onto a large screen for teaching purposes. Dassault Systèmes suggest that in a museum context, Giza 3D could be visualised using a virtual reality "cave" for the most immersive experience.

6.4.2 Findings from the Literature Review

The difficulty in devising semantic terms through which resources could be located is highlighted by the fact that some qualifying examples came to our attention during the literature review, while not being located using the search terms online. They are listed below.

Virtual Museum Transnational Network (v-must) (2011)

v-must is a European Union (EU) funded Network of Excellence which facilitates the development of virtual museums in the heritage sector. The project is timetabled from 1st February 2011 – 31st January 2015. v-must is an aggregate source of virtual museums developed with EU funding.

The following virtual museums featured on the v-must website qualify for further analysis:

***Aquae Patavinae* VR (2011-2012)** is a resource enhancing the landscape of the archaeological landscape of Montegrotto, near Padova in Italy, using virtual reality. The initial resource in VR invited users to activate a reconstruction of the site which was visualised in transparency above the extant remains, and then allowed them to walk inside the VR monuments. The resource is also available in an online desktop version. In this resource, the user can "flyover" the geographical area, before selecting features to land on and walk through. Browsing is interactive, and users may focus on specific features. Due to this resource being both walkthrough and interactive, and meeting the other criteria, we selected it as a possible test resource.

***The 39 Steps* (Avanquest Software 2013)** is a new-generation e-book which is described as bridging the "gap between literature, film and gaming". The product is made up of more than 300 hand-painted environments, alongside an original soundtrack, which readers navigate through and interact with to move through the story.

The 39 Steps is a digital interactive resource which was released by a traditional publisher, Faber, in collaboration with a software distributor, and involved the creative work of The Story Mechanics. *The 39 Steps* is sold as a CD-ROM through outlets distributing for publishers, such as amazon.co.uk.

The Virtual Museum of Iraq (2013)

The Virtual Museum of Iraq is a 3D explorable online environment, available in Italian, English and Arabic versions, comprising a museum environment with several halls, and various multimedia sequences showing modern and ancient Iraq through architecture and natural features. According to the museum website, the site contains 70 artefacts, 40 3D models, over 100 images on file, 22 films and 18 archaeological sites (The Virtual Museum of Iraq 2013).

In the environment the user can enter through a series of doorways and navigate around the scanned objects in each hall. Each hall consists of a 3D CGI environment in which scanned museum objects are embedded. The museum features both walkthrough options, which allow the user to choose to enter new halls, to progress within a "hall" (e.g. through an archway in the Babylonian room) and to highlight and consider more closely objects and their metadata, as well as video sequences and video pathways which create the dynamic impression of a walkthrough without all of the user features to determine a specific pathway. The museum contains several artefacts from ancient civilisations, and combines the realism of a museum with its galleries and exhibits with historical and fantasy elements which add a multimedia dimension connecting the gallery experience with the original cultural context in which the objects were used. They sometimes link visually to the more static museum rooms through overlaying of historical action with extant artefacts. The objects themselves can be highlighted, and a small number can be rotated. The objects are a mixture of scanned items and GCI graphics. This is not always obvious: for example, in the Sumerian Hall, three of the items which appear to be among the scanned objects are in fact computer generated. The sequences use a variety of media: maps, satellite imagery, 3D modelling, scanned items, archival photographs, and atmospheric music, which are often imperceptibly blended to the untrained eye.

The Virtual Museum of Iraq contains items found in the National Museum of Iraq, a physical museum located in Baghdad. The Virtual Museum was funded by the Italian Ministry of Foreign Affairs and realised by the Italian National Research Council. The realisation of the museum was achieved through the work of a multi-disciplinary team. The Virtual Museum of Iraq was created by a large team of researchers and technicians. 152 individuals are credited as contributing to the resource, as well as a number of organisations which are credited in the place of individuals. A number of specialists worked on the project, including authors of the written texts. Computer graphics and IT specialists were also considerably involved in the project. Responsibility for the visualisation of different rooms was spread across computer graphics companies and individual designers. Beyond the design aspects, translators, legal experts, diplomatic personnel and marketers were involved in the implementation of the virtual museum.

The justification for the creation of the virtual museum can be seen as twofold: first, awareness of the need to preserve Iraq's cultural heritage was raised following looting in 2003 during the Iraq War (2003-2011). In addition, the project was orientated towards knowledge sharing and access for the international community, and this, in turn, can be understood to be inspired by both the quality of museum resources and the difficulty for the international public of travelling to Iraq to see the objects in the National Museum. Thirdly, it was envisaged that the virtual museum be a communications portal for the National Museum (The Virtual Museum of Iraq 2013).

Open Virtual Worlds

Open Virtual Worlds (2013) is a research project at the University of St Andrews, Scotland. Research under this project title has generated virtual worlds of historical sites, including St Andrews Cathedral 1318 (which includes a virtual guide in the avatar of Robert the Bruce) Caen Township (a 19th century township, pre-Highland Clearances), Linlithgow Palace (14th century), Brora Salt Pans, Spartan Basilica, and Martyrs Church (a parish church in St Andrews). In addition, in January 2014, the following reconstructions were in progress: St Andrews Castle (12th century), St Salvator's Chapel (St Andrews, 15th century), Eyemouth Fort (1557), Mossfell Viking Longhouse, and Fethaland Fishing Station. Each environment is a digital reconstruction of an historical site. The user adopts an avatar and is able to walk around and fly through the environment. The virtual worlds can be accessed via personal computer using a mouse, or using a joystick in a game-like set up. In addition, for installations, it is possible to use a virtual reality viewer, and Open Virtual Worlds has created the "ACE (Armadillo Control Extensions) viewer" for this end.

In the St Andrews Cathedral example, the reconstruction was a collaborative effort between computer scientists and the School of Art History at the University of St Andrews. Contributors also came from the School of Classics and from the Special Collections at the University of St Andrews Library. This collaboration involved the provision of virtual books to be added to the virtual Scriptorum of the Cathedral (St Andrews Special Collections 2012), which is of interest because it involves the embedding of special collections library resources within a virtual environment, constituting a 3D digital library. At the time of writing (January 2014) this aspect of the collaborative work was in progress.

The visualisations use Open Virtual World (OVW) technology which uses server side software that can be run as required, and the communication protocol is open source. The aim of the Open Virtual

Worlds project is to develop OVW as a platform for cultural heritage, and also to build collaborative partnerships, as, for example, in providing experts with alternative visualisations in historical reconstructions.

Empire Exhibition 1938

The Empire Exhibition 1938 is a project conducted by the Digital Design Studio (DDS) (2012), a 3D design school specialising in 3D digitisation, at the Glasgow School of Art, Scotland. The resource recreates the principle buildings of the physical Empire Exhibition which was held in Glasgow in 1938. The project also produced a 3D map showing the relationship of various features to the topography of Bellahouston Park, where the exhibition was held. The featured public resource is not fully walkthrough, however, and so it is not included in our final selection.

The resource was developed by the DDS in collaboration with a range of people who could provide historical information: for example, interviews were conducted with those who visited the exhibition in 1938, and archives were consulted.

The project states that its aim was to create “a permanent resource” which would concern, specifically, the Empire Exhibition of 1938, and, more broadly, UK social and architectural history.

Scottish Ten project

Scottish Ten (2013) is the name of a 3D scanning project with collaboration between Historic Scotland and the Digital Design Studio at the Glasgow School of Art.

The Scottish Ten project involves the documentation of ten key World Heritage Sites using scanning technology. These sites are Mount Rushmore, New Lanark, Orkney, Rani ki Vav, St. Kilda, Edinburgh, Eastern Qing Tombs, Sydney Opera House and Antonine Wall. The scans have generated a number of 3D online tours some of them employing artistic innovations, such as the Maeshowe Chambered Cairn (Orkney) resource (historicscotlandtv 2012a), and Skara Brae prehistoric village (Orkney) (Watterson *et al*. 2012), Rani ki Vav (historicscotlandtv 2012b). Since these resources, in their public domain, are not fully walkthrough, they are also not included in our final selection.

For several of the projects, Scottish Ten worked with CyArk, a non-profit organisation working in digital preservation (3D laser scanning, modelling, archiving and public dissemination). Since the projects mostly involved digital documentation, there was little need for wider subject expertise, as was the case in the Open Virtual Worlds projects, for example, where wider knowledge came to bear upon the historical reconstructions. However, in research projects attached to the digital data, such as Watterson *et al*.'s work on Skara Brae (2012) wider contextual knowledge from archaeology and concerning theories of representation came to the fore.

Information on the Scottish Ten project (2013) is included, although it involves no bespoke walkthrough resources. This is because during the literature review, Scottish Ten was revealed as an important project in scanning and digital documentation of cultural heritage. While these scans do not involve game-like, manipulable or walkthrough features, they represent cutting edge work in exploring heritage sites remotely. The lack of interactive features highlights a possible divergent fork between digital documentation and interactive games, which could be readily bridged in future projects involving a range of stakeholders and technologies.

Valentino Garavani Museum

The Valentino Garavani Museum (Association Valentino Garavani Archives 2012) is an online virtual museum featuring walkthrough galleries, containing projections of 2D archives and 3D scanned dresses, as well as audio-visual media relating to the fashion designer Valentino Garavani. Each dress can be explored by accessing a panoramic view of it, a zoom feature, and associated archives, such as photographs or videos of catwalk debuts. There are galleries featuring archive footage and photographs, as well as video interviews with the designer. The virtual museum also contains a media library of over 5000 images, dresses, and videos of fashion shows.

The Valentino Garavani Museum is a project of l'Association Valentino Garavani Archives (AVGA), whose headquarters are in Davron, France. The virtual museum is therefore one of the only examples we found of an archive service which has developed a 3D resource.

The museum contained CGI to create basic gallery spaces, with scanning in 2D and 3D having taken place for archives and dresses, which are scanned on mannequin models.

The museum appears to play a role in the areas of co-location, publicity, and legacy-building. The co-location of archives in a virtual gallery environment allows for an exhibition of Garavani's designs over the years to be comprehensive, and for the design evolution to be observed, while the dresses can be located alongside more contextual archival information and multi-media resources. The virtual museum also seems to have a publicity and legacy-building role since it creates an online centralised portal giving prestige to a living designer. Information about Garavani's own life creates a virtual legacy to him. Garavani retired in 2008 and so the creation of the museum in 2011 can be seen in this context. It must also be mentioned that the costs of creating a virtual museum are likely to have been considerably lower than creating a similar exhibition in a physical gallery.

Google Art Project

The Google Art Project (Google Cultural Institute 2013) is an online resource where users can access scanned images of artworks held by Google's partner institutions. The Art Project also encompasses walkthroughs of galleries, with floorplans, using the same technology as "Street View" in Google's *Maps*, which is why the project is included in our list of findings. Unfortunately the close inspection of the objects and artworks afforded by the ordinary view is not available in the walkthrough version, since the two features are not integrated. At the cut-off date of 15th December 2013, determining the end of the search for resources, the Google Art Project contained data from 151 museums in 40 countries. The Google Art Project features the interior of galleries and museums. Since this involves simply photographing the interior of museums, it was judged by us that this offered little interactivity or design elements transcending visual representations of physical museums. *Google Maps* has also gone beyond mapping streets to encompass historical sites, such as the underground chambers of the Priscilla Catacombs in Rome (The History Blog 2013).

The Google Art Project's walkthrough feature uses Google Street View technology. Street View allows one to advance forward, pivot and to undertake panoramic views from a static position.

6.4.3 Findings of Interest but not Qualifying

A number of items indicative of 3D visualisation of cultural resources were identified, but failed to meet the established criteria on one count.

Smithsonian Museum's X 3D Explorer

The Smithsonian Museum's beta version of its 3D modelling programme, launched in November 2013 (Draxler 2013) and called the X 3D Explorer, allows users to explore interactive, digital versions of museum objects including a mammoth skeleton, the Wright Brothers' aeroplane, and an enlarged bee.

The resource has no defined audience. However, when the text of the resource was inputted into software which assigned a reading age, the level of the writing was given as being that of post-secondary education. Hence, the resource may be best read and received by an adult audience, if accessing the texts that precede the models themselves is important to the user.

This resource involved 3D objects, rather than virtual worlds, and so, while representing a vanguard or trend in 3D object visualisation, the resource does not fall into the remit of this study. The resource uses CT scanning, laser scanning and photogrammetry. The user can navigate around the resource, which is displayed on a grid, giving 360° panoramic views. The resource gives instructions as to how mouse and keyboard selections can facilitate navigation. The 3D objects are accompanied by written information and multimedia resources.

Shipping Galleries 3D Model, Science Museum London

The Science Museum London's *Shipping Galleries 3D Model* (Science Museum 2013; Digital Arts Staff 2013) is a point cloud 3D model that was made to preserve for public access a gallery which closed in 2012, and whose items were moved into storage.

However, this model was not interactive, and had few walkthrough options (a minimal flythrough was permitted), and so it was excluded from our list.

3D Citadel of Bam

The 3D Citadel of Bam (National Institute of Informatics 2004-2012) is a virtual reconstruction of the historical ruins of the city of Bam, Arg-e-Bam, in Iran.

The 3D Citadel of Bam was created by collaborators from the National Institute of Informatics; the Iranian Cultural Heritage, Handicraft and Tourism Organisation; Waseda University; University of Tehran, University College of Fine Arts; and L'école nationale supérieure d'architecture Paris Val de Seine (NSAPVS), Virtual Space of Conception in Architecture and Urbanism (EVCAU).

The models of the Citadel are constructed using 3D modelling, with documentary evidence used to inform the reconstruction (Ono *et al.* 2008).

The Citadel of Bam was famously partially destroyed by an earthquake in 2003. After the earthquake, UNESCO declared "Bam and its cultural landscape" to be an example of "World Heritage in danger" (2004). It remained labelled as such until 2013. In this context, the aims of the project, taking place under the auspices of the Digital Silk Roads project, was to aid in the post-earthquake reconstitution of Bam, by creating a digital reconstruction, and by gathering and collecting digitised data in the process (National Institute of Informatics 2004-2012). The "virtual reality" Bam was but one output of these aims realised.

However, although a series of walkthrough videos are available online and a substantial amount of digital modelling has taken place, the 3D Citadel of Bam is not publically available as a walkthrough virtual environment where the user is agent in determining a path.

Museums of the v-must network

The following virtual museums are featured on the v-must website, but do not qualify on all counts.

Reenchant Historical Heritage (2013) employs digital tablets and binoculars to provide augmented reality historical reconstructions at the Château Guillaume-Le-Conquérant (The Chateau of William the Conqueror) de Falaise in France. This was excluded using our criteria, since it involves augmented reality rather than visuals which can be accessed on a screen and from a distance.

Imago Bononiae (2013) is a work in progress (at the time of writing in December 2013) featuring a walkthrough and interactive version of Roman Bologna. It was excluded from our selection because it was not publically available in December 2013.

Matera Tales of a City (2012) comprises a range of digital resources aimed at facilitating a pre- and post-visit experience of the World Heritage Site of Matera in Italy. The resource, which included 3D reconstructions, is available in English, Italian or German. However, since these reconstructions are shown as videos rather than as walkthrough interactive environments, they are excluded from our search.

Locus Imaginis (2012) is an interactive and collaborative platform allowing users to add pictures of monuments to a database which are then positions on a 3D digital model of the monument and semantically annotated. Since this is not a walkthrough environment, it was excluded from our search.

Vrouw Maria (2012) was an interactive, virtual reality simulation of the Vrouw Maria shipwreck which sank in Finnish waters in the 18th century bearing a cargo destined for the Empress Catherine the Great of Russia. The resource was available as an installation in the Maritime Museum of Finland in 2012. It is excluded from our search because the resource is not publically accessible, since it was a time-limited museum exhibit.

Etruscanning 3D (2011-2012) was a physical museum installation using virtual reconstruction of 3D tombs and objects. However, since this installation was not distributed on the web or as a purchasable resource, it was excluded from our search.

The Cathedral of Santiago de Compostela (2011) is an application which is intended to allow “spatial, volumetric and sectional analysis” of the Cathedral of Santiago de Compostela, Spain. The application allows the user to examine cross-sections of the Cathedral as well as use zoom, rotate and pan features. Use is made of a multitouch device to enable common gestures to manipulate the model. However, since this was a model rather than a walkthrough environment, it was excluded from our search.

The Museum of Pure Form (2011) is a virtual digital art gallery containing 3D sculptures. However, since the museum uses innovative tactile technologies, it needs to be physically situated. At the time of writing (December 2013), the museum is currently visitable in Pisa, Italy. Since it is not an online resource, it is excluded from our search.

Sarajevo Survival Tools (2011) is a multimedia website virtual museum documenting Sarajevans' survival during the siege from 1992-1996. However, it is not sufficiently 3D or walkthrough an environment for our study.

Virtual Rome (2008) was an Open Source web virtual reality project aiming to create a 3D online virtual environment of geospecific data, 3D models and multimedia contents pertaining to ancient Rome. However, the project is not currently maintained (writing in December 2013) and cannot be accessed from the Internet, so it was excluded from our search.

Virtual Museum of Ancient Flamina (2008) is a VR installation at the Roman National Museum, Rome, Italy, involving the virtual reconstruction of a Roman villa. This project is available as a museum installation rather than as an online resource, so it is excluded from our search.

Teramo Virtual City (2010) was a virtual reconstruction with interactive features that was a museum installation at Teramo City Museum, Italy. Because it is not publically available online or to buy, it is excluded from our search.

Stymphalia Environment Museum (2009) is located in Stymphalia, Greece, and involves a wide range of interactive and VR features. However, due to its physical contingency and lack of availability online or for public purchase, it is excluded from our search.

Virtual Museum of Ercolano (MAV) (2008) is a further example of an immersive, built museum experience, featuring virtual reality experiences. It is also excluded since it is installation-based, rather than available online or for public purchase.

Last Supper Interactive (LSI project) (Fischnaller 2012) is an immersive interactive VR experience which allows the user to "step inside", and to "look out" onto the refectory space of Leonardo Da Vinci's *Last Supper* masterpiece. It is a natural interaction technology which relies on CAVE visualisation and is hence not included in our final list since it is not a desktop resource.

6.5 Selection of Examples for Experimental Methodology

It was important to select exemplary resources for the experimental methodology so that participant data could reveal relationships between design and the user experience. A minimum of three such resources were sought from the examples identified in this chapter.

All the resources were considered in the light of whether they were exemplary in the following ways

- Walkthrough virtual worlds
- Interactivity
- Collaborations with cultural institutions
- 3D digital design utilised as means of going beyond what can be observed in the built resource
- Resource currently online or available for purchase

Several resources identified were unsuitable for use as a result of become unavailable online through broken links or being no longer available to purchase. This highlights a problematic reality whereby time, expense and expertise are not available to the public in the longer term once a project has seen the duration of its course.

The list of eligible sources was collated and we tried out each resource, as a member of the public encountering it for the first time. Some were eliminated since on use, they were found to be lacking in some of the above points. This process is detailed, below.

Table 10. List of resources considered for laboratory trials with 3D digital libraries.

Resource	**Eliminated? With reason**
Virtual Trillium Trial (Virtual Field Trips 2009)	Y. Resource not currently online or available for purchase.
Latino Virtual Museum	Y. Resource not currently online or available for purchase.
Great Buildings (Architecture Week 1999-2012)	Y. Low or no interactivity.
Giza3D (Dassault Systèmes 2012a)	N.
Virtual Museum of Iraq (The Virtual Museum of Iraq 2013)	N.
Open Virtual Worlds (2013)	N. The St Andrews Cathedral model was chosen since it was available online and contains within it the possibility for library collaboration with the virtual scriptorium.
Empire Exhibition 1938 (Digital Design Studio 2012)	Y. Minimal interactivity.
Scottish Ten Project (2013)	Y. Minimal interactivity.
Valentino Garavani Museum (Association Valentino Garavani Archives 2012)	N.
Google Art Project (Google Cultural Institute 2013)	Y. Lack of integration of interactivity into walkthrough galleries.
Reenchant Historical Heritage (2013).	Y. Resource not currently online or available for purchase (it is an augmented reality resource).
Imago Bononiae (2013).	Y. Resource not currently online or available for purchase.
Vrouw Maria (2012).	Y. Resource not available online or for public purchase.
Aquae Patavinae VR (2011-2012).	Y. Resource not fully accessible online.
The 39 Steps (Avanquest Software 2013)	N.

The final list of possible resources is thus**:**

- Giza3D
- Valentino Garavani Museum
- Virtual Museum of Iraq
- Open Virtual Worlds (St Andrews Cathedral 1318)
- The 39 Steps

St Andrews Cathedral 1318 did not download on several standard desktop systems when tested, which presented a challenge for the practical classroom scenarios envisaged, and so was also eliminated at this stage. *The 39 Steps* (Avanquest Software 2013) was somewhat different from the other resources since it was an interactive, game-like first-person user point of view version of a novel. While embodying several principles of a 3D digital library, the fact that it is presented as an interactive digital publication, it presents possible conceptual inconsistencies with the other resources identified, and to maintain some experimental similitude which would allow for the investigation, in particular, of the architectural principles associated with virtual environments, only Giza 3D, Valentino Garavani Museum, and Virtual Museum of Iraq were finally selected.

This section concludes both the literature reviews and identification of resources which establish theoretical frameworks and suitable experimental resources that necessarily precede an experimental methodology. The following chapters deal with the design, implementation, reporting and analysis of a methodological approach to the exploration of the research questions.

PART II: USER TESTING WITH SELECTED RESOURCES

Chapter 7: Experimental Methodology

7.1 Introduction

Having identified a framework for the design of 3D digital libraries, combining architectural and HCI design, and having reviewed the literature concerning the study of user behaviour with library and information systems, this chapter now develops an experimental methodology suitable for studying 3D digital libraries which considers design in relation to user behaviour.

There is some precedent for the use of experimental methodologies as we are contemplating applying to 3D digital libraries, in the study of virtual environments. In Mikropoulos and Natsis' (2011) review of empirical research into educational virtual environments from 1999-2009, the authors found a total of 53 studies, of which 28 were descriptive and 25 experimental. The studies reviewed used a variety of data collection methods, as well as many using mixed methods. The methods included questionnaires (35 studies), interviews (23 studies), observations (10 studies), recordings (14 studies), log files (6 studies) and task completion exercises (7 studies).

Following these precedents, it is therefore appropriate that this methodology also mix its methods and take its cue from usability studies by considering usability against metrics, but it is also incumbent upon the methodology to take into account more qualitative descriptions of the user experience that are able to gather richer data on user behaviour as described in the literature review, which can incorporate complex affective and motivational states. In order to consider these states in relation to dimensional design it is also incumbent upon the experimental design to provide opportunities for users to speak about their "in world" experience.

The methodology is proposed not only as a precedent for future investigations of the user experience with 3D digital libraries; it is also designed to explore the research questions and seeks indicative results which can form the basis of further research. The questions – as a reminder – are given below.

RQ1 What are the key criteria relevant to the design of 3D digital libraries?

RQ2 How do 3D digital libraries encourage exploration and curiosity?

RQ3 What types of information behaviours take place with 3D digital libraries?

RQ4 In what ways do 3D digital libraries deliver benefits to the learning experience?

7.2 Ontological and Epistemological Approach

According to Guba and Lincoln (1994), paradigms can be characterised through their: *ontology (What is reality?)*, *epistemology (How do you know something?)* and *methodology (How do go about finding out?)*. These characteristics create a holistic view of how we view knowledge: how we see ourselves in relation to this knowledge and the methodological strategies we use to un/discover it (University of Southampton 2013).

This research follows a realist ontology, in that reality is perceived to exist and is knowable. In addition to realism, some critical realism is accepted since it is recognised that our own presence as researchers can influence what we are trying to measure. For this reason, when constructing an experimental methodology we are aware of how the experiment itself can influence the results and seek to acknowledge potential weaknesses and act to reduce them where necessary.

Epistemology concerns our perceived relationship with the knowledge we are discovering. It concerns the question of whether we are a part of that knowledge or whether we are external to it (University of Southampton 2013). The realism detailed above would seem to point to a realist epistemology, too, whereby the researcher is external to the knowledge discovered.

Qualitative research in this study is orientated towards the testing of theories, and is used in conjunction with quantitative methods to test a research hypothesis. This approach is in keeping with trends in qualitative research. Bryman (2008, p.373) states that "in more recent times qualitative researchers have become increasingly interested in the testing of theories" and "this is a reflection of the growing maturity of the strategy". Bryman concurs that "there is no reason why qualitative research cannot be employed in order to test theories that are specified in advance of data collection" (2008; p.373).

Hammersley (1992) proposes that while "validity" remains a key quality criterion across research methods, it can be reformulated in the light of a qualitative research context. Validity "means that an empirical account must be plausible and credible and should take into account the amount and kind of evidence used in relation to an account" (cited in Bryman 2008; p.381). However, the attempts of the researcher to assess the social reality need to be validated against plausibility and credibility, thus creating an approach which Hammersley (1992) himself deems "subtle realist". According to Hammersley (1992), "we must judge the validity of claims [about truth] on the basis of the adequacy of the evidence offered in support of them (p.69)" and this means that qualitative research can be held to be “valid or true if it represents accurately those features of the phenomena that it is intended to describe, explain or theorise” (1992; p.69).

7.3 Summary Methodology

The methodology will follow the following stages (discussed further in sections which follow).

1. Test scenario involving use of the 3D resource in a computer laboratory, involving
    a) Initial questionnaire to participants, to gather participants’ demographic information.
    b) Post-use usability questionnaire.
2. Focus group interviews with participants, approx. 1 week after the laboratory event.
3. 7 months later, longitudinal follow-up interviews with students and teachers.
4. Analysis (including transcribing and coding).

The experimental process is visualised, below

Summary methodology visualised

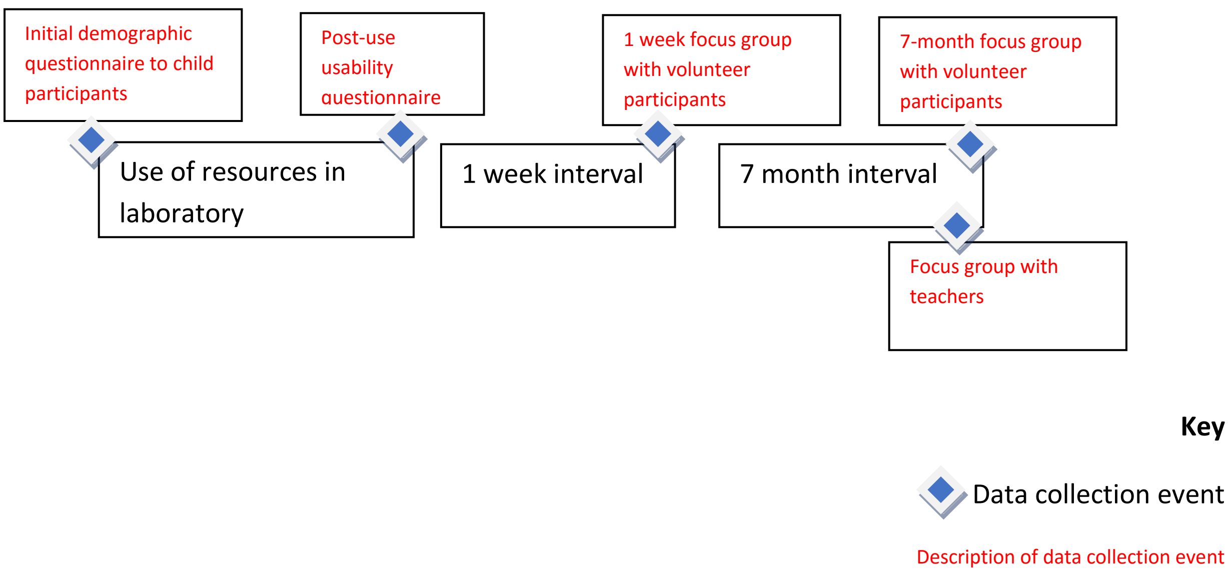

Fig. 9. Summary Methodology.

7.4 Quantitative Component

The qualitative component of the data collection employs HCI methodological approaches and is intended to collect data on the usability and usefulness of the 3D digital libraries. The following sub-headings review the role of quantitative data collection in HCI and specific methods, and gives justifications for the selection of methods. A description of trials taking place in a school computer laboratory are then given in detail.

7.4.1 Main Areas of Investigation

The main area of investigation for the quantitative part of the methodology is to examine the usability and usefulness of any of the three 3D digital libraries selected in Chapter 6 (*The Valentino Garavani Museum*; *Giza 3D*; *The Virtual Museum of Iraq*). We employ usability metrics identified in the HCI literature review and use an appropriate data collection method to provide measures of usability and usefulness and identify any problems. We also collect relevant demographic information on the users. This part of the methodology is therefore a baseline part of the entire methodology, which goes on to explore more qualitatively the user experience in relation to the 3D digital library environment.

7.4.2 Overview of Quantitative Methods in HCI

HCI research considers usability and the user experience. The term “HCI” arose in the 80's, when academics in the field started an annual conference called CHI (Computer Human Interaction), which soon generated the term “HCI”; while “usability” is a practical term drawn from product design. Madanes (2006) explains that the genesis of these terms was separate: user experience was a term coined to cover more aspects of the interaction than simply what was on the screen. Norman later clarified that “more aspects” referred to a “person's experience with a system, including industrial design, graphics, the interface, the physical interaction, and the manual” (peterme.com 1998). By inference, there is a difference in emphasis between the three, with HCI as an overarching academic term, user experience as a descriptor of the entire experience, and usability denoting that products are easy to use.

The use of mixed methods in HCI is increasingly common. For example, Kjeldskov and Graham (2003) and Kjeldskov and Paay (2012) produced a list of main research methods in mobile HCI, finding that research took place in the form of case studies, field studies, action research, laboratory experiments, survey research, applied research, basic research and normative writings. However, in order to maintain clarity in this study, usability was tested through questionnaires before and after a laboratory session, whereas conclusions were drawn about the broader user experience as a result of the qualitative (focus group) methodology following on from this.

The role of the laboratory trial is to collect data to analyse the demographic of the group and the usability of the 3D digital libraries. Therefore, methods drawn solely from HCI are used in this part of the experiment. In testing settings, HCI research generally "employs techniques to collect empirical data while observing representative end users using the product to perform realistic tasks" (Rubin and Chisnell 2008). The advantage of a well-structured study involving a developed system, according to Rubin and Chisnell (2008), is that it can be one of the truest and most accurate measures of usability, since the user, product and environment are "all in place and interacting" with each other.

7.4.3 Selection of Specific Methods from HCI

Questionnaires are the most commonly used tool for usability research (UsabilityNet 2006a). It was decided to make use of questionnaires in the methodology, with a pre-use demographic questionnaire, and a post-use usability and usefulness questionnaire. It was decided to use a paper questionnaire, since this was the most straightforward option of administering questionnaire before and after use of the libraries. The people who participate in a survey are technically called "respondents" (Blackwell 2013), although in this study they are referred to as "participants" and "users" too. User surveys are an element of "subjective evaluation", as identified by UsabilityNet (2006a), which can potentially be tailored to ask users to provide data about a range of features of the user experience, and they were therefore well configured to design to capture usability and usefulness measures based on metrics. Any well-designed survey that goes beyond identifying satisfaction meets the more desirable goal of "find[ing] out what features of the software give rise to unprecedentedly high or low levels of satisfaction" (UsabilityNet 2006a), and therefore offers investigative benefits in relation to the research questions.

The most important aspect of a survey methodology is the choice of questionnaire and UsabilityNet (2006a) recommends that existing questionnaires provide the basis of any usability questionnaire administered. For this reason, metrics drawn from other sources and questionnaires were used as the basis of the questionnaire devised. Questionnaires generally include a combination of closed questions (predetermined responses, either yes/no or multi choice), Likert scales to indicate strength of agreement with a statement, and open questions (free text, which must be coded for analysis) (Blackwell 2013). When open questions are used, a set of coding categories must be created, with a way of assigning each answer to one or more categories and dealing with those which fall outside of the coding scheme (Blackwell 2013).

Another methodological approach that was considered was observation and, specifically, the extent of observation that would or could take place during the laboratory trials. The main focus of observation in usability testing remains gathering discrete data in a laboratory when a user is executing a task although this can extend to the use of computers in more natural settings. A small amount of observation was planned but a greater degree of observation could have sat alongside the laboratory use of the system. In one typical example, data may be gathered through spoken feedback from participants while they are using the resource. This can involve either a question asking protocol, whereby the researcher asks the user questions about what they are doing, or a think-aloud protocol (Fidas *et al*. 2003), where the user is asked to talk about what they are doing with minimal interventions by the researcher.

Both question-asking protocols and think-aloud methods are intended to gather richer data about the user experience at the time of system use. This accrues benefits because of the immediacy of user feedback in relation to the task, as well as being orientated towards finding out what the user is thinking. However one reason that the think-aloud was not chosen was because the young people were in classrooms and the school was not equipped or able to spare the time to allow for this kind of observation. Secondly, a usability questionnaire was thought to be sufficient to establish usability of the system and to allow young people the experience of using one of the libraries. Later focus groups probed the user experience in terms of cognitive, behavioural and affective responses. In a think-aloud test the user tries to carry out realistic tasks using the system, and the researcher asks the user to “think-aloud”, explaining what he or she is doing and why. While this can reveal important clues as to benefits and problems of a system, and the strategies that users follow when using a system as well as clues as to how users think and feel about a system, it can easily focus on usability aspects rather than the engagement with a system or reflections on the learning experience which can be better probed, we suggest, in focus groups.

Observation may involve “performance evaluation” (UsabilityNet 2006). With minimal intervention by the observer, the researcher can record discrete events, such as time to complete task, and use notetaking to note any anomalous events or interruptions. It was considered apt to use such evaluation. Task completion time could be a significant observation in the user experience, and user questions or interactions during the testing could be important. Another option was tracking. Tracking was also not considered a priority because the usability questionnaires would yield enough data on usability, and because tracking would not provide enough cognitive information. Tracking may also have had the effect of unduly influencing user behaviour since they may have altered their behaviours as a result of the knowledge that they were being tracked through the system, adding a bias to the data collected (Rubin and Chisnell 2008).

A number of other methods were ruled out, due to their inappropriateness to the study. For example, HCI methods which are used in the development of a product are not usually relevant to the analysis of completed resources. For example, "exploratory studies" are conducted fairly early in the development cycle, when a product is in the earliest stages of definition and design (Rubin and Chisnell 2008). A further example of this type is the assessment test, which is conducted either early or midway in the product development cycle, and is in fact the most typical type of usability test conducted, according to Rubin and Chisnell (2008). Assessment tests typically evaluate the usability "of lower-level operations and aspects of the product" (Rubin and Chisnell 2008). We work under the assumption that this kind of testing or a test of equivalent effectiveness will already have occurred with finished resources, although some usability problems may remain. Assessment tests are followed by validation tests or verification tests, usually tailored to measure usability against established benchmarks or ensure that earlier identified problems have been remedied and that new problems have not arisen (Rubin and Chisnell 2008). The scope of validation tests overlaps with broader usefulness considerations, as well as architectural design and the overall user experience, and has potential applicability after the product is complete, and is closest to the questionnaires and laboratory scenarios described.

Rubin and Chisnell (2008) cite the "comparison test" as an option in usability testing, and this falls within an experimental paradigm, as a type of control test. When it is applied on or toward the end of the system lifecycle, a comparison test "can be used to see how the released product stacks up against a competitor's product" (Rubin and Chisnell 2008). One example of how it could be applied in this or similar research, is if a relevant comparison were to be sought between a 3D digital library and an alternative resource, such as a search engine or 2D resource. The basic methodology of the comparison test involves the side-by-side comparison of two or more clearly different designs (Rubin and Chisnell 2008). Data are collected for each alternative and the results compared. Classical experimentation requires that, as far as possible, alternatives should vary along a single dimension. The allocation of the same information-seeking task to participants, but giving them entirely different resources, would likely create a scenario where it is harder to determine cause and effect or which is the operative heuristic, and so results would be less statistically valid but potentially of value. Rubin and Chisnell (2008) state that a good test forces participants to "really consider and contemplate why one design is better and which aspects make it so". This test was not the focus of this study because the heuristics and user behaviours explored are potentially so many that richer narrative data is first sought, to provide new research directions. In future research, a comparison test may be effective to verify or deny the conclusions reached and suggestions advanced in this research.

Other methods that were considered but ultimately not selected include usability evaluation methods which rely on inspection. Dix (2006) identifies three major evaluation methods: heuristic evaluation, cognitive walkthrough, and review-based evaluation. Heuristic evaluation is a form of usability inspection originally proposed by Nielsen and Molich (1990), whereby usability specialists judge whether each element of a user interface follows a list of established usability heuristics (UsabilityNet 2006d), and is often orientated towards the identification of usability problems in user interfaces (Botella *et al*. 2011). Another inspection method is the "cognitive walkthrough" (Blackmon *et al*. 2002), which involves "walking through" the system and evaluating its design with reference to cognitive principles as they apply to the user as learner. In review-based evaluation, results from the literature are used to support or refute parts of the design (Dix 2006). In this approach "design rationale can also provide useful evaluation information" (Dix 2006). It could be suggested that review-based evaluation in HCI relates most closely to methods in architecture, in books where principles and compositional elements are identified (Robertson 1924; Curtis 1935; Edwards 1952; Ching 1996; Lorda 2012).

The scope of both heuristic and review-based evaluation is to seek to discover if, in principle, a number of design heuristics are embedded within the design. The scope of cognitive walkthrough aims to evaluate a system design on the basis of how well it supports a user in a learning task. This technique is usually undertaken by an expert in cognitive psychology. In the cognitive walkthrough, the key considerations at each stage are: "what impact will the interaction have on the user?", "what cognitive processes are required?", and "what learning problems may occur?" (Dix 2006). UsabilityNet (2006d) states that it "is beneficial to carry out a heuristic evaluation on early prototypes before actual users are brought in to help with further testing". However, with evaluation methods, there may be a difference in evaluators' ability to identify and attitude to usability problems and there may be limitations in how their severity is judged without reference to user testing (Hertzum and Jacobsen, 2001; Molich *et al*., 2004). It was considered that this approach would not be stringent enough in relation to the research questions because it was more important to have participants actually use the systems and talk about them in order to obtain data on the user experience.

7.4.4 Test Environment, Equipment and Logistics

It is intended that the testing will take place within the computer laboratory, in a real-life learning situation. This setting accrues benefits from both field and laboratory settings. A classroom or school computer laboratory is in many ways akin to a field study environment, because it is a real, rather than artificial, learning environment where schoolchildren and teachers have real world learning to accomplish. It is also compatible with experimental methodologies because in a classroom, many of the variables can be altered because one is working with a select group of users, and the learning tasks can be structured according to an experimental methodology.

The equipment required is a computer laboratory with an Internet connection and sufficient processing speeds to run the three resources. The system requirements of Giza3D for Microsoft Windows were:

- Microsoft Windows 32 or 64 bits (XP, Vista or Seven)
- Processor: Pentium IV 2.5 Ghz or AMD equivalent
- 2 GB RAM
- Graphic parameters: Graphic card compatible with Pixel Shaders 3.0 (512 MB VRAM)
- Sound : Compatible with DirectX 9.0c (Dassault Systèmes 2012a)

The system requirements for the *Virtual Museum of Iraq* and the *Valentino Garavani Museum* could not be found, but on pre-testing in a laboratory, both systems were found to run smoothly on the above requirements.

The laboratory setting should not be confused with a strictly experimental laboratory setting, in which a greater number of variables can be controlled. Such experiments, as discussed in the methodology, often use precise measures, such as eye tracking or think-alouds which would be impractical with a classroom full of participants, where the aim is to investigate the use of the system within a field setting, structured as a natural classroom activity. To remove the possibility of slow running compromising the user experience, the resource will need to be tested *in situ* beforehand.

7.4.5 Participants

A school was identified that was willing to take part in the research. The school was an independent fee-paying and selective girls' school in England. This group of participants will usually be from a wealthy socio-economic background (although there may be some exceptions with pupils receiving bursaries or scholarships), as well as having demonstrated higher academic attainment in order to be admitted to the school. The fact that participants are girls limits the results to a certain group, which may be significant where gender differences in use of types of technology are noted.

The reason for this choice of participants and school came down to finding a school within the United Kingdom whose management were willing to facilitate the process of research by allocating time in the school day for both those who wished to take part in laboratory sessions and for those who subsequently volunteered to take part in focus groups – a difficult demand for any researcher to make of a school. This required on the establishment of a good relationship between the researcher and a named contact in the school who would understand the process and communicate with both the participants and the school management. Hence, the choice of school was largely bourne out of the serendipity of the researcher's knowing one such contact in a school who was a head of department with the leverage to communicate the research both to the teachers whose lesson time the research cut into and to disseminate the information and consent forms to the year group concerned.

It was recognised that a school which was for female students only and part of the fee-paying independent sector would have its limitations in presenting a specific research community, but it was also noted that every group of research participants has its own specific characteristics, be they economic, by gender, geographic, or otherwise. One benefit of the group in question was that the relative homogeneity of the group meant that differences in the data could not be explained away by the highly differing demographic and experiential backgrounds of the participants. The researcher weighed the homogeneity of the participant group against the difficulty of securing a research partnership with a school. In hindsight, the ease with which the school day was structured and the satisfactory participation rate – all of the school year taking part in laboratory sessions and several focus groups taking place – would seem to indicate the benefits of initiating contact through a personal contact who was fully supportive of the aims of the research and its advocated for its benefits to the teaching and learning community. This was helpful in establishing the partnership and negotiating changes to the school timetable, and their enthusiastic and organised communication at the information and consent phase may well have encouraged students and teaching staff alike to volunteer to take part.

The participants are drawn from the final year in the English educational system when all students in a year study a broad and comprehensive curriculum: Year 9 (aged 13-14). In the school in question, all participants studied History and Art in classes which were not streamed by academic ability within the school. After this year, students specialise as they make subject choices and some drop History and Art. Working with a group of students who have opted to study a particular course at school, college or university could potentially confuse the results in a test design aimed at leading to detailed analysis as to the learner benefits of using a specific system. Furthermore, the juncture before the transition to subject specialisation gives an impetus to the experiment which uses resources related to the History and Arts curricula. The choice that is often made between arts subjects, sciences and “vocational” subjects which offer more practical training is one that provokes a perennial debate on the relative values of these subjects and the purpose of education.

The selected participants had similar experiences to each other before the test because they attended the same school and studied the same subjects and were also part of a similar demographic. The test group – involving a whole year group – reflected this, although there will always be variables and limitations. For example, a classroom in a school in a particular area may involve people with similar levels of development and backgrounds, but there may still be a wide range of intellectual abilities and backgrounds even within that limited selection of participants.

Ethical practice was observed as the experiment was explained to the participants (Kristensson 2013). An outline of the experiment was communicated to potential participants via Information Sheets, which were presented in advance of the researcher’s visit to the school, along with Consent Forms. Examples can be found in the Appendix. The teachers at the school were briefed in advance so that they could take on responsibility for communicating the research to the students prior to the researcher’s arrival, at the point of the distribution of Consent Forms. This rested upon clear email communication between the researcher and participating teachers prior to arranging dates on which the experimentation and focus groups would take place.

7.4.6 Resources Used

The resources selected for experimentation are Giza 3D (Dassault Systèmes 2012a), The Valentino Garavani Museum (Association Valentino Garavani Archives 2012), and The Virtual Museum of Iraq (2013). Stills from each of the resources are shown in the figures which follow.

For the use of the 3D digital libraries in the laboratory, at least 10-12 participants are desired for each condition (i.e. for each of the 3D digital libraries). Since a part of the experimental design is to allow a free choice between resources at the beginning of the laboratory task, the precise size of these control groups cannot be established. However, at the time when informed consent was given, the entire sample of participants resulted in a cohort of 72 students, resulting in a reasonable likelihood that the required number of participants would be met for different conditions.

The resource content is also an important consideration because both the subject matter and terminology of the resource may have age-appropriate attributions. The subject matter of ancient

Egypt (the subject matter of Giza3D) is typical of mid- to late primary education in both England and Scotland. The attribution of an age group to a resource covering a timespan from prehistoric to Islamic Iraq is less clear, as the subject of Iraqi archaeology is not often studied in schools or the majority of university courses in the UK, and furthermore, although the reading level of the resource is accessible to schoolchildren, headings referring to the "Sumerian" or "Assyrian" periods may be off-putting to younger users. The subject matter of the Valentino Garavani Museum, which includes high fashion dresses, was more comfortably matched to secondary education, for both reasons of interests and hobbies of older schoolchildren, but also because it facilitates the analysis of a particular designer's work which is typical of secondary rather than primary art curricula in both England and Scotland. It is anticipated that gender differences may emerge with interest in some of the resources, such as the Valentino Garavani Museum which may have greater uptake among girls than among boys. Because of the diversity of the resources, we suggest that a secondary school age group is appropriate, since participants, in their teenage years, may have begun to develop diverse interests as an expression of their personality.

Fig. 10. Still from Giza 3D

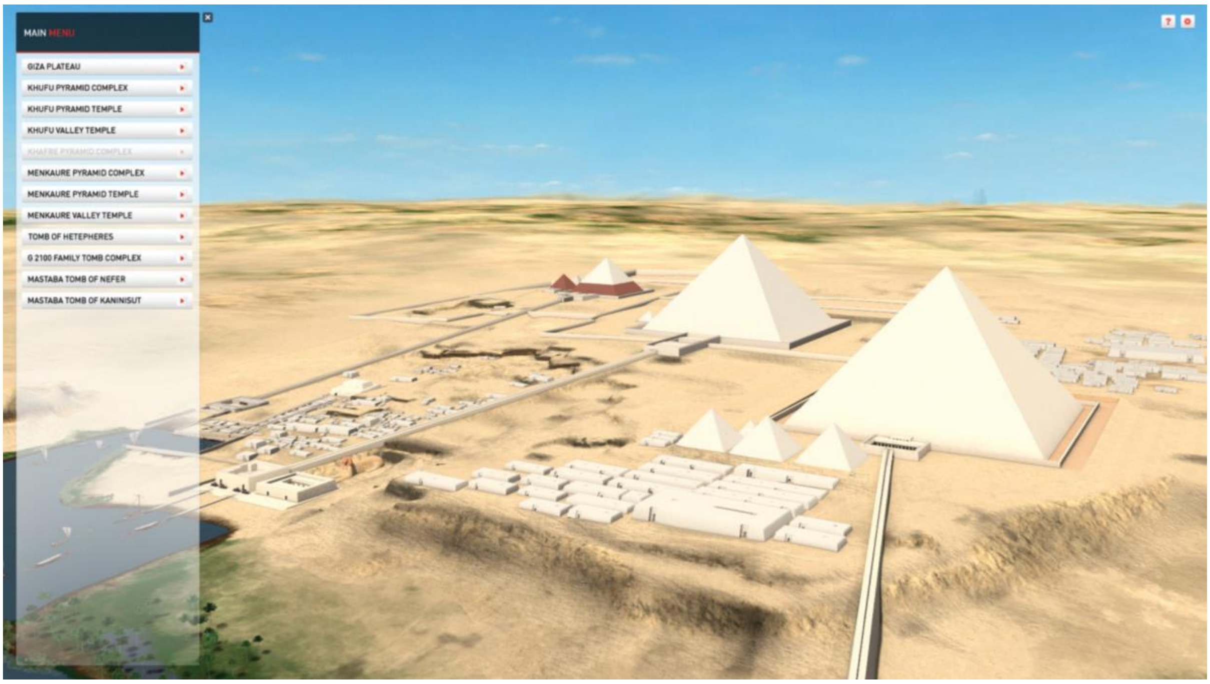

Fig. 11. Still from Giza 3D

Fig. 12. Still from The Valentino Garavani Museum

Fig. 13. Still from The Valentino Garavani Museum

Fig. 14. Still from The Virtual Museum of Iraq

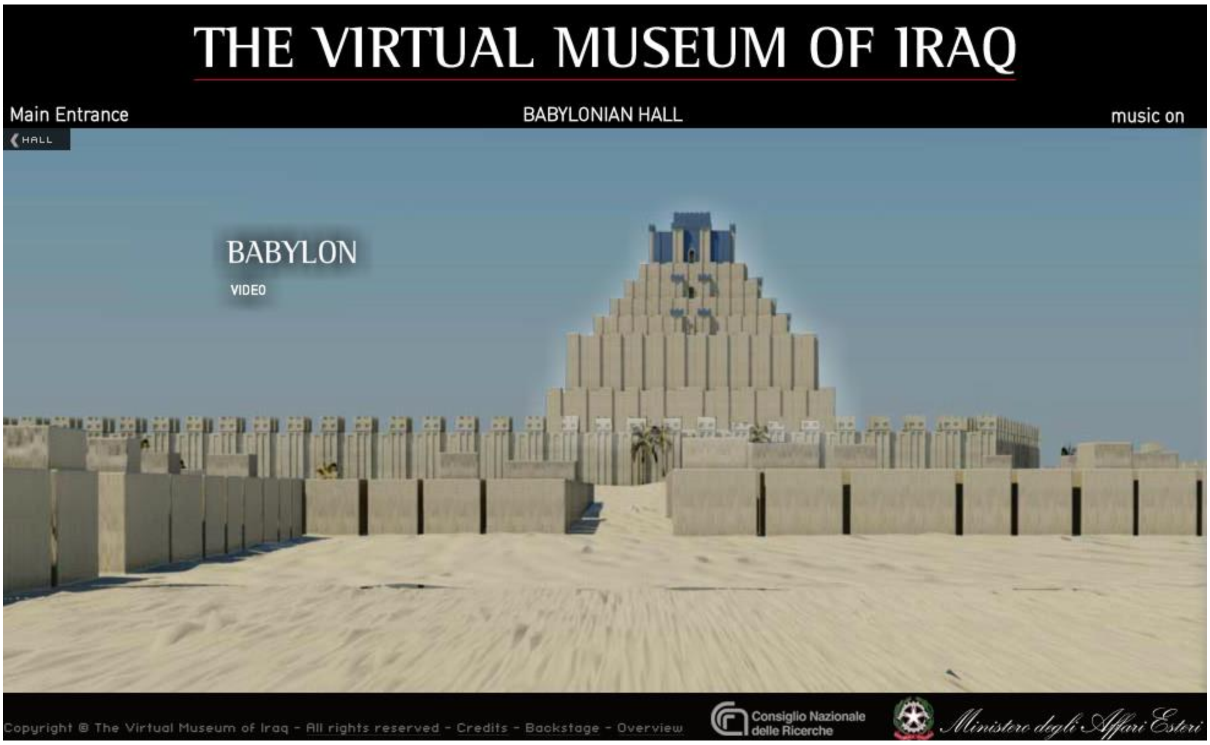

Fig. 15. Still from The Virtual Museum of Iraq

7.4.7 Design of Session

Laboratory sessions were planned with time given for giving instructions, running the test, answering a questionnaire, and a post-test interview (UsabilityNet 2006c). In the sessions themselves, the user was welcomed and the task verbally introduced.

The participants were given the task instructions (UsabilityNet 2006c) (see Appendix for the Initial Information Sheet they were given). The participants were asked to use one of the three systems for as long as they liked during the time allotted within a single class period. The period lasted 45 minutes, and after the preliminaries and post-use collections took place, this allowed for a maximum time spent exploring of 36 minutes. The three options were also presented as options on a screen. The test moderator was on hand to provide any prompts that the student participants need.

A small amount of observation by the test moderator occurred. This consisted of noting at what time the participants started the task, and then, for each participant, any questions asked, and the time at which they stopped exploring the system or systems. The experimenter will be engaged in this observation activity for the duration of the classroom activity.

The test moderator encountered the child and staff participants at the following key moments:

- Announcing their presence in the school and engaging in necessary introductions to obtain consent from participants.
- As test administrator in the computer laboratory, administering the initial questionnaire for participants, overseeing and observing a laboratory task, and administering a post-use questionnaire.
- As focus group leader in groups of 5-12 student participants.
- As focus group leader in interviews with Art and History teachers.

It was considered whether the task should be a non-directed task involving free exploration of any or a combination of resources, or whether it should be offered as a structured activity involving the completion of a worksheet structured to elicit learning outcomes. We opted for a “freer” task, in keeping with the simple design of the methodology which is intended to limit other influencing factors and allow for clearer analysis of the data collected. It was possible to attribute “direction and motivation” to the use of the resource by making the resource usage a part of either a History or an Art lesson (although participants are free to use any of the three resources and not necessarily a historical resource in a History lesson or the fashion resource in the Art lesson), and introducing the activity at the start of the History or Art lesson itself, thus contextualising it within a History or Art learning objective.

Beginning with the usability testing, a key decision was how structured the scenario should be. Following usability research, it is common for users to be asked to use a system to achieve a specific outcome – e.g. make an online booking, retrieve information or undertake some other structured task. In experimental design involving a 3D digital library a real-world classroom learning activity could be structured around use of one of the resources. This produces an experimental condition in a specific context. However, it was decided that a task simply involving the “task” to explore would be appropriate to the nature of the system and research. Our study makes no initial presupposition as to user interest or intentions, and it is anticipated that if exploratory browsing occurs, decisions as to what to explore will be formulated as a result of the subjective intention of the user. This kind of experimental design also reduces the problematic situation of users being allocated a resource in an experiment designed only to investigate their use of the resource, whereby experimental designs have only had validity within those circumstances.

7.4.8 Questionnaire Design

Demographic questionnaire

The questionnaire asks for participant ages, working on the assumption that pupils in Year 9 are aged 13-14, with occasional outliers of 12 and 15 (e.g. if the pupil is a year behind or ahead in respect to the school year corresponding to their age). Age is sought by year rather than months, since this provides a sufficient amount of detail for the purposes of the study.

The initial questionnaire is also designed to establish a baseline of digital use so it becomes clear if there is a correlation or connection between prior digital use and access to the digital space and uptake of the resources. It may be the case that a minimum level of digital use in (especially in online activity or gaming) has a positive influence on the user experience of the 3D digital libraries. In addition, this demographic information is relevant because the sample involves only female research participants, where digital use may have some differentials with the population as a whole.

The questionnaire then asks pupils to estimate how many hours they spend online per day. This question gathers data of potential relevance in the interpretation of results. The scale of timings is based on reasonable inferences about the modal and average times spent online per day by the general public, following Ofcom's (2013) research into Internet usage. The key interest was whether, as a baseline measure of use, pupils spent their time online gaming, on academic study or on other personal pursuits. The measure of this is to ask pupils to assign three percentage figures adding up to 100.

Participants were also asked about their prior interest in the subject matter of the three 3D digital libraries being tested. The subject matter was ascertained by examining the content of the 3D digital library through the lens of a library cataloguer, and assigning a subject according to the Dewey system, which is used in the school library. A seven-point Likert scale is used to ask participants to rank their interest in each option.

The use of a seven-point Likert scale here and throughout follows assertions in the usability literature that it is more effective than the five-point Likert scale (Finstad 2010). Traditional five-point Likert scales are anchored with 1= *Strongly Disagree* and 5 = *Strongly Agree* and are used to evaluate aspects of usability in a quick and reliable fashion. However, Russell and Bobko (1992) found that five-point items were unable to capture the subtle degrees of measure the participants wanted to express, while Finstad (2010) found that users of five-point scales were more likely to interpolate (attempt a response between whole integers). Finstad (2010) comes to the conclusion that the seven-point Likert scale is the most apt of scales numbering more than five points, since

Lewis (1993) found that seven-point scales resulted in stronger correlations with *t*-test results. The seven-point scale performed among the best for direct ranking matches and test-retest reliability, and while a 100-point scale performed marginally better, the seven-point scale outperformed it on subjective usability measures. Osgood *et al*. (1957) reported that in the course of running studies with a range of response alternative possibilities, seven was their best choice, since it was found that the 9-point items, with three discriminative steps on either side of the neutral option were used at low frequencies, while with the 5-point Likert scale, respondents were irritated by the categorical nature of the options which they felt did not match their subjective experiences. The seven-point Likert scale is often presented in usability questionnaires with “strongly disagree” and “strongly agree” written at the far end of the poles, and the question worded accordingly, so that an expression of agreement is the appropriate answer to the question asked. The scale is numbered, left to right, from 1 to 7. From a questionnaire usability perspective, the words remain at either end of the scale, without the scale being visually dominated by words at each point of the scale.

Every effort was made to word the questions so that they were constructed at an appropriate reading and comprehension level for participants aged 13-14, with questionnaires processed through reading comprehension software in Microsoft Word. For additional external verification, the questionnaires will be shown to a teacher at the school before their administration, to highlight any usability or terminology issues from the teacher perspective, which may be valuable.

Usability questionnaire

Testing in HCI and usability studies considers “metrics” or ways of measuring or evaluating a particular phenomenon or thing. There is a difference between metrics and test methods. For example, time spent on a task might be a metric; using tracking technology is a test method.

The post-use questionnaire has the primary aim of measuring the usability and usefulness of the three respective systems. To this end, we investigated the key metrics (measures) associated with usability and usefulness attributes in the HCI literature review. Following a goal – question – metric paradigm advocated by Kan (2003), we sought valid questions from authoritative sources. Among these, Buchanan and Salako’s (2009) measurement framework for usability and usefulness stood out since it was the result of a literature review seeking common approaches across the literature, and also encompassed the area of usefulness. Their measurement framework aims to summarise existing frameworks and to complement existing standards (Buchanan and Salako 2009).

Other summaries of usability attributes and associated metrics can be found elsewhere in the literature. Seffah *et al.* (2006) compiled a list of attributes with reference to Constantine and Lockwood (1999), ISO 9241-11 (1998), Schneiderman (1992), Nielsen (1993), and Preece *et al*.

(1994). Seffah *et al.* (2006) then go on to identify quality measures, especially those from the Skill Acquisition Network (SANe) (Macleod 1994) and the Diagnostic Recorder for Usability Measurement (DRUM) (Macleod and Rengger 1993). Finally, they identify "relevant data", which point towards metrics, for usability measures, such as those identified in ISO 9241-11 (1998). They then go on to identify 127 different usability metrics from the literature. Seffah *et al.*'s (2006) research is valuable but it does not yield a single model. While Buchanan and Salako's (2009) model is more simplified, so that it could be arguably considered to be over-simplified, it does accrue the benefit of being summative in relation to prior models.

Pleasure and comfort are aspects of the user experience not explicitly addressed within Buchanan and Salako's (2009) criteria, but the notion of "pleasure" is appended from the BS ISO/IEC 25010:2011 framework (International Organization for Standardisation2011). A question corresponding to this facet of the user experience might seek to identify whether the user enjoyed using the system and it was considered that this could provide a valuable overall measure of possible comparative value in bivariate analysis.

Buchanan and Salako's (2009) measurement framework is cited below, and afterwards, the extra questions are appended, along with a discussion of any modification to the questions to be asked in a post-use usability questionnaire, in the light of the 3D digital library design paradigm.

Table 11. Usability and usefulness: a measurement framework. Buchanan and Salako (2009).

Goal (improve…)	**Question (asks if…)**	**Metric (measures…)**
Effectiveness	Information required was located	Tasks completed
Efficiency	The system responded quickly to the task (without delay or error)	Time to complete
Aesthetic appearance	Text type and font size are engaging and readable Colours, graphics, and icons have been used appropriately	Attractiveness Appropriateness
Terminology	The terms used to label the menu functions are understandable The menu functions are logically related	Comprehension Consistency
Navigation	Orientation is straightforward	Steps to complete
Learnability	Steps required to complete tasks were understandable	Repetition failed commands
Relevance	Information retrieved reflected the query Information retrieved contributed to the requirement	Relevant results Utility
Reliability	Information retrieved was from a credible source	Credibility
Currency	Information retrieved is current Information retrieved is valid	Creation date Last citation

The alterations made to Buchanan and Salako's (2009) questions are not intended to dramatically change the approach of the usability questionnaire, since they only seek to adjust it in the light of the task and systems used. The main changes relate to the expected information-seeking to be found in an exploratory resource, which differs from the retrieval paradigm for which traditional usability questionnaires are designed.

1. “Information required was located” becomes “When I looked for information during exploration, I was able to find what I was looking for”.

This question is changed because of the exploration paradigm which differs from a task based on the retrieval of information from the resource. It is taken into account that the user may be seeking information during their use of the resource, but the seeking takes place within the context of browsing. This consideration aligns the usability goal of effectiveness more closely with the usefulness consideration of relevance, generating a similar question when the task involves exploration and depends on the user perception of value. The newly reworded question retains its salience because it contains an expression of the utility of the resource in relation to the user intention.

2. “The system responded quickly to the task without delay or error” became “The system responded quickly to what I wanted to do without delay or error”.

This was reworded due to the looseness of the defined task and in language more suited to a younger group of participants.

3. “Text type and font size is engaging and readable” remains the same.

4. “Colours, graphics, and icons are used appropriately” remains the same, but an additional question is added: “The visual scenery is attractive”.

This question derived from considering the design of the 3D digital libraries, where the GUI also involves 3D “scenery”. It was thought that “visual scenery” was an appropriate way to designate the 3D environment’s appearance. This was described in relation to attractiveness, a usability heuristic.

5. “The terms used to label the menu functions are understandable” remains the same.

6. “The menu functions are logically related” becomes “The menu functions listed on the menu are logical”.

This wording was considered more specific and also was considered more simply worded for the younger participants.

7. “Orientation is straightforward” remains the same.

8. “Steps required to complete tasks were understandable” becomes “Steps I took during exploration were understandable”.

This wording was to remove the potential difficulty in understanding the notion of tasks in relation to an exploratory system.

9. “Information retrieved reflected the query” was subsumed into the first question listed due to the exploratory nature of the system.

10. “Information retrieved was from a credible source” becomes “I think that the information presented was from a credible source”.

This was reworded due to the lack of retrieval paradigm.

11. “Information retrieved is current” – see below.

12. “Information retrieved is valid”.

The final two questions were omitted because their respective metrics were “creation date” and “last citation” which could be found by heuristic evaluation of the system. A statement “I enjoyed using the 3D digital library” was added, since enjoyment is considered a relevant metric in the light of the role of affective experiences in ISB.

In addition to the added question stating “I enjoyed the 3D digital library”, users were asked to list the “three worst” and “three best features of the system”. This decision was made because the selection of a validated questionnaire does not preclude the post-use questionnaire from weaknesses in data capture. Important features of the user experience may not be identified by the questionnaire, and this question about the “best” and “worst” features aims to identify any important aspects of the user experience that the standardised questionnaire might have missed.

In order to mitigate against potential limitations to the design and to elicit further responses, free response boxes were given to allow the user to make any further comments in relation to their responses. The use of comments boxes is commonly applied in usability questionnaires.

7.5 Qualitative Component

7.5.1 Main Areas of Investigation

Traditional usability testing with usefulness criteria was used in the first stage of the experiment. This also ensured that participants had a shared experience of a session using one of three digital libraries to talk about in focus groups and tested the usability of the resources. The first phase of the experimental design concentrates on a free exploration scenario with one of three 3D digital libraries that were offered to them and a post-use usability questionnaire was designed to obtain numerical measures of metrics following a goal – question – metric paradigm as advocated by Kan (2003). The vocabulary and wording of the questionnaire takes into account the specific tasks associated with exploring a 3D digital library. Focus group interviews follow a semi-structured agenda. The focus groups are designed to more closely look at the user experience, which comprises cognitive, affective, and behavioural aspects, which are harder to gauge in the laboratory or with questionnaires. There is also potential for users to discuss their experience with a wider range of design aspects, such as architectural design. As a result of the widened scope of this part of the methodology, methodological approaches from the social sciences are explored for appropriate data collection methods.

Interviews taking place at an interval after the initial research event allow us to study the benefits or effects of the resources over time. It was originally planned that 6 months should elapse between initial encounter with the resources and follow-up interviews, but due to operational restraints in the school curriculum, follow-up interviews occurred 7 months after the initial event. According to Menard (2002; p.80), the "conclusion is inescapable" that "for the description and analysis of dynamic change processes, longitudinal research is ultimately indispensable". While it is not proposed to study the participants continually for the months following their encounter (such an approach is beyond the scope of the study and would probably not yield relevant results since all findings need to be linked back to the use of the resources in order to investigate the hypotheses), it is argued that the longitudinal concern can be satisfied against the study scope by means of a cross-sectional encounter: a pre-coded interview designed to explore the information seeking experiences of the participants at the 7 month interval.

The main aim of the 7-month interval focus group was to find out if users have looked for more information on the subject of the 3D digital library that they used since the original use, and, if possible, to ascertain what information was sought, where it was sought, when this occurred, and why this information was sought. Secondly, the focus group aims to ascertain whether and how many of the group returned to the site on a further occasion after the classroom session and what the motivations for this were. In the case that users did not look for further information or return to the resource again, the questions seek to find out what their reasons were. Furthermore, the participants are asked if they plan to go back, since having that intention also expresses an interest.

7.5.2 Overview of Qualitative Methodological Approaches in the Social Sciences

In our methodology we considered whether increasing interdisciplinarity (involving methods beyond HCI) would provide richer answers to our research questions, in the light of Kjeldskov and Paay's (2012) implication that this is a desirable development in future HCI research, and it was concluded that this would be a suitable approach due to the interdisciplinarity of the study and the research questions based on relationships between design and use.

The qualitative approach is not so much a distinctive research strategy, according to Bryman (2008, p.367), but rather a research orientation that emphasises words (Bryman 2008, p.266). Qualitative research tends to view social life in terms of processes (Bryman 2008, p.388), and there is also a concern to show how patterns or events evolve over time (Bryman 2008, p.388). According to Bryman (2008), several steps are appropriate in the process of qualitative design. The formulation of research questions and the selection of sites and subjects have already been addressed in this research. Hence, we move to Bryman's (2008, p.372) *step 3*: the collection of relevant data.

Interview-based methodologies are extremely common in qualitative approaches, and often differ in approach from interview techniques in HCI. Interviews in HCI research tend to be orientated towards generating quantitative data (see UsabilityNet 2006e), resulting in more structured interviews, with approaches structured to maximize the reliability and validity of measurement (Bryman 2008, p.437). There is emphasis on the standardisation of the interview process, and follow-up questions or changes in the order or wording of questions is discouraged (Bryman 2008, p.437). In qualitative approaches there is often greater emphasis on the interviewee's point of view. Bryman (2008, p.437) also points out that in qualitative research there is often an interest in the participants' introducing new concepts, whereas in interviews aimed at generating more quantitative data, there tends to be a greater focus on providing more direct answers to the questions proposed.

7.5.3 Selection of Interview Methods

In the social sciences, wide range of interview types with different degrees of structure can be found between the two extremes of structured interviewing and qualitative interviewing (Bryman 2008, p.436). In qualitative research, the range is narrowed, from the *unstructured* interview to the *semi-structured* interview (Bryman 2008, p.436), and, indeed, researchers sometimes use the term "qualitative interview" to encapsulate both types of interview.

In an unstructured interview, the interviewer may have just a few notes, as an aide memoire, or may ask just one initial question, allowing the participant to respond freely, with the interviewer following up on the points that are made. Unstructured interviewing is similar to an ordinary conversation (Burgess 1984). In a semi-structured interview, the researcher has a list of questions or topics to be discussed, and by and large, the same topics will be discussed and similarly worded questions asked from interview to interview. The interviewee also has a great deal of freedom in how to reply. Questions may not follow on exactly as on the schedule, but in response to the interviewee's input. According to Bryman (2008, p.439), unstructured interviews are favoured in the case where researchers are concerned about the potential of even a rudimentary interview guide to impede access to the genuine views of the participants. Again, according to Bryman (2008, p.439), the semi-structured interview is favoured when the researcher begins the investigation with a fairly clear focus, so that more specific issues can be addressed. In this research, it is clear that the semi-structured interview is most appropriate because both the literature reviews and the usability testing result into our entering into the interview stage with a clear focus, and clear questions to explore.

It has been decided that semi-structured focus group interviews will be used in this part of the investigation. This is because focus groups, as opposed to one-to-one interviews, are especially appropriate with adolescent participants. While adolescent-focussed researchers often find their participants are unable to articulate their viewpoints during one-on-one interviews (Basset *et al.* 2008), focus groups have been shown to work well in interaction design with adolescents, because the technique allows for peer support and social interaction (Poole and Peyton 2013), both of which are important to adolescent participants (Robbins *et al.* 2012). The focus group allows people who have had a shared experience to be interviewed in a relatively unstructured way about the experience (Bryman 2008, p.475). According to Bryman, the method is particularly advantageous because it "allows the researcher to develop an understanding about *why* people feel the way they do" (2008, p.475). The group aspect facilitates this process because as an individual listens to others' answers, he or she "may want to qualify or modify a view; or alternatively may want to voice agreement to something that he or she probably would not have thought of without the opportunity of hearing the views of others" (2008, p.475), although a drawback is that it could lead to "groupthink" due to distortion and dominant patterns (Janis 1972), and a strongly opinionated member may bias the results or affect the extent to which other participants speak (Hevner and Chatterjee 2010). Focus groups can fall foul of the criticism that they are essentially one-shot case studies and thus have limited validity (Nachmais and Nachmais 2008). Rushkoff (2005) argues that focus groups can offer poor quality data because participants often aim to please the researcher. On the other hand, despite the fact that the above criticisms limit the wisdom of using a focus group as a stand-alone method, Lindlof and Taylor (2002) countered that they can be a useful follow-on method, generating new data which highlights new ideas and provides new insights. The nature of focus groups also promotes validation and disclosure – aspects which may be missing from the one-to-one interview (Tracy *et al*. 2006).

For focus groups, test moderators prefer a group size ranging from 8-12 (see Kitzinger and Barbour 1999), 6-8 (see Krueger 2009), while Brown (1999) says that the group should consist of 4-12 if the group is homogeneous and 6-12 if heterogeneous. Each group in this research is relatively homogenous, since it consists of girls of a relatively similar socio-economic background studying the same subjects in the same school, who have all used the same resource. This could justify a focus group size as small as six and up to the maximum number of participants set by Bryman (2008) as 12.

7.5.4 Participants

Participants are volunteers coming from the entire year group which used the 3D digital libraries in the laboratory in June 2014.

Given the chosen ideal of 8-12 participants per focus group, the aim was to recruit the upper limit of twelve students in case of absences on the day.

The data collection also contains a group interview with class teachers who have responsibility for the Art and History classes from which the student participants come. These will be teachers whose regular responsibility is to teach the participants in question. Due to the numbers of teachers involved in Art and History tuition to the group of students, numbers may be smaller than those considered viable for a focus group, necessitating a group interview approach.

7.5.5 Resources Used

Visual aids comprised images which were pointed out at the start of the first question. Images were also prepared for other stages in the focus group where there was not a great deal of discussion, but in the event, it was not found necessary to use them, since discussion was fluent.

The focus groups were recorded and then transcribed after the event, for the sake of later analysis.

7.5.6 Design of Focus Groups

We decided upon a semi-structured approach for the focus group interviews, represented by an interview guide comprising six key areas. The use of six points follows the example given by Draper and Oakley (n.d.). The use of an interview guide follows research such as Schlesinger *et al.* (1992) which contained specific questions to be answered. At the same time, the research demonstrated that the questions themselves could remain fairly general in scope, allowing users to answer freely. Hence, in this research the questions were mostly orientated towards allowing for some comparability between focus group sessions (Bryman 2008, p.483), while the questions remained open and were designed to be non-directive. This approach was suited to later qualitative thematic analysis. Questions aimed at eliciting a narrative response could also provide interview data for narrative analysis.

The chosen interview questions take into account the intellectual development and capabilities of those in early adolescence, aged 10 to 14 (Poole and Peyton 2013), which includes developed abilities to consider hypothetical questions, reflect on how their choices might impact the future and recognise other points of view to their own (Mack *et al.* 2009). In the 7-month interval focus groups with students, it was decided to use a more structured approach to obtaining data via a pre-coded interview in order to categorise the type and extent of information seeking that had occurred since the use of the resources.

Focus groups: one week interval

Techniques to cultivate a comfortable atmosphere will be used. These are important, but especially so with adolescents, since in this context, the view of the researcher as an authority figure may lead to apathy (Stringer 2007), silence (Basset *et al.* 2008) or discomfort (Heary and Hennessy 2002). Given that the school environment requires the researcher to observe a dress code, this effect can be overcome by other techniques, such as providing a more relaxed environment within a school (in this research, a common room and then a meeting room were used rather than classrooms during the focus groups, and snacks were provided), and in the consent forms and research introductions the participants were reassured that there were not "right or wrong" answers and encouraged to speak freely. The researcher also introduced herself using her first name, giving her the "least adult role" (Mandell 1988) within a school setting, where teachers are known by their surnames. Some strategic decisions were made with respect to the age group (13-14), where discussion may prove harder to elicit. This strategy included using visual prompts at the start of the discussion, as a contingency at other stages of the session. Less talkative participants were asked their views before moving on to the next question.

Following Bryman (2008, p.481), there is a balance to be struck by the moderator, between "allowing the discussion to flow freely and intervening to bring out especially salient issues, particularly when group participants do not do so", with the moderator concurring with Bryman (2008, p.481) who recommends erring on the side of minimal intervention, using interventions only when the group is struggling in its discussions or when it has not discussed a key element of the research topic.

The focus group questions are as follow:

Agenda point 1: Students' information behaviour during the task

Could you describe what you did when you used the 3D digital library? Can you talk me through it? Do you remember what you looked at in particular?

Agenda point 2: What did they like?

What features of the 3D digital library did you like? What features of the 3D digital library did you not like?

Optional visual aid: graph representing results from questions 12 and 13 of the questionnaire, showing the three "best" and "worst" features as listed by users of each 3D digital library. Researcher asks "do you agree?" and "why/why not?"

Agenda point 3: Feeling of engagement and curiosity with the 3D digital library

Would you like to use similar resources in school in the future? Why/why not?

No apposite optional visual aid could be located for this question but the researcher will attempt to encourage discussion by summarising points made and asking if they are representative statements.

Agenda point 4: Extent of learning and increased interest in the subject matter

Why did you decide to pick that particular 3D digital library, out of the three? How do you feel about the subject matter having used it? Would you access anything else on the subject matter now?

Agenda point 5: The aesthetics of the system

I see that in the usability questionnaire, the ratings for the visual scenery were as follows: [show participants graph showing distribution of responses and average rating]. Do you agree with those overall ratings on the visuals of the system?

What did you think of the style and design? Visual prompts: "still" shots of the resources]. Researcher's question: "what do you like/dislike about the style and design?"

Agenda point 6: Students' information behaviour after the task

Have you looked at the resource again since you tried it in the laboratory? Would you go back to it again? Why/why not?

Focus groups: 7-month interval

A brief demographic questionnaire, using the same pre-coded questions as those preceding the first round of in-school testing for consistency, was administered at the start of the focus group. As in the demographic questionnaire at the start of the usability experiment, the data gathered shows participants' age (in years), and how long they spend online and on different tasks online, following the question design previously employed. The purpose of this briefly administered questionnaire was to observe any demographic differences between the focus group and the original cohort, as these could influence the results. The use of a baseline question asking their interest in the subjects of the two digital libraries was used in order to note any outliers who had extreme interest or disinterest in the subject, as this could affect their responses.

The participants were invited to volunteer from among the original cohort of participants in the classroom exercise. Between 6 and 12 people were sought for each focus group in line with research recommendations noted earlier in the research. A minimum of six, it was noted, allows for narrative analysis of results, while 12 is recommended as a maximum feasible number of participants in the focus group setting. It was agreed that had numbers been too great for the focus groups, participants would be randomly selected.

The 7-month focus group interviews consisted of the following structure:

- Prior to interviews: distribution of demographic questionnaire. The demographic questionnaire was identical, bar the inclusion of one further question, to the one which was distributed to the volunteers from the year group prior to the laboratory exercise. The purpose of the redistribution of the questionnaire at this venture is to ensure that any demographic differences between the users of the resources as whole and those volunteering for focus group interviews was documented and, if necessary, taken into account.

- The focus group proper began with the use of visual prompts and verbal explanation to encourage participants to recall the original classroom activity in which they used the resource for the first time, at this 7 month venture. The prompts were produced using a professional printing service, in colour on A3 paper. Four prompts were used for each resource using a variety of images indicative of the resource visual interface. The use of the visual prompts occurred alongside a verbal recounting of the school's participation in the first stage of the research. For clarity and in order to ensure the comfort of participants, the following statement was included: "We are here today to talk about [resource name], which you used when I visited in June. Can I just check you were all there and remember the classroom session? I am back to ask you a few more questions to complete my research. Please feel free to speak very freely – for example, if for one of the questions you think that you have not got an answer that is a helpful, honest answer. There is no "right" answer and whatever you have to say is of interest to me."

- After the demographic questionnaire and introductory prompting exercise, the focus group questions begin.

A number of contingencies were considered, since it was not known in advance to what extent participants would engage with the questions. In this case, a contingency plan was put in place to replicate the original focus group questions in order to increase the amount of data available and possibly elicit new responses. The questions and flowchart are shown below.

The questions used are shown below:

1) [At this stage, the first question is announced so that participants are conscious of the process in which they are involved.] **"Have any of you looked for any more information on this subject since then?"** [A show of hands is sought]. [Addressed to all:] "Can any of you tell me a little bit more about that?" [In the course of the discussion, the researcher seeks answer to "**What** did you look for?, "**Where** did you look for it?", and "**When** did this happen?", as well as asking "Was there any particular reason you wanted to know that? ("**Why?**")".] [Not all participants will volunteer information, but in order to widen the discussion to those who have not yet contributed, participants will be asked "Was your experience similar to that, or different?".
2) **"Now I would like to ask whether any of you returned to the site again after the classroom session. Can I take a show of hands?"** [A tally is taken.] "**Why** did you go back?"
3) [If the answer to either 1) or 2) is "no" for some participants:] **"Is there any particular reason that you didn't?"**
4) [If the answer to 2) is "no" for some participants]: **"Do any of you plan to go back to the site?".**
5) [If more material is needed: Repeat of original focus group questions.]

The questions are visualised as a flowchart, below.

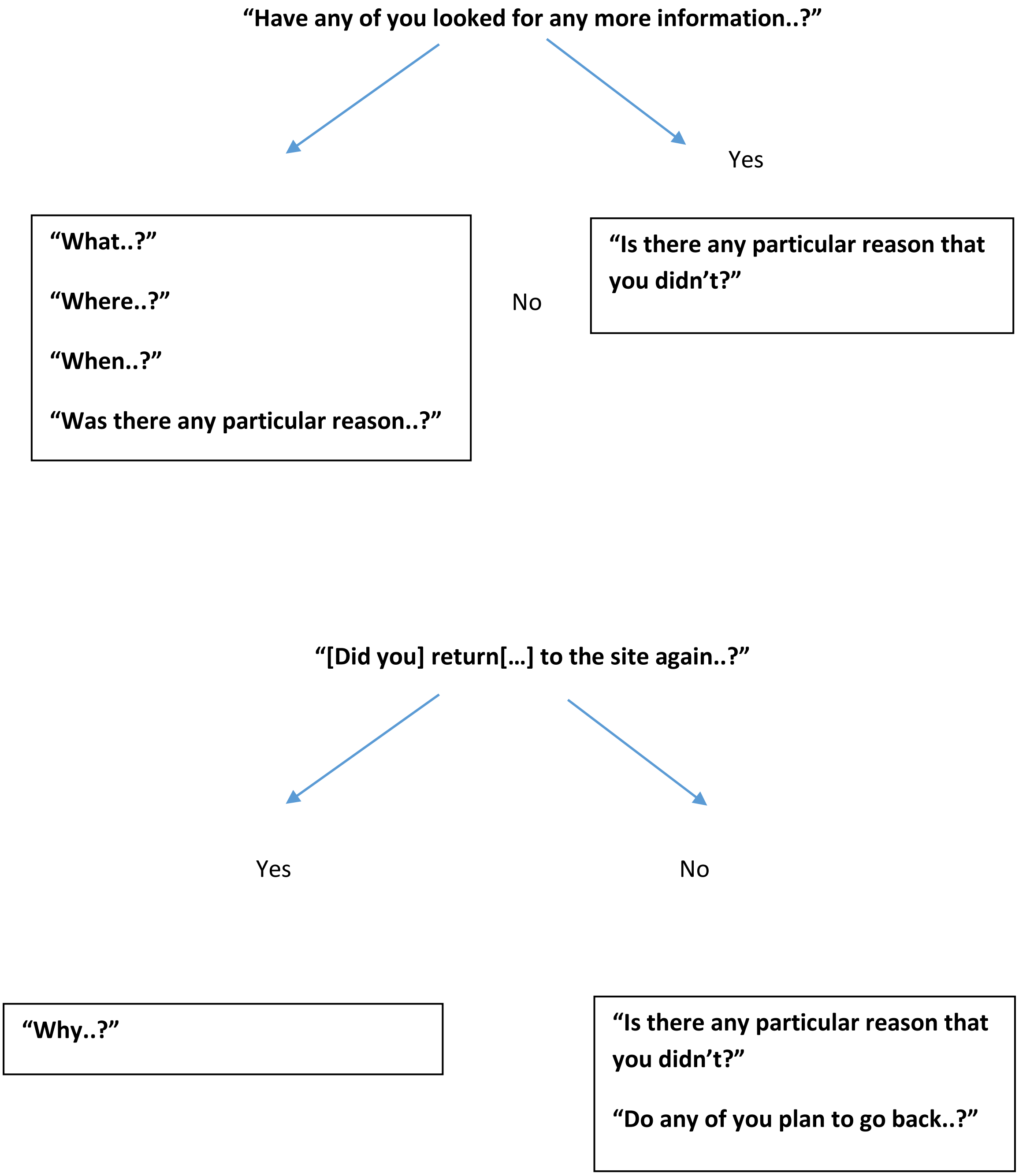

Fig. 16. Flowchart of researcher questions for 7-month interval focus groups.

Focus group with teachers

The teachers from History and Art, the lesson groupings in which the participants originally took part in the experiment, received a brief demonstration of the resources and description of the research methodology. Then, the following questions were asked:

1) **"Did you notice any changes in the students' behaviour or interests as a result of their using either Giza 3D or the Valentino Garavani Museum (VG) resources? Did they talk about it?"**

In addition, the teachers were asked to discuss whether they would use the resource in the classroom, to add context to the research questions. The question were worded as such:

2) **"I appreciate the practical considerations, but purely in the learning context would you consider using this type of resource in the classroom and why?"**

7.6 Ethical Considerations

Ethical approval was obtained via the University of Strathclyde Ethics Committee, with all experiments run in strict accordance with the University Code of Practice on Investigations of Human Beings in compliance with the EPSRC statement on Scientific Misconduct. Further professional guidance was also sought in codes such as the Code of Professionalism and Conduct of the General Teaching Council of Scotland (2012) and the Code of Conduct and Practice for Registered Teachers (General Teaching Council for England 2009). Documents on conducting research with minors were also consulted, including the Market Research Society (MRS) Code of Conduct (2014), which contains specific mandatory provisions relating to research with children, the Ethical Guidelines for Educational Research of the British Educational Research Association (BERA) (2011), and Articles 3 and 12 of the United Nations Convention on the Rights of the Child (United Nations 1989). Data collection, management and disposal will strictly adhere to the Data Protection Act (UK Government 1998).

The MRS Code of Conduct (2014) contains principles with are adopted by researchers of all backgrounds. In its provisions relating to children, the Code states that children need special consideration as "potentially vulnerable members of society". Point B27 requires the consent of a responsible adult, acting *in loco parentis*, for participants under the age of 16. This requirement contained in the MRS Code of Conduct (2014) is to be balanced with Articles 3 and 12 of the United Nations Convention on the Rights of the Child. Article 3 states that in all actions involving children, the "best interests of the child" shall be the primary consideration, while Article 12 emphasises the right of children to express their views freely, "the views of the child being giving due weight according to the age and maturity of the child" (United Nations 1989), while the General Teaching Council for England's Code of Conduct and Practice for Registered Teachers states that teachers should involve children in decisions that affect them. For this reason, it is felt optimal that we obtain consent of both child and parents.

Key ethical considerations and steps made prior to the research are outlined below.

Harm: The research will follow an "ethic of respect" which treats participants "fairly, sensitively" and "with dignity" (BERA 2011). Attention will be paid to issues of participant distress or discomfort. During interviews and interactions, participant rights to make their own choices and decisions will be respected, with no participants singled out for attention, correction or judgement. The researcher will make attempts to put the participants at ease. Any behaviour of serious concern will be brought to the attention of the appropriate staff member by the researcher. Attention will be paid to the "bureaucratic burden" of participation in research (BERA 2011), by facilitating a smooth start and finish to research and presenting surveys in appropriate formats with the questions having already been pilot tested. In addition, the researcher will undertake a Criminal Records Bureau (CRB) check required in England for adults working with vulnerable groups, in which children are included, ensuring that research with under-16s is conducted in line with legal requirements (BERA 2011).

Consent: no aspects of this research will be covert. Informed consent will be sought from all participants (United Nations 1989) and the parents/guardians of participants under the age of sixteen in keeping with the MRS Code of Conduct (2014). Informed consent forms will, in terms meaningful to participants (with advisory group's guidance), outline the purpose and scope of the research, how it will be conducted, and how data will be managed and used (see BERA 2011). It will be made clear that participation is voluntary with approximate participant time commitments provided. It will also be made clear that participants will not be obliged to answer all questions asked during interviews/interactions, and will be able to withdraw from participation at any point, for any or no reason.

Privacy: informed consent will provide subjects with advance understanding of what participation involves, and allow subjects to decline participation on, among other grounds, privacy. For volunteer participants, anonymity and confidentiality of personal information will also respect privacy. The school itself will also be anonymised. Data will be kept securely. Participant and location anonymity will be respected at all times with assigned identifier codes stored securely and separately from transcripts (with no names or locations on transcripts).

Deception: the sponsors, purpose, and potential beneficiaries of this research will be communicated to participants from the outset (via the informed consent form), including expectations of participants, and how participant data will be managed and used for research and (service) development. In relation, it will be made clear to participants that while all steps and safeguards will be taken to ensure anonymity and confidentiality, this cannot be 100% guaranteed due to factors outwith researcher control (Bryman 2008).

Incentives: the school management will be offered the incentive of communicating research activity or research findings to the school community or a wider public, and the possibility of the researcher giving a careers-type talk to the school or a part of the school community. Care will be taken that this incentive does not create a bias in sampling or participant responses (BERA 2011), with a key effort being that the talk or communication of research activity or findings (beyond that which is required to minimise deception and maximise consent) will be offered after the gathering of data.

Responsibilities to sponsors of research: According to BERA (2011) guidelines, the school is deemed to be a sponsor of research, by allowing access to its facilities and participants. Written agreements will state the "purpose of the research, the research methods to be used, any conditions of access to data or participants, ownership of data, the researchers' right to publish, requirements for reporting and dissemination, deadlines for completion of the work" and, in recognition of the dynamics of research, the agreement will also include provision for negotiating changes sought by either the researchers or the sponsors (BERA 2011).

Data management: All digital data (text and audio) is to be stored on secure institutional data servers with automated remote backup. The data will be stored for a minimum of ten years, during which data will be stored and managed in accordance with the University of Strathclyde's Records Management policy (University of Strathclyde 2009), and after which disposal of datasets including metadata can take place.

7.7 Pilot Trials

It is often recommended that pilot studies take place especially when questionnaires are involved, to test the suitability of the design (Blackwell 2013). Kristensson (2013) also recommends that a pilot study is used in controlled experiments. A pilot study is "a trial run of an experimental procedure, not expected to produce valid research data" (Kristensson 2013).

The pilot study was an effective trial from the researcher's perspective, since the test moderator assumes responsibility for the preparation and execution of a test, as well as adequate data collection and collation, and so it proved a useful preparation exercise. Rubin and Chisnell (2008) state the importance of a moderator's being familiar with experimental methodology and test rigour. In addition, Rubin and Chisnell (2008) point out the difficulties of impartiality when moderators have also been involved in design from an early stage, and so the feedback of pilot study participants was helpful.

A pilot trial took place two weeks prior to the live events. They involved four PhD students at the University of Strathclyde. The participants were two male and two female students. Two of these (one male and one female) had expertise in computer science (and therefore some research familiarity with usability trials), while two were involved in research in library science not related to usability. The participants in the pilot trials were a different age group to the actual participants, which was not ideal, but their feedback was nevertheless helpful for the reasons outlined by Rubin and Chisnell (2008) above.

The trial consisted of the quantitative element, involving the questionnaires and laboratory trial, followed by a focus group interview one week later. The laboratory trial was conducted as-live but with minor modifications for the trial. One of these was that, while the procedure for introducing all three digital libraries was followed, the participants were asked to select only one – the Valentino Garavani Museum. This was to ensure similitude of experience, since the four participants would go on to participate in a pilot focus group. The participants completed the initial questionnaire, and spent a free amount of time exploring the library. This ranged from 20 minutes to 40 minutes, at which point there was a cut-off when the participant still exploring the library (and any others, had there been) was asked to stop and complete the usability questionnaire.

The researcher made the following notes during the pilot trial in the laboratory:

- Write "raise your hand when you have finished the questionnaire" in the verbal instructions when giving out the usability/usefulness questionnaire.
- Include instructions on how to log on to each 3D digital library on the information sheet.
- Time needed for usability/usefulness questionnaire (as a cut-off point) was 15 minutes for PhD students – possibly allow 20 minutes for school pupils?
- The participants wrote more comments than expected on their usability/usefulness questionnaires.

- Need to schedule 5 minutes at the end of the class for a “how was that?” discussion to help participants feel at ease.
- Take a supply of pens for participants without pens.
- Pre-number the usability/usefulness questionnaires so that they can be quickly distributed and the same number assigned to the initial questionnaire.

All of these changes were incorporated into the task running sheet.

The researcher asked for informal feedback on the way the session had run from the participants at the end of the laboratory trail. The points that were raised were:

- In the usability/usefulness questionnaire, one participant was unsure when the questionnaire asked for her three best and worst “features”, because she wanted to refer to displays she had enjoyed but was unsure if “features” referred to technical aspects. The researcher explained that the aim was to be very open, and to ask participants to interpret “features” as they liked. Because of the confusion, the researcher asked whether “things” would be a less leading word than “features”, and the participants agreed.

Changes were made accordingly. The word “features” was removed. On further consideration, it was decided that the question would be worded “What did you like most?” and “What did you least like?” with numbering from 1 to 3 indicating the option of listing three options.

The responses to the questionnaires also highlighted one potential usability issue with the questionnaires. Note is made below:

- In response to the question “When looking for information during exploration, I was able to find what I was looking for”, one participant wrote “wasn’t looking for anything!”, and another wrote “I didn’t have any specific search tasks, so can’t comment on how easy that would be”. Another commented, “Only in the Library section was I truly looking for specific info. Elsewhere it was a general browse. In the library I did a search for ‘Marisa’ and found info about Marisa Berenson, as I wanted”.

These comments highlighted the difficulty in wording a question which is normal in usability questionnaires as a measure of effectiveness, in the light of this being an open, exploratory task. Attempts to reword the question to indicate that information is sought as part of the exploration process seem to still generate responses that cause the participants to focus on looking for specific information. It is uncertain how to word this question in the exploratory context, when associations are often made with information retrieval, and so it is problematic since it is not clear for users.

As a result, it was decided that this question would be split into two parts, with the second evaluative part being optional. It would thus be worded:

While you were browsing, did a particular question or information need come to mind?

Yes / No

If yes, please rate the following statement: I was able to find what I was looking for.

Strongly disagree	*1*	*2*	*3*	*4*	*5*	*6*	*7*	***Strongly agree***

The pilot trial participants were consulted about this change in a follow up email, and expressed agreement with the change.

The focus group was successfully conducted according to the defined parameters, and no major issues were identified with this part of the methodology. Transcription was attempted afterwards. With four participants comprising both genders, and a low incidence of interruption, it was possible to distinguish the speakers. However, it was anticipated that a more homogenous and larger group may make it harder to identify individual speakers, especially if conversation moved more rapidly.

7.8 Datasets

Table 12. Datasets.

Dataset name	Summary description	Format	Management and storage
Demographic details, including Internet usage.	Age, online usage and prior interest in 3D digital library subjects of participants.	Open Document file; tables.	Following ethical, departmental and university guidelines.
Usability questionnaire ratings	Likert scale responses to usability questions.	Open Document file; tables.	Following ethical, departmental and university guidelines.
Teacher views	Transcripts and associated codes and categories from focus groups with teachers.	Open Document files; text.	Following ethical, departmental and university guidelines.
Student views	Transcripts and associated codes and categories from focus groups with students.	Open Document files; text.	Following ethical, departmental and university guidelines.

7.9 Data Analysis Methodology

7.9.1 Quantitative Data

The usability questionnaires will generate nominal data (e.g. age of participant, name of resource used), ordinal data (e.g. students' ratings on usability questions corresponding to usability attributes and metrics, using a 7-point Likert scale), and ratio data (e.g. the time taken by each student to explore their chosen system). All of the variables call for answers in terms of real numbers, rather than other types of data such as "either/or" dichotomies. However, these numbers have different significances.

In the case that comparison of variables becomes relevant, each of the questions in the usability questionnaire which gathers quantitative data is assigned a variable number. The usability questionnaire generated twenty-four quantitative variables.

Variable 001 is a measure of how long the user spent using the system. This is calculated by a record of the start time (hour and minute), recorded by the researcher at the start of the exploration of the resource, and the finish time (hour and minute), which is different for each user. On raising their hand to request the post-use usability questionnaire, the researcher writes the finish time on top of the paper. The time spent using the system is calculated by subtracting one figure from another. The variable has an upper limit because the exercise takes place in a class period, and there is therefore a point at which all participants will be asked to stop using the system, regardless of their intention to continue exploring. This potentially means that a number of responses will be clustered at the upper end of the variable. Variable 001 is therefore an *ordinal variable*, its categories can be rank ordered (as in the case of interval/ratio variables), but the distances between the categories are not equal across the range.

Variable 002 involves four possible age categories from 12 – 15. It is thus an interval/ratio variable.

Variable 003 involves a rank ordering of amount of Internet usage, with 2 hours – 2 hours 59 minutes implying heavier usage than 1 hour – 1 hour 59 minutes, and 1 hour 59 minutes in turn implying heavier usage than 0 – 59 minutes. This therefore produces an ordinal variable, whose categories can be rank ordered, but the distances between the categories are not the same.

However, the following variables, variables 004-007, which relates to a question in which participants are asked to assign percentages to their different types of internet use does not imply a rank ordering. Although the participants are asked to assign a numeric value, we are interested in this value as data. Therefore, while variable 003 has value as a rank value, which corresponds to other responses in the questionnaire, 004-007 are useful in combination with 003 since the percentage of time spent on each activity can be compared with the median point of each indication of time spent on the Internet, to produce a calculation as to time spent on each type of Internet activity calculated per day. The calculation is *percentage in [004] / median time of selection in [003]*. This then produces a value that can be correlated to other responses on the questionnaire. The values produced by 004-007 are thus interval or ratio variables, in which the distances across the categories (minutes) are evenly spaced.

Variables 005-010 involve a Likert scale. In this variable, each participant's reply for each item is scored, and the scores for each item are then aggregated to form an overall group score. This can highlight key usability issues, strengths and weaknesses. The Likert scale, strictly speaking, produces an ordinal variable (Bryman 2008, p.322). However, many writers argue that the results of Likert scales should be treated as interval/variable ratios because of the large numbers of categories they produce (see Bryman 2008, p.322). Especially since we are using a seven-point numbered Likert scale, with verbal indicators as to degree only offered for the extremes, rather than for each number, we have decided to treat the data from variables 005-010 as interval/ratio data.

At variable 011, a significant action takes place: depending on which 3D digital library the participants used, the questionnaires are divided into three sets. This results in a threefold division of data sets from this part of the questionnaire (which is administered after the participants have explored the 3D digital library, while the preceding questions are administered beforehand). The division of data into three separate sets at this point is significant to the structure of the experiment since focus groups will be formed on the basis of which 3D digital library was used.

Variables 012 – 020 and 024 are similarly categorised, as results following a Likert scale which are nonetheless treated as interval/variable ratios.

Variables 022 and 023 differ slightly, because the participant is not given pre-selected options to specify their personal "best" and "worst" features of the system. They are given three numbered spaces in which to specify their answers. It may not be clear what these rankings represent (is "1" always better than "2" or "3"? Will participants all make three responses?): as a result, no significance is given to the rankings. It is merely recognised that the eliciting of three features may cause the participant to go beyond the most obvious "best" or "worst" feature, and list more than one. The data for this question will thus be coded by grouping common responses and quantifying how many times they are listed. These can then be listed in a frequency table.

At this stage number of issues relating to the generation of quantitative variables using questionnaire data can be foreseen which may impact upon the research. One such issue is how to handle "missing data". Missing data arise "when respondents fail to reply to a question – either by accident or because they do not want to answer the question" (Bryman 2008, p.321). Missing data can be coded as "0" but it is important to ensure that software is informed of this fact, since "0" could have other meanings, such as in question two (2), where a participant could intend to signify "0" as a value for time spent using the Internet where the option "0 – 59 minutes" is offered.

The question of how to analyse the free responses given in the boxes beneath questions was also considered, and it was decided that coding should take place. Representative responses will be quoted in full or in part in the analysis where they add insight.

Analysis of variables can be either univariate, bivariate or multivariate (Bryman 2008, pp.322-330). Univariate analysis can be simply achieved with the use of a frequency table in which the number of people and the percentage belonging to each category are represented. The frequency table can be used in relation to all types of variable (Bryman 2008, p.322). Further measures of interest in univariate analysis concern measures of dispersion – i.e. the amount of variation in a sample. This can be measured by the range or, better, the standard deviation which although also affected by outliers, offsets their impact by dividing the number of values in the distribution.

Bivariate analysis "is concerned with the analysis of two variables at a time in order to uncover whether the two variables are related". With the variables generating quantitative data there is value in exploring if there are any relationships between variations in one variable with variation in another. Bivariate relationships will be explored, although statistical significance is not guaranteed due to the research design. There are a number of methods available for bivariate analysis, including contingency tables, Pearson's *r*, Spearman's rho, Phi and Cramer's *V* (Bryman 2008, pp.326-330). Since the comparisons to be made are between ratio/interval variables, and in the case of usability ratings, ratings from a Likert scale which can be considered as ratio/interval variables, the most appropriate method is Pearson's *r*, since this method is principally used for examining relationships between interval/ratio variables (Bryman 2008, p.327). Pearson's *r* generates a coefficient between 0 and 1 which indicates strength or relationship, while the coefficient, being either positive or negative, indicates the direction of a relationship.

7.9.2 Qualitative Data

Bryman (2008, pp.538-539) considers two broad general strategies to qualitative data analysis: analytic induction and grounded theory, and narrative analysis following a thematic approach.

Analytic induction is often described as an *iterative* approach, since there is a "repetitive interplay between the collection and analysis of data (Bryman 2008, p.539). According to Bryman (2008, p.539), the central characteristic of analytic induction is that it "is an approach to the analysis of data in which the researcher seeks universal explanations of phenomena by pursuing the collection of data until no cases that are consistent with a hypothetical explanation [deviant or negative cases] of a phenomenon are found". This approach differs methodologically from the research design detailed up to this point, which instead involves case studies rather than universal cases.

Grounded theory is also described as an *iterative* approach (Bryman 2008, p.539) whereby "analysis starts after some of the data have been collected, and the implications of that analysis then shape the next steps in the data collection process" (Bryman 2008, p.539). Although grounded theory is sometimes a disputed term with a number of definitions abounding (Bryman 2008), a recent authoritative exposition of grounded theory given by Strauss and Corbin (1998, p.12) defines it as "theory that was derived from data, systematically gathers and analysed through the research process". "In this method, data collection, analysis, and eventual theory stand in close relationship to one another" (Strauss and Corbin 1998, p.12), and a key shaper of this relationship is the fact that coding in grounded theory involves the coding of data as it emerges (Charmaz 2000, p.515). This research differs from a grounded theory approach.

Our research begins with research questions, and a sampling of research participants, followed by data collection, but it differs from grounded theory insofar that in that methodology this data collection would be followed by a characteristic "movement backwards and forwards" between these initial steps (Bryman 2008, p.545). "Early coding suggests the need for new data, which results in the need to sample theoretically, and so on" (Bryman 2008, p.545). Furthermore, this research begins with a new theoretical framework for 3D digital libraries implicating the three interdisciplinary areas of usability/usefulness, classical architecture and ISB. These frames provide important explanatory frameworks for understanding the data collected in the light of the research questions. They have already generated likely codes, which may be rarefied as the investigation progresses, but it is not the approach of this research to have no idea of codes until after the collection of data.

An alternative approach is thus to use narrative analysis, which can in turn be broken down into component approaches. Riessman (2004) distinguishes four models of narrative analysis: thematic analysis, structural analysis, interactional analysis, and performative analysis. Of these, the latter three involve analysis of *how* things were said, while thematic analysis, in common with other approaches using coding, emphasises *what* is said rather than *how* it is said. As a result, thematic analysis is the narrative approach most salient to this research with its realist ontological assumptions and epistemological assumption of rational correspondence between disciplines. It is also not important to emphasise structural, interactional or performative aspects within the scope of this research, since it does not set out to study the nature of communication, by looking at features of speech such as narrative mechanisms, the co-construction of meaning, or narrative as performance.

Thematic analysis is one of the approaches in narrative analysis. Thematic analysis is "one of the most common approaches to qualitative data" (Bryman 2008, p.554). Bryman (2008) also lists it as a stand-alone approach, apart from narrative analysis. Bryman (2008) recommends following a Framework approach, as developed by the National Centre for Social Research in the UK (Ritchie *et al.* 2003), while Hevner and Chatterjee (2010) consider that "template analysis" is a useful way of exploring themes in design since it allows for "at least a few pre-defined codes which help guide analysis". In other approaches such as grounded theory the coding process itself is said to generate theory (Strauss and Corbin 1998, p.22). However, some have questioned whether it is realistic for researchers to suspend their awareness of relevant theories or concepts until a late stage in the analysis of data (Bulmer 1979), or suggest the benefits of researchers being sensitive to existing conceptualisations (Bryman 2008). This approach can better build upon the work of others (Bryman 2008) and perhaps also serve us better in the methodological design we are using.

In this research, we make use of the codes for analysis of design and behaviour that were identified in the literature reviews. The first step involved exploring the transcripts of the focus groups and interviews with the content examined in the light of the research questions. The focus group data (from the initial focus groups, 7-month focus groups, and teachers' group interview) was first analysed for examples of user behaviour occurring in relation to HCI heuristics for each 3D digital library. The data was then analysed for behaviour in relation to architectural themes. The data could then be compared across digital libraries to consider commonalities and unique instances of HCI heuristics and behaviour. The use of design and behavioural themes a framework through which data can be interpreted as consistent with Hevner and Chatterjee's (2010, p.130) advocacy of template analysis as an appropriate approach to design questions. The themes may also be added to on reviewing and analysing the data, in the case that new themes are found. This allows for the refinement of themes based on the data content, in order to validate the themes found in the literature reviews.

As a practical approach, a series of steps will be followed to implement this analysis methodology. Following the recording of interviews (subject to participant consent), transcription took place at an early stage. The transcripts were read through and were gradually annotated with reference to thematic codes. Coding and analysis was technologically assisted using spreadsheets and colour-coded annotation, and the researcher experimented with narrative expositions of the trends found in the transcripts. Following this process, analysis lead us to "consider more general theoretical ideas in relation to codes and data" (Bryman 2008, p.551), drawing more widely on the literature reviewed for the study to explain patterns in the data. Forming connections between codes (and indeed with the quantitative data) was also a process requiring intellectual interpretation. Finally, reflecting on the overall importance of findings in relation to the research questions in the Conclusion chapter was also a matter of the researcher's interpretation (Bryman 2008, p.552).

8 Chapter 8: Findings

8.1 Stage one

Stage one began with laboratory sessions using the 3D digital libraries during the school day. The year group was split over four class periods, each class period lasting one hour, with 36 mins maximum possible for browsing the 3D digital library of choice once time to introduce the task and complete questionnaires was taken into account. 69 female students participated in the laboratory sessions but 68 completed both demographic and post-use usability questionnaires, so henceforth findings and analysis concern these 68 participants for whom we have data.

One week later, focus groups took place involving volunteers from the laboratory session participants, and were composed as following: one focus group of 9 Valentino Garavani Museum users; one focus group of 7 Valentino Garavani Museum users and one focus group of 9 Giza 3D users. The implications of focus group composition is discussed under the relevant heading, 8.1.3.

8.1.1 Demographic Questionnaires

Of the students taking part and completing questionnaires for the laboratory sessions, 15 (22.06%) stated that they were aged 13, 51 (75.00%) that they were aged 14, and 2 (2.94%) that they were aged 15. For the whole group before they were broken down into users of each individual 3D digital library of the choice of three presented, the median answer for time spent online per day was “up to 3 hours”. The median interest ratings for the subjects of the libraries were 4 for the “Pyramids of Egypt” (corresponding to the subject of Giza 3D), 3 for the “cultural artefacts of ancient Iraq” (corresponding to the subject of The Virtual Museum of Iraq) and 6 for “high fashion design” (corresponding to the subject of Valentino Garavani).

Valentino Garavani Museum users

The majority of participants chose to use the Valentino Garavani Museum (VG) 58 (84.05%) questionnaires were completed by such users. Eleven 13 year olds, forty-five 14 year-olds and two 15 year-olds used the resource, with a mean age of 13.84 years.

Question 2: hours online per day

8 users (13.79%) reported spending up to 1 hour online per day, 13 users (22.41%) reported up to 2 hours, 20 users (34.48%) up to 3 hours, 7 users (12.07%) up to 4 hours, 6 users (10.34%) up to 5 hours, 2 users (3.45%) up to 6 hours, and 2 users up to 7 hours per day. The median selected time spent online per day was “up to 3 hours”.

Question 3: Internet activities

The mean reported percentage of time spent using the Internet for academic study was 21.70%. Following a calculation of each person's reported time on each activity (total reported time online X percentage reported for specific activity) the group's mean reported time online doing academic study was 37 minutes per day (to the nearest minute).

The mean reported percentage for social networking was 62.58%, corresponding to a mean 98 minutes per day.

The mean reported percentage for "other personal use" was 20.43%, corresponding to a mean 38 minutes per day.

The mean percentage of time spent using the Internet for gaming was 3.72%, corresponding to 7 minutes per day (following the calculation reported above).

Question 4: prior interest in the subjects covered by the 3D digital libraries

For the users of VG, when asked about their interest in the subject of high fashion design, the median value was 6. When asked to rate interest in the Pyramids of ancient Egypt, the median value was 4. When asked to rate interest in the cultural artefacts of ancient Iraq, the median value was 3.

Giza 3D users

9 (13.23%) questionnaires were for users who had chosen to use Giza 3D (Giza) and answer usability questions on that resource. Four 13 year-olds and five 14 year-olds chose to use Giza, making the mean age 13.56.

Question 2: hours online per day

2 users (22.22%) reported spending up to 1 hour online per day, 3 users (33.33%) reported up to 2 hours, 2 users up to 3 hours, 1 user (11.11%) up to 4 hours, and 1 user up to 5 hours per day. The median selected time online per day was "up to 2 hours".

Question 3: Internet activities

The mean reported percentage of time spent using the Internet for academic study was 36.11%. Following a calculation of each person's reported time on each activity (total reported time online X percentage reported for specific activity) the group's mean reported time online doing academic study is 43 minutes per day (to the nearest minute).

The mean reported percentage for "other personal use" was 31.11%, corresponding to a mean 37 minutes per day.

The mean reported percentage for social networking was 28.89%, corresponding to a mean 35 minutes per day.

The mean percentage of time spent using the internet for gaming was 2.78%, corresponding to 3 minutes per day (following the calculation reported above).

Question 4: prior interest in the subjects covered by the 3D digital libraries

For the users of Giza, when asked about their interest in the subject of the Pyramids of Ancient Egypt, the median value was 6. When asked to rate interest in the cultural artefacts of ancient Iraq, the median value was 5. When asked to rate interest in high fashion design, the median value was 3.

Virtual Museum of Iraq user

Of the 68 total questionnaires, only one was completed for the Virtual Museum of Iraq. The results of one participant do not give an adequate sample for analysis, and so further discussion of findings and analysis is given only for VG and Giza. This results in the total participant number of 67 as is henceforth reported.

8.1.2 Usability Questionnaires

Valentino Garavani Museum

Time spent using the resource

22 participants (33.93%) used the Valentino Garavani Museum for the full 36 minutes, 7 (12.07%) used it for 33 mins, 9 (15.52%) for 32 mins, 7 for 31 mins, 3 (5.17%) for 30 mins, 1 (1.42%) for 28 mins, 2 (3.45%) for 27 mins, 2 for 26 mins, 2 for 25 mins, 2 for 24 mins, and 1 for 14 mins.

The mean time using the system was 32.26 mins.

Questions 1 and 2: finding specific information while browsing

Of the 58 participants who used VG, ten (17.24%) responded in the affirmative when asked, in Question 1, if they had tried to look for specific information while browsing.

Those who responded in the affirmative where asked to rate whether they had been able to find what they had been looking for on a scale of 1 to 7, from 1 (strongly disagree) to 7 (strongly agree). Answers varied from 4 to 7 on this scale, with a mean of 5.5, a median figure of 5.5 and a mode of both 4 and 5.

Three respondents, all rating their experience as "6" added extra comments. One referred to the quality of experience of searching without referencing the specific need, writing:

> *Easy to find. Easy to read i.e. short informative and interesting sentences* (1:003)

While two referred to specific instances:

> *It was easy to find out who wore the dress and when* (1:007)

> *I was looking for his red collection "Rosso Valentino" of 2008 but I had to go through all of them to find it...* (4:009)

The further comments made by VG users are visualised below using Venn diagrams isolating experiences of "ease" and of "difficulty" and showing responses linked either explicitly or implicitly to these concepts. "Explicitly" refers to when a statement refers directly to the question being asked, and "implicitly" refers to when the extra written response is understood to be related to the question being asked. Numbers in the Venn diagrams indicate the number of extra comments represented by the summaries.

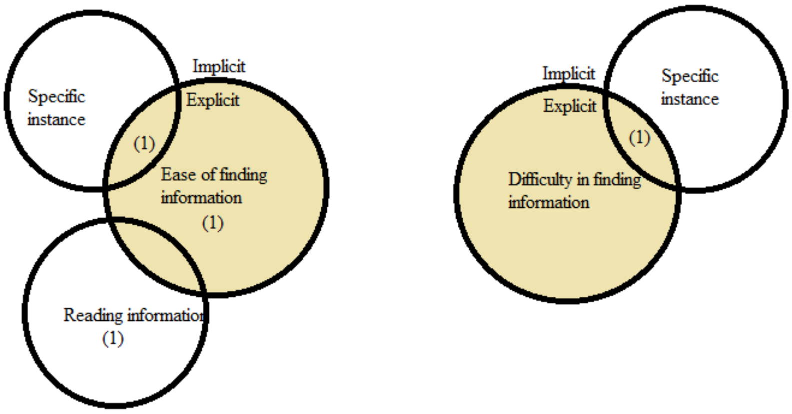

Fig. 17. Valentino Garavani, Extra comments, Question 2 – When looking for information during exploration, I was able to find what I was looking for.

Question 3: the system responds quickly to user without delay or error

58 of 58 users (100.00%) answered this question with a median answer of 6.

29 (50.00%) left comments in the comments box, as described below:

7 responses used the vocabulary of "quickness" and "slowness". Four comments cited either a fastness or speediness in the responsiveness of the system (1:006, rating 7; 3:018, rating 7; 3:016, rating 5; 4:004, rating 7). Three responses noted that in specific instances the system could be slow in its responsiveness (1:007, rating 6; 2:013, rating 3; 4:014, rating 4).

A significant minority of comments mentioned particular instances in which they had found the system either "quick" or "slow". One participant noted that it was "quick going room to room" (1:003, rating 6), while five participants noted that it was slow progressing from room to room (1:004, rating 6; 4:005, rating 3; 4:009, rating 4; 4:017, rating 5; 1:002, rating 5). One participant noted that their own experience of slowness had occurred because of the settings she had chosen (1:004, rating 6). One user highlighted how fast responsiveness also needed to be tempered: "It was almost too quick moving the mouse so I kept on accidently going past things" (1:011, rating 7). Another noted that the system was generally quick but was slow in specific instances (4:011, rating 5).

6 users referred to "loading" in their answers. Two participants noted "quickness" in "loading" (1:004, rating 6; 1:001, rating 6): one referring to "loading" in general (1:001, rating 6) and one to the loading of videos and images (1:004, rating 6). Two responses noted that "sometimes" (1:015, rating 5) or in the case of "one or two rooms" (4:002, rating 6), the system "took a while to load" (1:015, rating 5; 4:002, rating 6). Another noted slowness in some instances: "Only on some of the photos was it a bit slow to load", but also notes that "overall it [the resource] was very big" (1:005, rating 6). One user states that she chose to explore Giza 3D, but gave up after it took a long time to load, and this was the reason she chose to explore the Valentino Garavani Museum instead (3:014). This user had indicated a joint preference for both the Pyramids of Egypt and the Cultural artefacts of ancient Iraq in their initial questionnaire.

Three responses use vocabulary relating to errors, such as the system "crashing": "It crashed briefly" (2:009, rating 6) and to "a few glitches" (2:013, rating 2), or to lack of errors: "really easy to do things - no errors" (4:016, rating 7).

Other responses referred less to speed and errors but highlighted aspects of navigation which allowed or precluded access to the collections that the user desired (e.g. 1:001, rating 7; 1:006, rating 7; 1:008, rating 6), e.g.:

> *Easy access to everything* (1:001, rating 7).
>
> *It was easy to navigate around the museum although a bit hard to see what I'd already visited.* (1:008, rating 6).

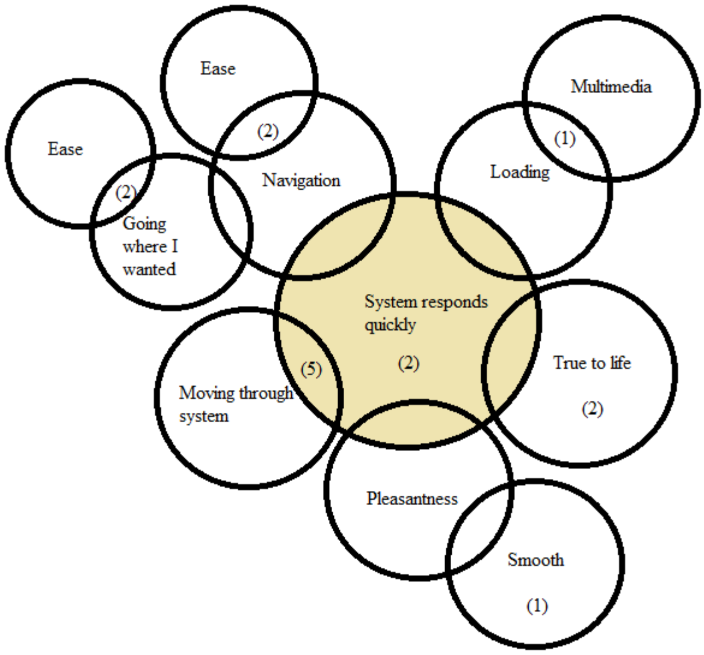

Fig. 18. Valentino Garavani, Extra comments, Question 3 – The system responds quickly without delay or error, answers related to quickness.

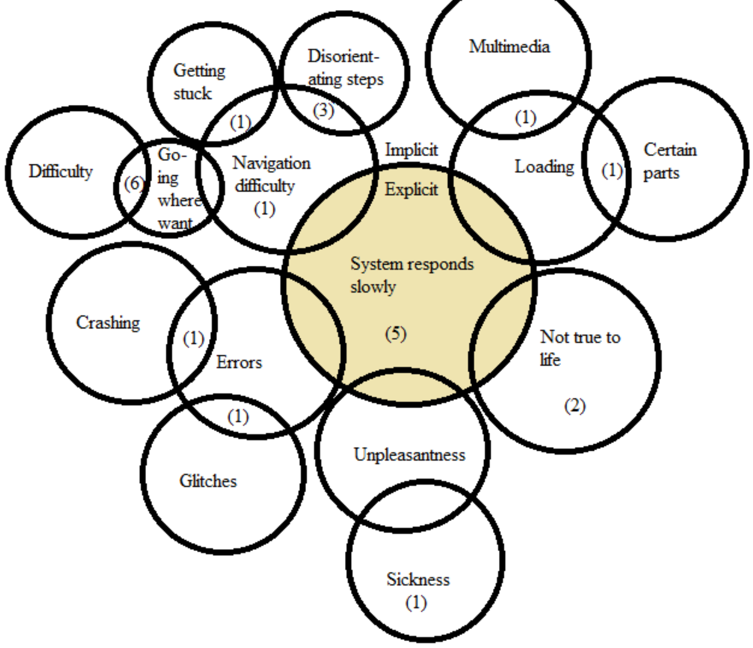

Fig. 19. Valentino Garavani, Extra comments, Question 3 – The system responds quickly without delay or error, answers related to slowness

Question 4: the text type and font size is engaging and readable

58 of 58 users (100%) answered this question, with a median answer of 6.

22 of these users (38%) made further comments, as discussed below:

Two users expressed overall satisfaction with ease of reading: “all information was easily read” (1:004, rating 5); “it [the font] is easy to read” (1:009, rating 6). Two users stated that it was hard to read at specific point: “a bit hard to read at times” (2:003, rating 6); “italics harder to read” (3:014, rating 4). One user linked ease of reading to simplicity: “it’s quite plain, but that’s good to read” (4:011, rating 5).

Size (“smallness” or “largeness”) of font was identified by 8 users with the majority of these finding it small and one finding it “clear”. Several users referred to the font size as too small (1:009, rating 6; 2:017, rating 5; 3:005, rating 5; 1:007, rating 6). Two participants found the text too small in a specific instance (1:004, rating 5; 1:003, rating 4), e.g. “Some text on pictures – say from magazine covers was too small to read” (1:004). One user suggested that the smallness of the font was to do with its placement on the horizon within a 3D system: “some of it was far away so I would have to walk a bit to see what it said” (2:003, rating 6).

Two users used a similar phrase to describe their feelings about the font: it was “readable but [not] engaging” (2:002, rating 4; 3:001, rating 4).

8 users referred positively to graphic aspects of the font style: 5 made positive comments, 2 suggested a change in colour, and 1 thought the colour gave an “essence” of Valentino (4:016, rating 6). “Black background and white writeing [*sic.*] good to read” (1:003, rating 4); another, “very clear colour” (4:003, rating 6); and another, “Everythings in capitals (All Titles) and font was quite thin but this was to a good effect” (4:002, rating 5). One user referred to other aspects of its graphic appeal (1:005, rating 6): “quite simple but stylish too”. One user wrote: “I would say that some of the colours were boring, maybe use different colours” (3:008, rating 6).

The positive value of the limited use of the written word was noted by one user: “There wasn’t much writing which made it easy to not get distracted or bored” (1:011, rating 6).

One user referred to the size of the dresses: “the dresses were quite small and hard to look at in detail” (4:005, rating 3).

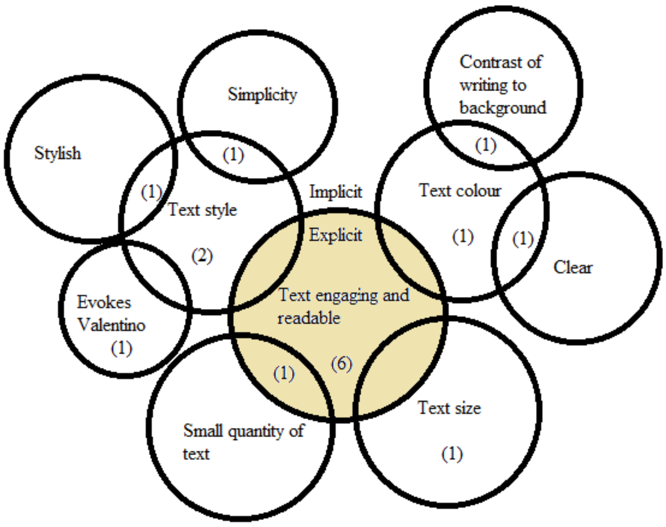

Fig. 20. Valentino Garavani, Extra comments, Question 4 – The text type and font size is engaging and readable, answers affirmative.

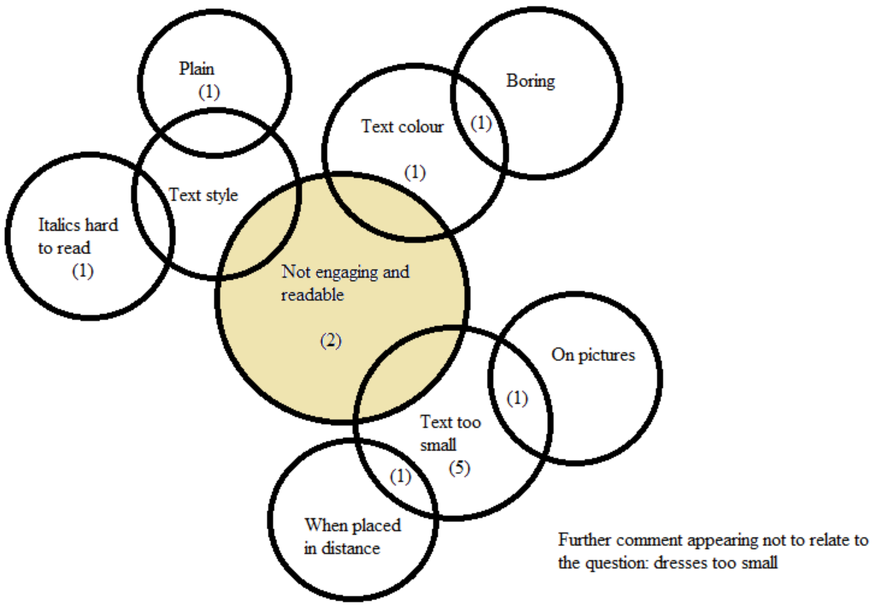

Fig. 21. Valentino Garavani, Extra comments, Question 4 – The text type and font size is engaging and readable, answers negative

Question 5: colours, graphics and icons used appropriately

58 of the 58 users (100%) answered this question, with a median answer of 7.

15 (26%) commented in the in the comments box, and their comments are discussed below.

One participant wrote, “beautiful graphics” (1:004, rating 7). One respondent wrote: “The use of colours on this site is very effective” (3:015, rating 6); another, “I love the colours in this exibition they are very simple and effective” (1:009, rating 7). 4:003 (rating 7) wrote: “Red on Cream / white is Easy”.

Two users referred to how the use of colours, graphics and icons evoked a certain style: “An almost futuristic atmosphere, it was amazing!” (3:018, rating 7); “I found it very elegant, classy and "Valentino style"” (4:009, rating 7). Another wrote that “all the reds were good since he used a lot of red” (4:11, rating 6), drawing on prior knowledge of Valentino branding.

When answering this question, users referred to different features of the system. One respondent matched the language of the question, writing that “the colours and graphics were good at points” (1:007, rating 6). 2 referred specifically to the 3D objects, namely the dresses: (1:005, rating 7), “I LOVE THE VIRTUAL MODELS” (4:012, rating 7), which were referred to as either “very accurate” (1:005, rating 7) and as features which “really brought it to life” (4:012, rating 7). 2 responses to the question about “colours, graphics and icons” indicated the wider application of these concepts in a multimedia resource: “I liked the films” (1:011, rating 7); “I really like the pictures and videos” (1:009, rating 7). One user made note of the colour scheme: “A lot of red was used which went together nicely although different colours might have made it more interesting” (1:001, rating 5).

One response referred to wider factors of the user experience, namely the lack of “fast forward” option on the video clips in the system. “Although no button to press to fast foward in any of the clips I saw” (4:002, rating 6). One respondent wrote: “The layout was a bit complicated at times” (4:015, rating 4). Another user referred to the use of white which they felt affected their comprehension and orientation within the system: “It amout of white is quite large, sometimes I didn't know if I was staring at a wall or courner [*sic.*]” (4:014, rating 5).

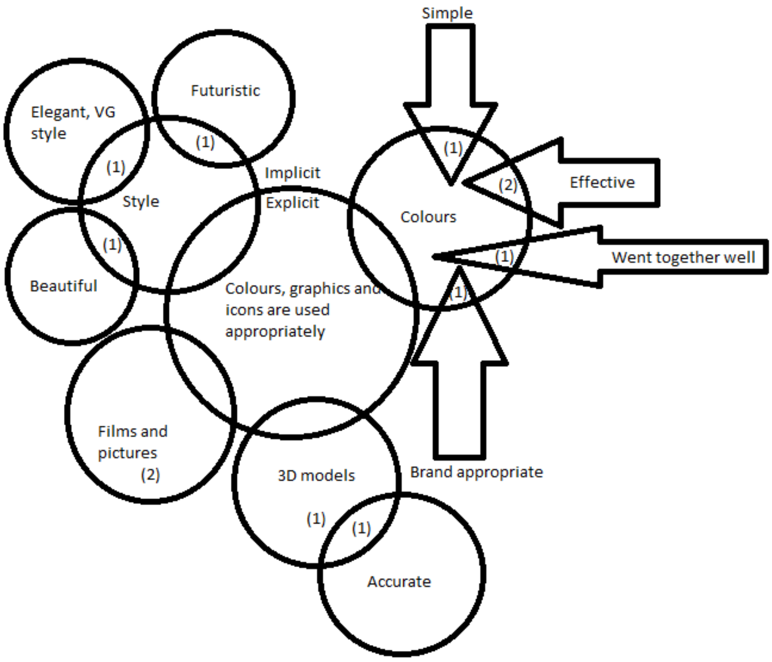

Fig. 22.. Valentino Garavani, Extra comments, Question 5 – Colours, graphics and icons are used appropriately. Visual of responses related to appropriateness.

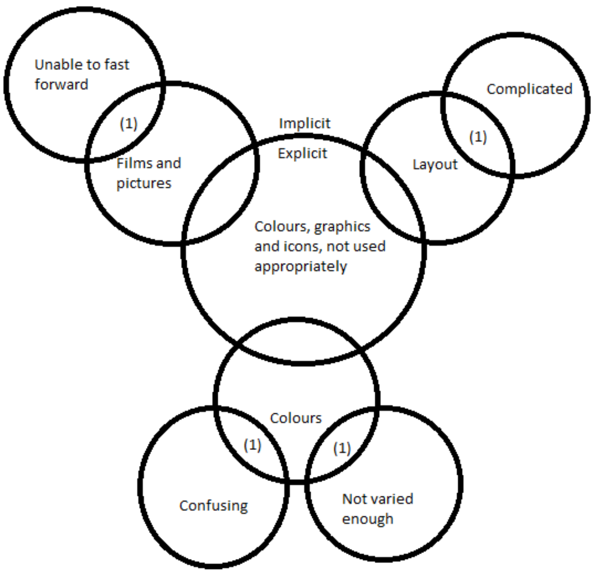

Fig. 23.. Valentino Garavani, Extra comments, Question 6 – Colours, graphics and icons are used appropriately. Visual of responses related to inappropriate use.

Question 6: The visual scenery is attractive

58 of 58 respondents (100%) answered, with a median answer of 6.

20 respondents (34%) added comments. The respondents providing comments had a mean rating of 5.5, a median of 6 and a mode of 7; the lowest rating being 3 and the highest, 7.

Five respondents referred to the "plain" look (2:016, rating 5; 2:013, rating 3; 4:003, rating 4; 4:017, rating 5). Of these, one was positive about the plainness: "Because of the plain white and red the clothes are more standout which is very good" (1:008, rating 6).

Five respondents referred to colour scheme. One wrote, "the background was white in every room" (3:014, rating 3); another "too white" (3:001, rating 3). One wrote "it's very red and plain in some parts" (4:017, rating 5).

One participant referred to crowded parts: "it's crowded in other [parts]" (4:017, rating 5).

Three participants made comments about conveying a certain style: "Black background and red and white really suites [*sic.*] valentine [*sic.*]" (1:003, rating 7), another stating "very futuristic" (3:018, rating 7). 4:016 (rating 7) wrote: "looks like a museum, but sophisticated and sheik [*sic.*, i.e. "chic"] as it is about fashion".

Two participants used aesthetic vocabulary: "the visual scenery is laid out beautifully and is extremely attractive" (1:009, rating); "It is appealing to the eye" (3:016, rating 5); and "Yes, very attractive and colourful" (4:002, rating 7).

Two participants wrote about the feature of the "sky" being displayed through skylights in the museum: "I liked the blue sky" (2:003, rating 7); "The clouds outside the main entrance roof were good" (4:011, rating 5).

Three participants wrote about the dresses. "All of the costumes were detailed, and colourfull [*sic.*]", wrote (1:011, rating 7); "the dresses are very realistic", wrote (1:005, rating 7). One participant wrote "You couldn't see the whole of the dresses" (1:003, rating 6).

Two respondents referred to un-lifelike aspects. One participant wrote that the scenery, although "pleasing to the eye" (see above), was "unrealistic" (3:016, rating 5). Another put "its [*sic.*] slightly computerised" (3:005, rating 6). In contrast, 4:004 (rating 6) put "very realistic".

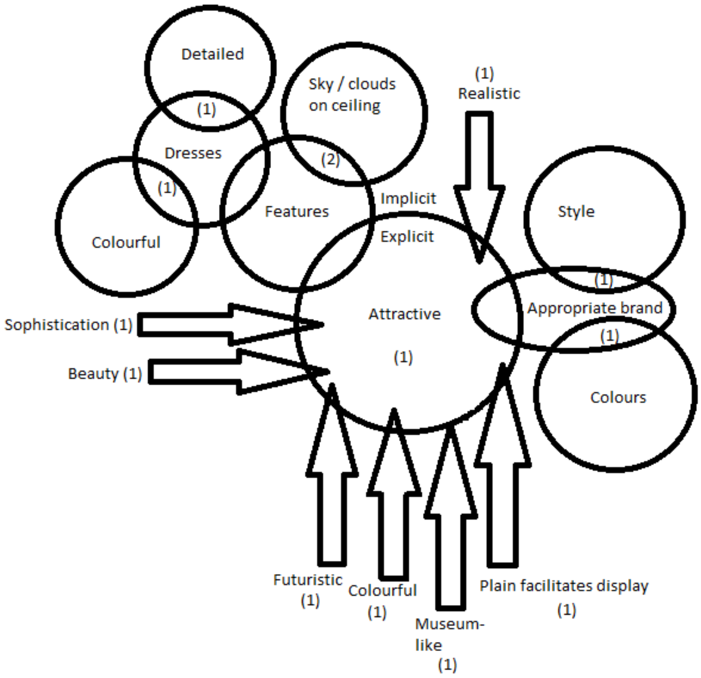

Fig. 24.. Valentino Garavani, Extra comments, Question 6 – The visual scenery is attractive. Answers relating to attractiveness.

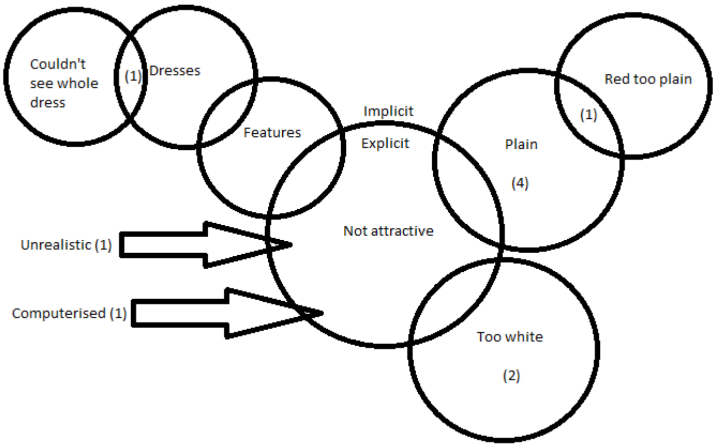

Fig. 25. Valentino Garavani, Extra comments, Question 6 – The visual scenery is attractive. Answers relating to lack of attractiveness.

Question 7: terms used to label the menu functions are understandable

58 of 58 respondents (100%), all answered this question, with a median rating of 6.

8 of the respondents (14%) added further comments, which are discussed below.

1:011 (rating 7) wrote: “there weren’t too many tables so it wasn’t confusing”

Two users referred to ease of finding. 1:007 (rating 6) wrote: “it is easy to find where to go”, while 1:006 (rating 7) related this to understanding, writing: “You understand what the headings mean, which make it easier to find specific information”.

Two users referred to content differing from the menu description. 3:002 (rating 5) wrote: “sometimes they had other things in them which was not featured on the menu”. 4:003 (rating 4) wrote: “didn't (for all of them) entirely explain what was in the exhibition”.

Four users referred to clarity and understanding. Two were positive: “you understand what the headings mean” (1:006, rating 7); “it wasn’t confusing” (1:001, rating 7). Two referred to negative aspects. 3:001 (rating 4) wrote: “sort of but not very clear”. One of these users noted that the lack of understanding could be because the terms were familiar to people with prior subject knowledge. 4:002 (rating 5) wrote: “yes [they were understandable] to people who are interested in Garavani. However I didn't really get them until I looked at the link”. 3:005 (rating 4) wrote: “they [i.e. the terms used in the menu] are brief”.

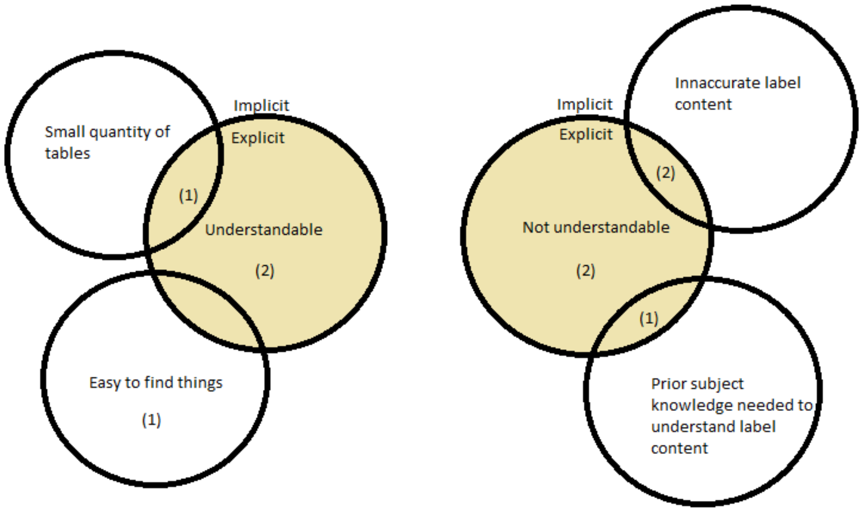

Fig. 26. Valentino Garavani, Extra comments, Question 7 – The terms used to label the menu functions are understandable.

Question 8: menu functions listed are logical

Of the 58 respondents, 58 (100%) answered the question. The median rating was 6. The ratings ranged 3 from to 7

Five respondents (9%) made further comments. Of these five, the mean rating was 5.2, the median 5, and the mode both 5 and 6. Their ratings ranged from to 4 to 6.

One comment mentioned that the menu functions "were a bit confusing" (1:008, rating 5).

1:001 (rating 6) wrote: "good ordering".

4:012 (rating 4) wrote: "I didn't c [*sic.*] menu bar".

4:002 (rating 5) wrote: "yes because I found the links at the top of the menu were most interesting and those were the ones people often visit first".

4:011 (rating 6) wrote: "How it goes from room to room but you can go on a menu to a random room"

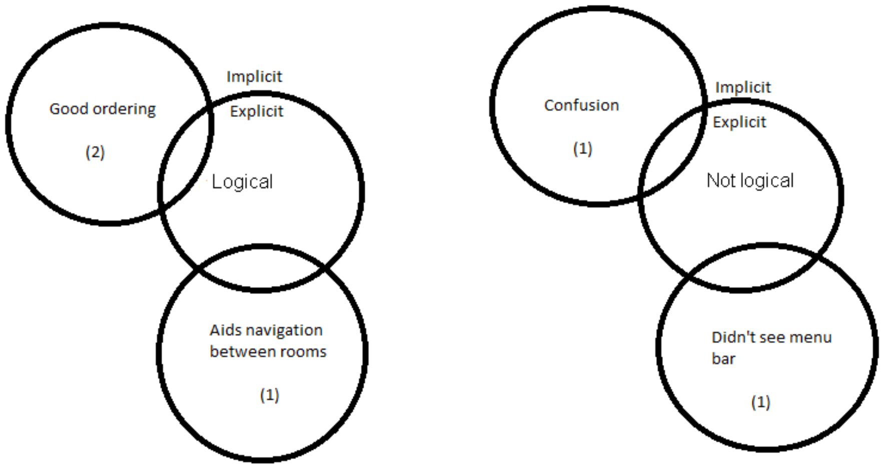

Fig. 27. Valentino Garavani, Extra comments, Question 8 – Terms used to label the menu functions are logical, all responses.

Question 9: Orientation is straightforward

58 (100.00%) respondents answered the question. The median rating was 5. The ratings ranged from 1 to 7.

27 of the 58 (46.55%) made further comments. Of these, the mean rating was 4.04, the median 4, and the mode 3.

Six responses referred to difficulty in getting around in general (1:008, rating 5; 3:001, rating 1; 1009, rating 4; 2:003, rating 7; 4:008, rating 3; 4:009, rating 3; 4:015, rating 3). 1:009 (rating 4) wrote: "getting around the digital museum is a bit difficult to get used to as it is as if you [are] walking around the museum - I didn't particularly like this feature". 4:009 (rating 3) wrote: "It was a bit hard to move around it and the map icon was really small". 4:015 (rating 3) wrote: "It was quite dificult to navigate around with the mouse".

One response suggested keyboard-based navigation as an alternative: "It may have been easier to use the keyboard arrows to navigate rather than to keep clicking with the mouse" (1:008, rating 5). One user reported that they liked the method of navigation presented to them in the system. 2:003

(rating 7) wrote: "I like walking whilst also being able to look round at the same time! Like minecraft!"

Some responses wrote about features that went against their intuition when navigation using the mouse. "Sometimes you get mixed up which way to move the cursor" (2:016, rating 6); "Sometimes it was difficult to turn or change directions" (2:011, rating 5). 3:013 (rating 1) wrote: "hard to get right angle and to move". "At times it wouldn't stop moving", wrote 2:009 (rating 3). 3:014 (rating 3) wrote: "Sometimes started moving up when mouse left still". "It turns a different way to the way your mouse moves so it's a little confusing to start" (1:011, rating 4). 3:002 (rating 5) wrote: when you went right then it would have been more natural to drag left". Another respondent wrote: "I would find myself looking up and at the museum with a wonky angle and I didn't know how to get out of it" (1:013, rating 2). Three participants noted that the system did not do what she wanted it to do or they had difficulty in doing what they wanted to do: "When I tried to look at the back of a certain dress, sometimes the model would 'turn around' to face me again so I could never see the back of the dress" (1:012, rating 6). It "was hard to get to where I wanted to go" (4:005, rating 5); "it was hard to navigate through rooms" wrote 4:017 (rating 3).

Two responses noted difficulty in finding things. 1:004 (rating 4) wrote: "I couldn't get back to the main enterance [*sic.*] after going into specific pages"; "Sometimes hard to find where to go" (1:002, rating 5).

Two users referred to experiencing dizziness or sickness while using the system (2:009, rating 3; 3:013, rating 1).

A minority of users referred to experiencing confusion (1:006, rating 4; 3:001, rating 1; 4:016, rating 4; 4:011, rating 4), e.g. 3:001 (rating 1) wrote: "I find 3D orientation very confusing as all the white is hard to see if there is another wall sticking out or if it is a shadow". 4:011 (rating 4) wrote: "It is a bit confusing at first turning around and moving but otherwise its [*sic.*] good".

Three respondents referred to ease of navigation (1:001, rating 6; 3:018, rating 7; 4:002, rating 5), one of these stating it was easy, provided one read the instructions (4:002, rating 5).

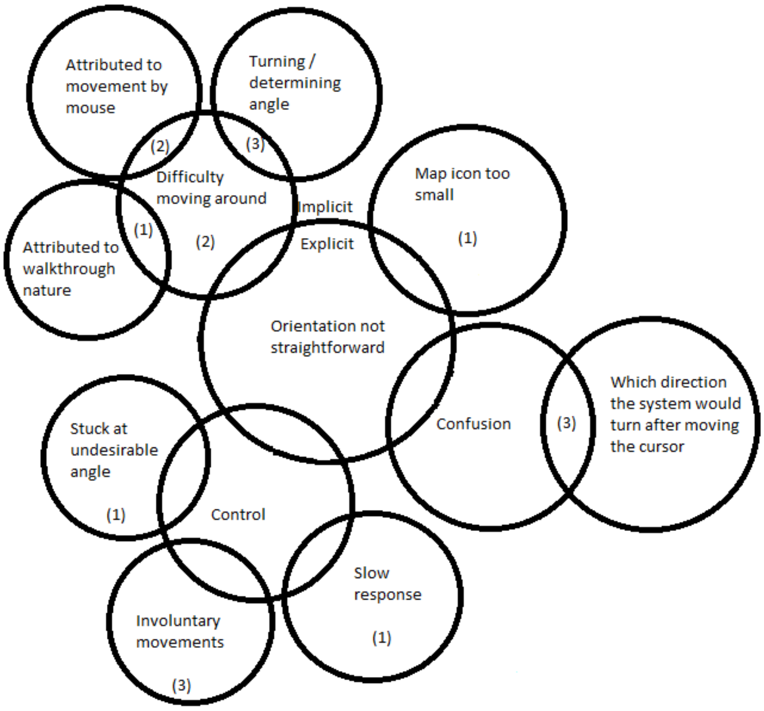

Fig. 28. Valentino Garavani, Extra comments, Question 9 – “Orientation is straightforward”, answers grouped around response that orientation is not straightforward.

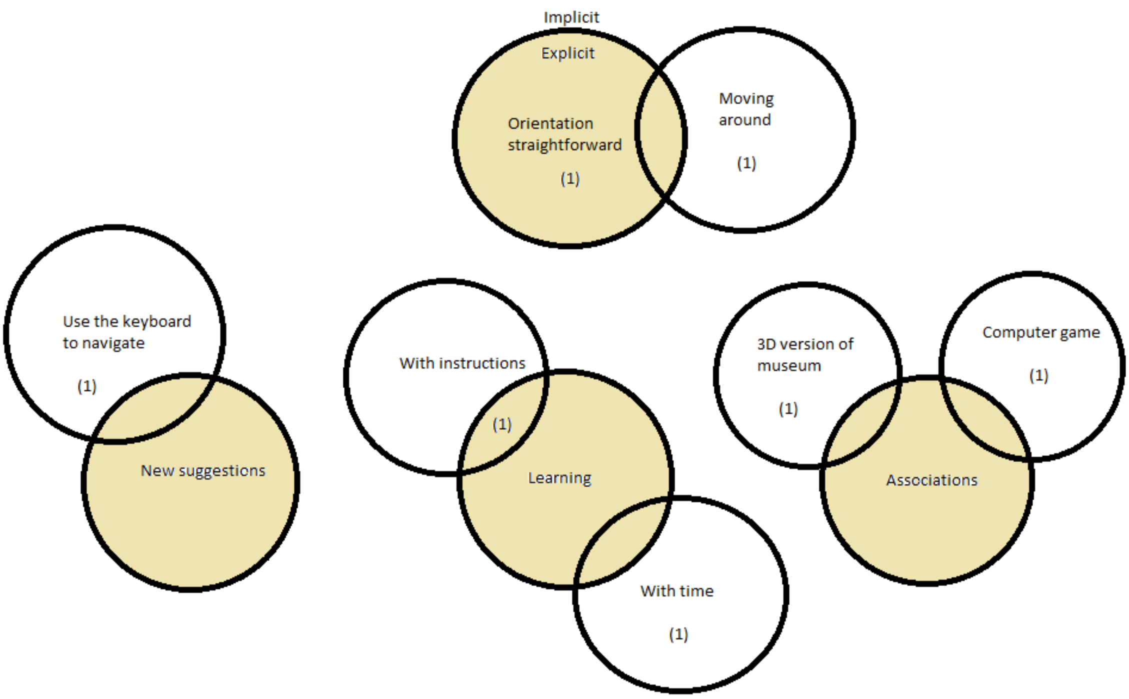

Fig. 29. Valentino Garavani, Extra comments, Question 9 – “Orientation is straightforward”, answers grouped around other responses.

Question 10: Steps I took during exploration were understandable

58 (100%) of the respondents answered the question and the mean rating was 6.

Of the 58 respondents, 7 (12.07%) made further comments. For this group, the mean rating was 5.14, the median was 6 and the modal rating was 6.

Select comments included “Some were hard to understand” (1:007, rating 5); “I couldn't really work out where I was” (4:005, rating 3); and “yes, every room was named clearly” (4:002, rating 7).

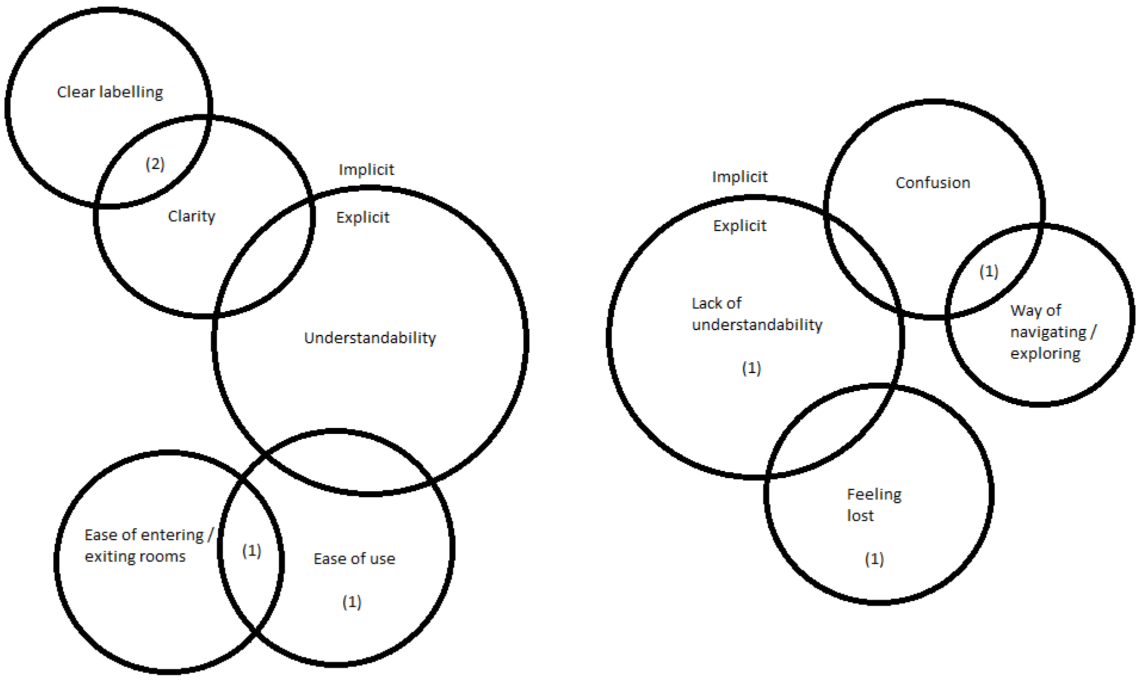

Fig. 30. Valentino Garavani, Extra comments, Question 10 -understandability of steps with factors.

Question 11: credibility of source

58 of 58 respondents (100%) answered the question. For these, the median rating was 6.

Of the respondents, 14 (24%) made extra comments.

Five users referred to the informational content in their comment: “Very detailed information” (1:001, rating 7); and three to the importance of interviews with Valentino in establishing credibility (2:003, rating 7; 2:004, rating 5; 1:005, rating 7; 4:003, rating 7; 4:011, rating 6). Another wrote:

"The information had lots of evidence to support it, for example, pictures and the original plans for the dresses" (1:006, rating 7).

One further user stated: "It did not say some of the sources of the video clips." (4:002, rating 5).

Three respondents wrote that they could not tell whether the resource was credible or not (3:001, rating 4; 4:005, rating 4; 4:002, rating 5; 4:014, rating 4).

One of the comments spoke generally of the resource: "Really fun, interesting and interative [*sic.*] to do and learn!" (1:003, version 6).

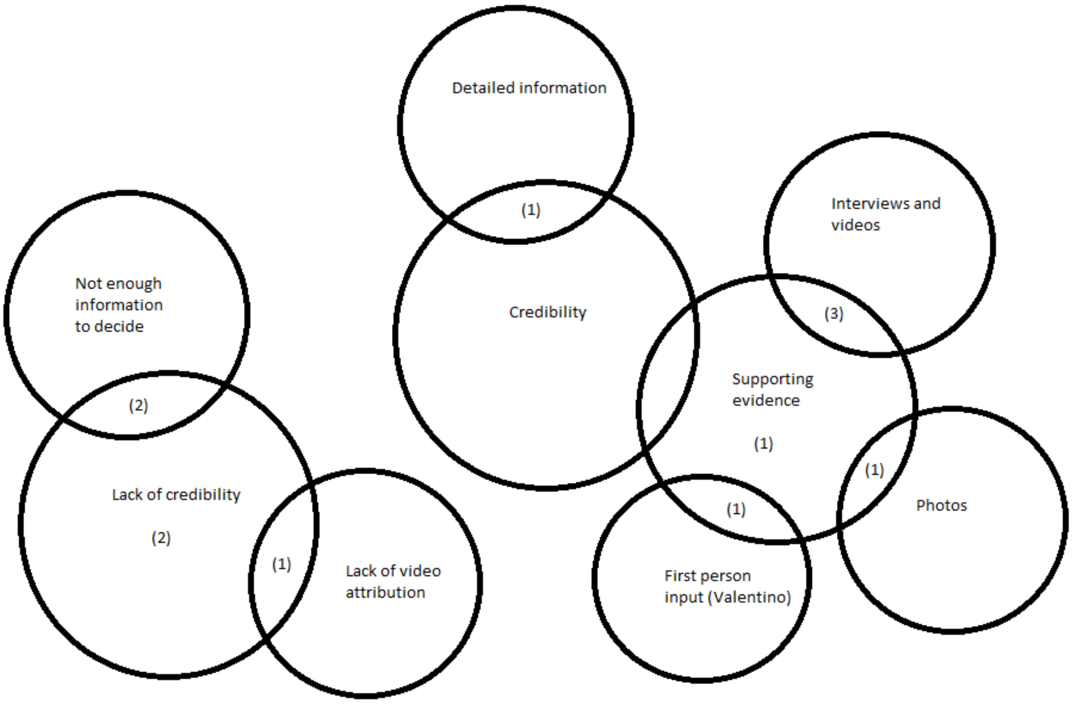

Fig. 31. Valentino Garavani Museum, Extra comments, Question 11 -credibility and factors.

Question 12/13: what did you most like / least like?

When it came to "likes", for the VG respondents 53 (91.38%) left three comments, one (1.72%) left just two comments, three (5.17%) left just one comment, and one left no comments whatsoever.

VG "dislike" comments were given as follows: 30 (51.72%) left three comments, 22 (37.93%) left two comments, four (6.90%) left just one comment, and two (3.45%) left no comments at all.

Because of the quantity of responses, categories have been assigned to the comments, which are summarised below.

Table 13. Valentino Garavani Museum, Question 12 – What did you most like?

Researcher-assigned category	Comments summary and numbers
3D objects	General dresses 8 Colourful dresses 1 Variety of dresses 2 Graphics of dresses 2 Interaction with designs 2 Mannequins 2 Models realistic 1
Multimedia features	Videos 17 Videos - as if you were there 1 Music 5 Variation of music 2 Photos 2 Pictures 8 Audio 1 Drawings 1 Animation 1
Specific areas	Entrance hall 1 Library 6 Model shoots / top model gallery / fashion show 4 Exhibitions 2 Variety of things to interest different people 1 So much to see 1 Original drawings 1 Collections 1 Famous people wearing dresses 2 Chronological gallery 1 Themes galleries 3 White theme gallery 1

	Valentino masterclass 1 Galleries 1 Valentino Seen By... 1 Interviews 1 Skylight 1
Style and graphics	Style 1 Graphics 2 Attention to detail 1 Visual design 2 Cleanness/sharpness 2 Creative 1 Simplicity 2 Realism 5 Futuristic 1 High-definition 1 Stylish 1 Fonts 1 Black and white makes clothes stand out 1 Use of colour 4 Bright colours 1
Navigation	Map 3 Easy to explore 2 Options buttons at beginning 1 Easy to see where you are 1 Room to room navigation 1 Smooth (not jerky) 1
Information features	Additional information data cards 1 Showing the dates 1 Different photos of same dress 1 Information easy to find 2 Variety of information 5

	About Valentino 1 Clicking piece to find out more information 1 Timeline of dresses 1 Interesting information 1 Information on clothing 1 Information on designs 1 Quantity of information 2 Arrangement of information 2 Learning about history of Valentino 2
Experience	Different 1 Interesting 2 Atmosphere 1
Other	Free of charge 1

Below: Table 14. Valentino Garavani Museum, Question 12 – What did you least like?

Researcher-assigned category	**Comments summary and numbers**
3D objects	Dresses repetitive 1 Hard to see dresses 2 Couldn't see whole dress 4 Involuntary rotation 1 Couldn't see dress/models close up 2
Multimedia features	Music 7 Music – limited or repetitive 3 Music weird 1 Videos 1 Videos do not pause / fast forward 3 Videos too long 2 Catwalk videos too long 1 Quantity of videos 1 Automatic playing of videos 1

	Magazine covers 1 Pictures instead of photographs 1 Couldn’t see whole picture 1 Lack of interactive games / quizzes 1
Specific areas	Entrance hall 3 Tutorials 1 Doorways 2 Spring / Summer collection 2008 1 Valentino Seen By... 1 Events videos 1 Library 2 Valentino Mansion 1 Creating Couture 1 Exhibitions and events 1
Format	Not as good as the real thing 1 Lack of online gift shop 1 Takes away from family experience of museum visits 1
Style and graphics	Red colour scheme 3 White colour scheme 2 Lack of variety of colours 1 Simple /little detail 2 Emptiness 2 Eye-catching 1 Small font 1
Navigation	General 5 Difficulty exiting rooms 3 Difficulty going through doors 1 Map 1 Understanding menu 1 Items blocked the way 2 Mouse navigation 5

	Not knowing which areas already seen 2 Orientation 9 Difficult going forward 2 Mouse orientation went opposite way to expected 2 Moving around 2 Difficult turning around 2 Awkward movement 2 Slow movement 1 Having to go back to the entrance hall 1 Keyboard navigation 1 Not knowing where I am 2 Method of moving around 3 Not clear how to explore 1 Can't go anywhere I want 3 Over sensitive 1 Finding way back to entrance hall 1
Information features	Naming 1 Black information boxes 1 Not enough information on friends and muses 1 Too much reading 1 Basic information on dresses 2 Menu 3 Menu unclear 1 Titles unclear 1 Not enough information before entering room 1
Errors	Not loading 1 Pixilation 2 Videos stopping 1
Other	Feeling dizzy 2

The “likes” and “dislikes” of the group show that the resource created a strong visual impact, whose style and graphics were liked by the users. Users recalled multimedia and information sources positively, and considered particular areas of the museum that they liked. Users appreciated the experience of being able to navigate around the dresses.

“Dislikes” pertained to difficulties in interaction, navigating and orientating around the system. Comments also referred to specific multimedia resources, information sources and specific areas. Some “dislikes” related visually to the plain colour scheme in the background.

Question 14: enjoyment of resource

47 out of 58 participants (81.03%) answered the question. The median rating was 6.

24 of the 47 respondents (51.06%) made extra comments. For these respondents, the mean response was 5.73, the median 6, and the mode 7.

Two respondents used very positive exclamations to express their feelings in general about the resource (1:013, rating 7; 2:016, rating 7).

One respondent was positive about the resource’s originality: “I have never experienced anything like it! The concept is brilliant!” (3:018, rating 7). Another wrote “It was really creative” (1:006, rating 6).

One respondent referred in general to the resource in negative terms “it wasn’t that exciting” (2:009, rating 2). Two respondents found the resource enjoyable or positive but not interesting: “It was enjoyable although none of the topics were of real interest to me.” (4:004, rating 6); “It was a bit boring in some places but it was really cool” (4:011, rating 5).

Five respondents referred to finding the resource interesting (1:013, rating 7; 1:005, rating 7; 4:003, rating 7; 4:009, rating 7; 1:004, rating 5), e.g.: “I think this website was extremely clever and so, so interesting.” (4:009); “It was really interesting and I enjoyed seeing his work” (1:004).

Two respondents referred to the resource as simultaneously interesting and fun: “Very interesting and fun to use.” (1:001, rating 6; 4:012, rating 7). This is also implicit in 1:007 (rating 5). “I enjoyed it because it was very interactive and educational as well as being fun” (3:012, rating 7).

Two respondents referred to learning: “learned lots. Useful if learning about valentine [*sic.*]” (1:003, rating 4); also, see 3:012, above paragraph.

One respondent referred positively to the appearance of the resource: “Really cool to look at” (1:003, rating 4).

Four respondents referred to navigation features of the resource: “I liked that it also had a map so it was easier to get around” (1:002, rating 6). Three of these were negative: “I really thought it was interesting but the white made it hard to navigate.” (3:001, rating 5); “It was cumbersome to move around and took time so that lessened the enjoyment” (4:017, rating 4); “I did get stuck in a wall/photo on wall at one point meaning I was made to go back to the start near end” (4:014, rating 4).

One respondent referred to enjoyment of certain features of the resource: “I enjoyed viewing all the different dress styles and information surrounding them (1:005, rating 7).

One respondent compared the resource favourably to more traditional means of communication: “It was more interesting than just pictures and writing” (1:011, rating 6).

In contrast, three respondents referred to how they would like to also see the museum in person or would prefer a “real life” museum (2:004, rating 5; 3:016, rating 4; 3:005, rating 5).

One respondent stated that using the system was not a choice that they would ordinarily make (1:004, rating 5).

One respondent referred to feeling unwell as a result of using the resource (2:009, rating 2).

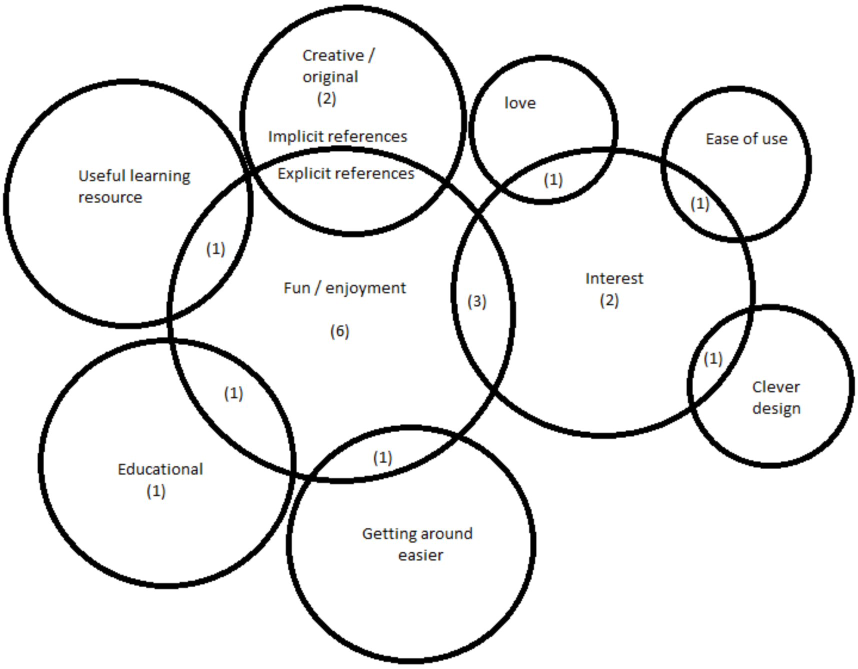

Fig 25. Valentino Garavani Museum, Extra comments, Question 14, references to fun / enjoyment.

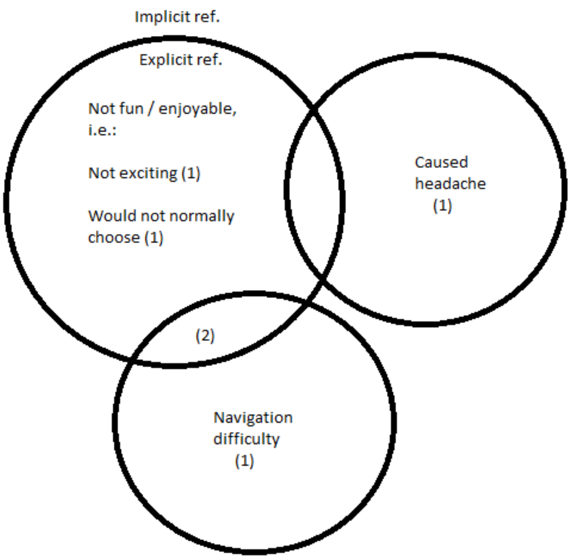

Fig 26. Valentino Garavani Museum, Extra comments, Question 14, references to lack of fun / enjoyment.

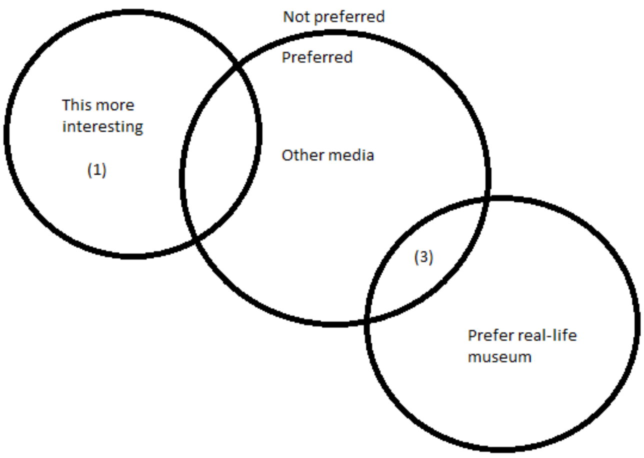

Fig 27. Valentino Garavani Museum, Question 14, comparisons to other media.

Giza 3D

Of the 9 participants, 8 (88.89%) used Giza 3D for the full 36 mins, while 1 (11.11%) used the resource for 32 mins. The mean time spent using the resource was 35.55 mins.

Questions 1 and 2: finding specific information while browsing

Of the 9 participants who used Giza 3D, one (11%) responded in the affirmative when asked, in Question 1, if they had tried to look for specific information while browsing. This participant rated her experience as "6" and made no further comment.

Question 3: the system responds quickly to user without delay or error

Of the 9 users, all (100%) answered this question. The median answer was 5. 4 further comments were made in the comments box.

Three responses referred to slow loading speed in relation to the first screen they encountered on trying to enter the system (1:017, rating 4; 2:008, rating 5; 1:010, rating 3). Others referred to better loading speeds in other parts of the system: "loading the pyramids was fast" (3:010, rating 6). Referring to the general speed of system, 2:008, rating 5, said that "it got better after a while".

Three responses refers to errors, namely, the system "freezing" (1:017, rating 4; 1:011, rating 3; 3:010, rating 6), e.g. "there were a couple of bugs where the screen froze" (1:017).

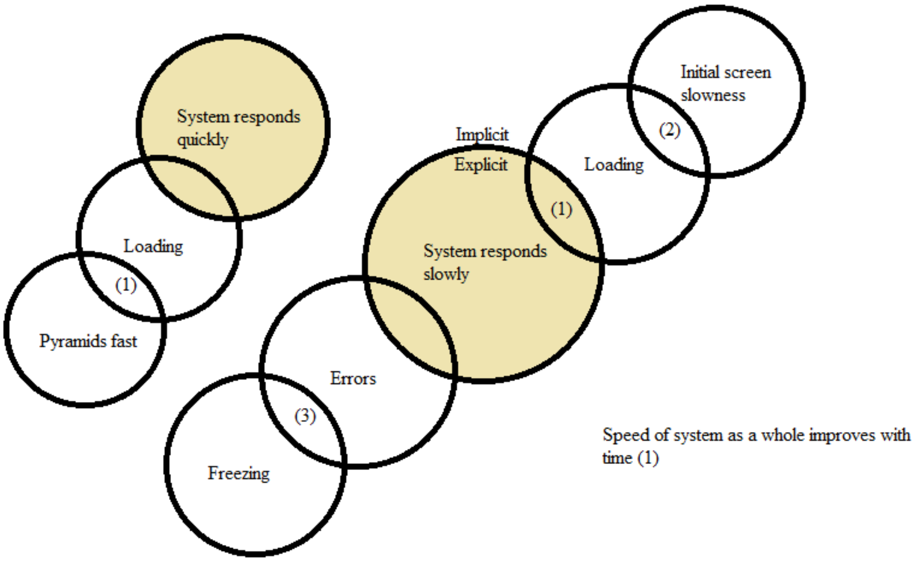

Fig. 32. Giza 3D, Extra comments, Question 3 – The system responds quickly without delay or error..

Question 4: the text type and font size is engaging and readable

9 of 9 users (100%) answered this question with a median value of 6.

4 (44%) made comments. The comments were as follows:

Easy to read, colours of writing contrast to the colours of the background (1:017, rating 6);

some of the text was too small and looked uninteresting to read (2:008, rating 5);

There wasn't much text, mostly audio (2:012, rating 6);

It was very easy to read but not very engaging (3:010, rating 5).

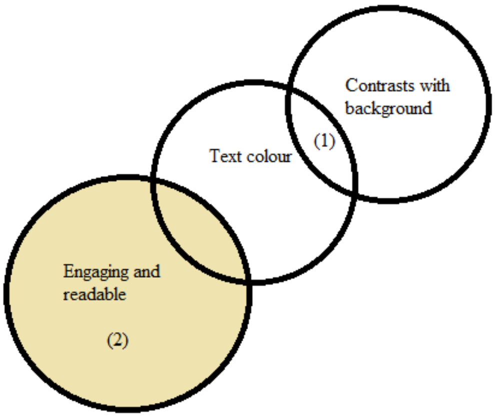

Fig. 33. Giza 3D, Extra comments, Question 4 – The text type and font size is engaging and readable, answers positive.

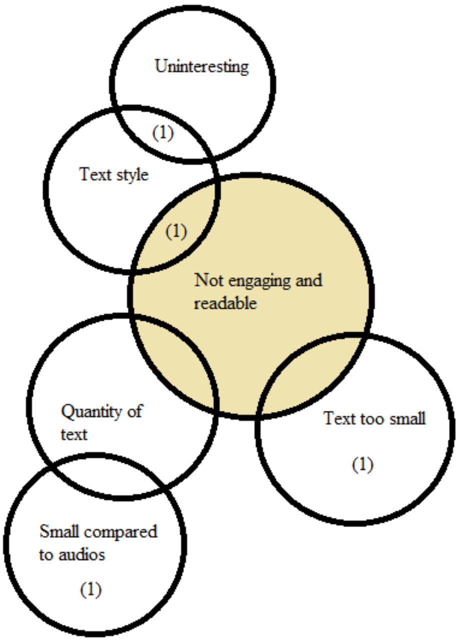

Fig. 34. Giza 3D, Extra comments, Question 4 – The text type and font size is engaging and readable, answers negative.

Question 5: colours, graphics and icons used appropriately

9 of 9 (100%) users answered this question, with a median answer of 7. 3 (33%) made further comments. Their answers are reproduced below, and referred to effective colour, use of colour to link labels to 3D places, and the third comment made a suggestion for improved interactivity and more sophisticated use of graphics and icons in the system.

The graphics are very vivid and clear (1:016, rating 6);

The pyramids which you hovered over went red and so did the corresponding text which was useful (3:010, rating 7).

Love the idea of an object/photo gallery. But it could be even better if the objects were animations in the interactive tour and you could click on them for info and the ruins today. Graphics in the object library didn't have any detail/info. (1:010, rating 7);

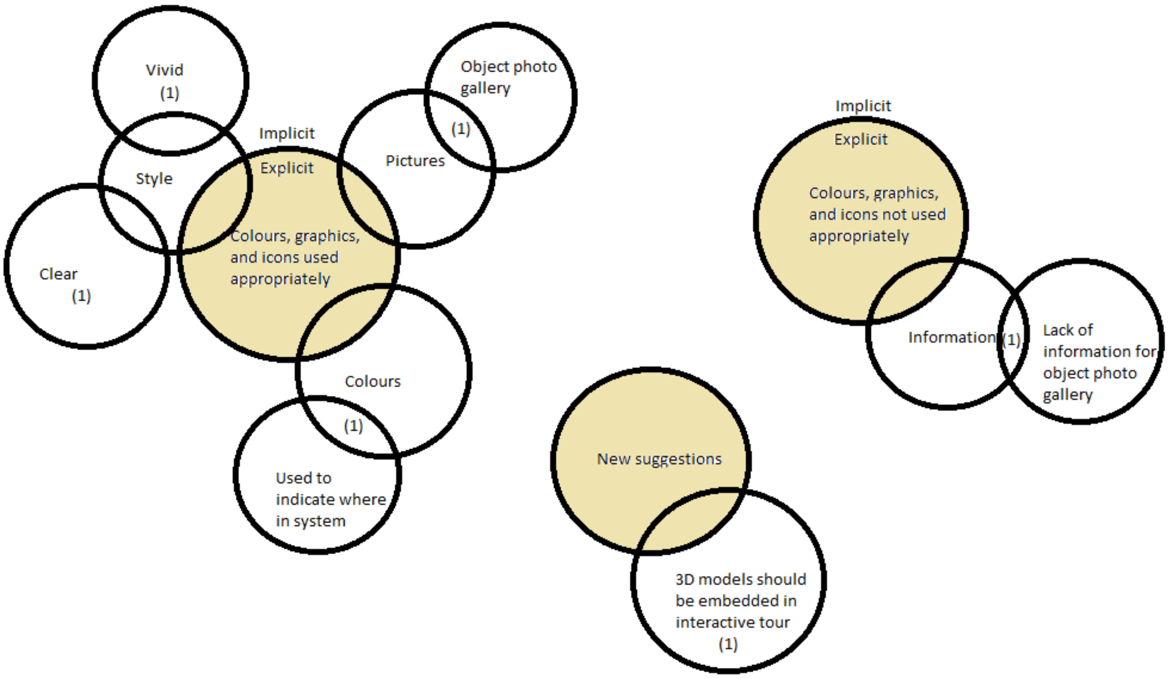

Fig. 35. Giza 3D, Extra comments, Question 6 – Colours, graphics and icons are used appropriately.

Question 6: The visual scenery is attractive

9 of 9 respondents (100%) answered this question, with a median answer of 7. 2 respondents (22%) added comments:

Of course the scenery cant [sic.] *be too attractive: it's a reconstruction. However, considering that they didn't have too much to go on, it's quite good (1:017, rating 5).*

It has a detailed animation but viewpoints allow you to see the real ruins (1:010, rating 7).

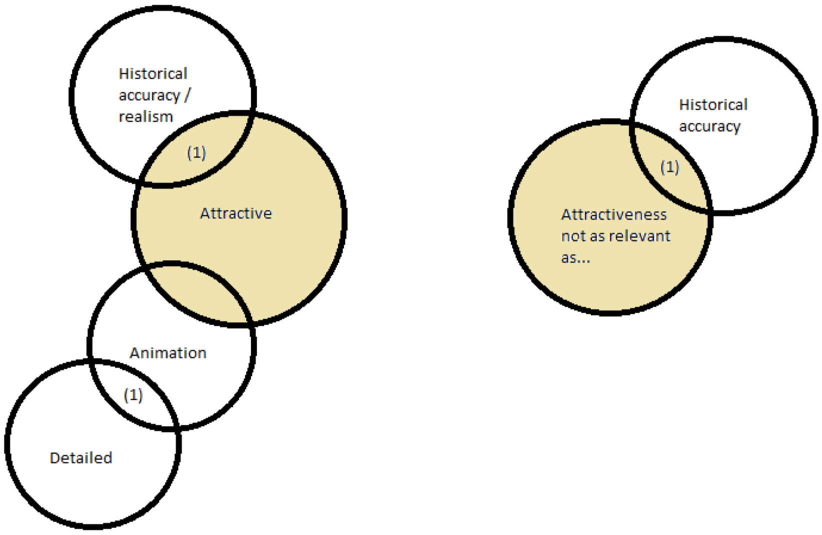

Fig. 36. Giza 3D, Extra comments, Question 6 – The visual scenery is attractive. All answers.

Question 7: terms used to label the menu functions are understandable

9 of 9 respondents (100%) answered, with a median answer of 6. 3 (33%) added further comments, two stating that it was easy to navigate (1:010, rating 7; 2:008, rating 5), and one writing:

Sometimes, because you're [sic.] *viewpoint was changing, you could not tell which pyramid you were going to (3:010, rating 6).*

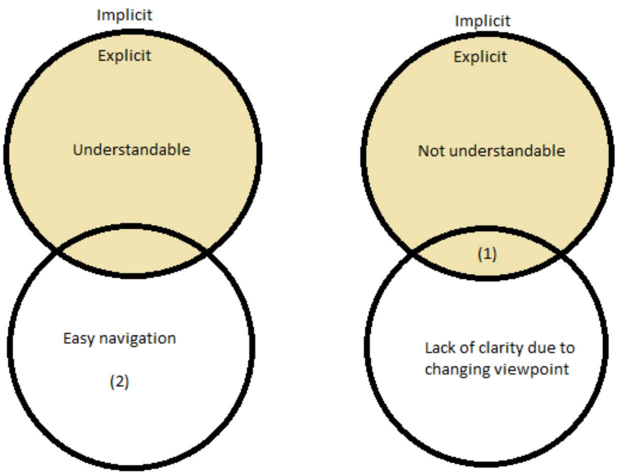

Fig. 37.. Giza 3D, Extra comments, Question 7 – The terms used to label the menu functions are understandable, all responses.

Question 8: menu functions listed are logical

9 of 9 respondents (100%) answered, with a median answer of 7. One respondent (11%) made further comments:

When looking through all the complexes you can get information in a logical manner 1) Guided intro 2) Object gallery 3) photo etc. (1:010, rating 7).

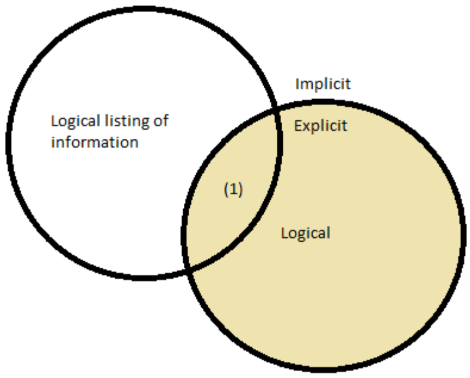

Fig. 38. Giza 3D, Extra comments, Question 8 – Terms used to label the menu functions are logical, all responses.

Question 9: Orientation is straightforward

9 of 9 (100%) respondents answered the question, with a median answer of 6. 5 of the 9 (56%) made further comments, as follow:

It would be helpful if it said which sections had an audio on the guided tour (1:016, rating 5);

When I first started doing interactive tours, it took me a while to understand how to use it, but once I got used to it, I had a lot of fun playing around with it. (1:017, rating 4);

Sometimes difficult to see something you want to see (2:010, rating 6);

At first I didn't know what to do (2:012, rating 5);

It was nice that it kept revolving, but sometimes you could not tell where individual pyramids were. (3:010, rating 4).

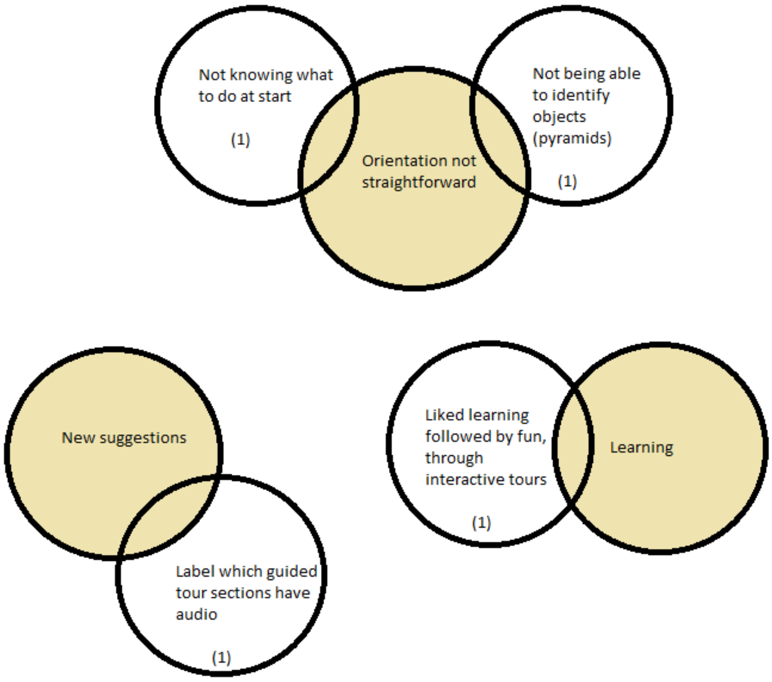

Fig. 39. Giza 3D, Extra comments, Question 9 – "Orientation is straightforward".

Question 10: Steps I took during exploration were understandable

9 of 9 (100%) respondents answered the question and the median rating was 6. 2 of 9 (22%) made further comments, as follow:

It was easy to find what you wanted to see (1:010, rating 6);

There weren't many instructions (2:012, rating 5).

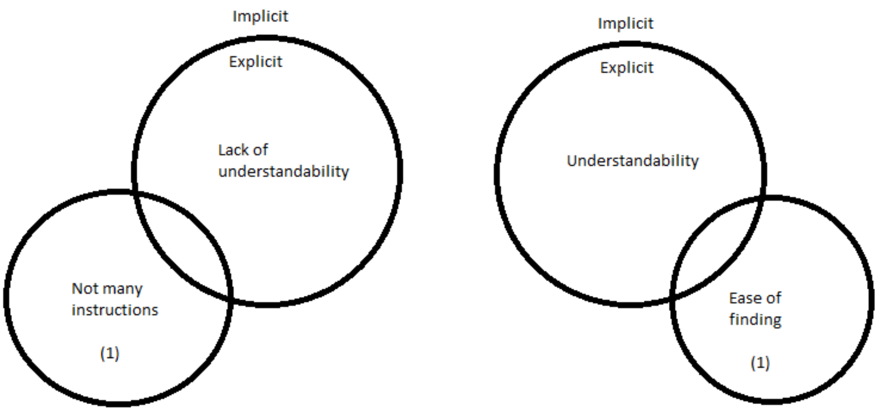

Fig. 40. Giza 3D, Extra comments, Question 10, understandability of steps with factors.

Question 11: credibility of source

9 of 9 respondents (100%) answered the question, with a median answer of 6. 2 of 9 (22%) made extra comments. The first comment answers the question by listing two of the organisations involved in the development of the resource, while the second states:

I would have used this website as a source! (2:008, rating 6).

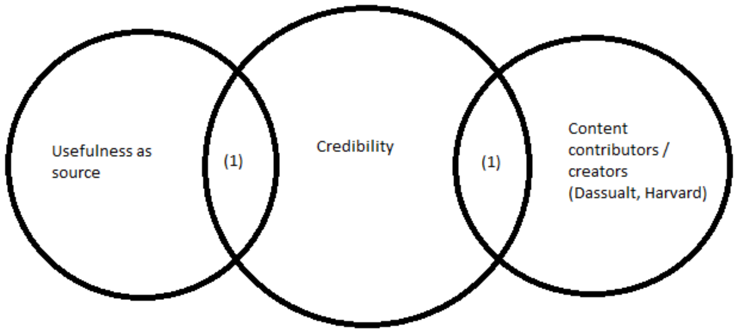

Fig. 41. Giza 3D, Question 11, credibility and factors.

Question 12/13: What did you most like? What did you least like?

For Giza, 8 of 9 (88.89%) respondents listed three features that they liked; 1 (11.11%) respondent listed two liked features.

When it came to dislikes, for the Giza respondents, 3 (33.33%) gave three features that they disliked; 3 listed two features, and 3 listed one disliked feature.

Table 15. Giza 3D, Question 13 – What did you most like?

Researcher-assigned category	**Object of summary and numbers citing**
Objects	Detailed 1 The people 1
Multimedia	Animation detailed 1 Music 2
Specific areas	Guided introduction / interactive tour 5 Object gallery 1 View of the Nile 1 Mastaba's Tomb 1
Format (e.g. display method)	Viewing from different points 1 Independent exploration 1 Interactive 1 Layout 1
Style and graphics	General graphics 1 Detailed graphics 1 Text size 1 Visual appearance 2
Information features	Ease of finding 1

Table 16. Giza, Question 13 – What did you least like?

Researcher-assigned category	**Object of summary and numbers citing**
Objects	Not being able to click on something to see it better 1
Multimedia	Music 1 The voice of the narrator 1
Format (e.g. display method)	Scale 1
Specific areas	Guided introduction consisting of videos only 1
Style	Font too small 1 Colour 2 Colour bright 2 Colour repetitive 1
Navigation	Confusing 1 Initially difficult 1 Involuntary revolving 1
Information features	Lack of information in object gallery 1 Quantity of instructions 1

The comments show that users liked the graphics, objects and multimedia aspects of the system. They recalled specific areas that they liked, and liked being able to explore the resource.

The "dislike" comments show that navigation difficulties were an issue. Users highlighted the use of colour and information content as aspects that they did not like.

Question 14: enjoyment of resource

8 of 9 participants (89%) answered the question. The average rating for this question was 6.75, the median was 7, and the mode was 7. 3 of the 8 respondents (37.50%) made extra comments, as follow:

It's a really engaging and useful resource I would definitely use it to research. It gave you a better insight in to real Egyptian life. (1:010, rating 7);

Easy to find information. (3:010, rating 7);

I think it's a great idea and really useful for learning. The visual side is fantastic and knowledge and graphics are really good. I would definitely recommend it to anyone interested in what it has to say and do. (3:017, rating 7).

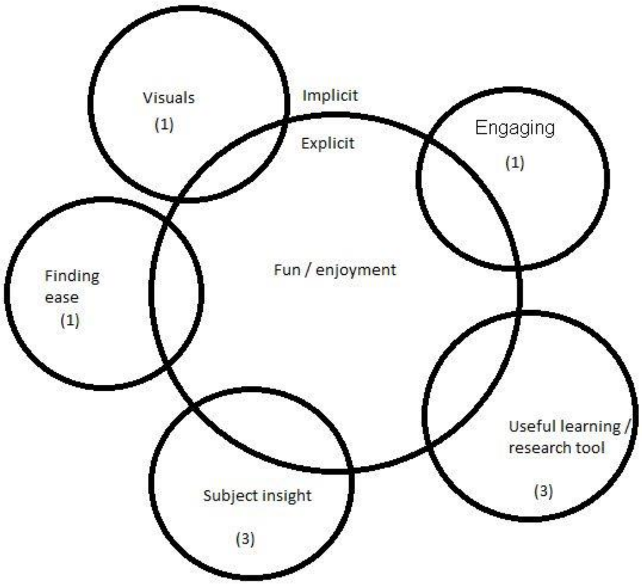

Fig. 42.. Giza 3D, Extra responses, Question 14, references to fun / enjoyment.

8.1.3 Focus Group Interviews

The composition of focus groups, which consisted of VG Focus Group 1 (FG1) of 9 participants, VG Focus Group 2 (FG2) of 7 participants, and Giza FG of 9 participants, warrants a brief discussion. It was initially projected that three focus groups of 6-12 participants would be held: one for each of the three 3D digital libraries offered to the participants during the laboratory trials. In reality, only one participant elected to use the Virtual Museum of Iraq, and the majority of participants selected VG. The school offered three available slots for focus groups to take place so it was decided, pragmatically, to allow for two focus groups of VG users, and one of Giza users.

Valentino Garavani Summary

Quotations are cited as coming from either FG1 (1) or FG2 (2).

An initial review of findings prior to further coding and analysis indicates that VG users were motivated by an initial interest in fashion and wanting to see the dresses. Several quotes from the transcript indicate the participants' initial interest in fashion, and in Valentino as a designer, and to finding the resource title the most “exciting”. An indicative quote was: “Yeah. I love Valentino. He’s one of my favourite fashion designers, so that looked really, really good”. (1)

Fashion was also seen, by two users, to naturally translate to visual, rather than textual communication:

> *“Yeah, cos it was fashion, you kind of watch it and wear it, you don’t read about it, necessarily, so it you, you know, you see it, you don’t read it.” (1)*

> *[A participant describing her mother’s interactions with her about Valentino:] “Well, she describes the dresses, and I could sit there and it’s like, “unless you draw me a picture, I’m not quite getting what you’re telling me”. “My mum talks about Valentino a lot, so I was just curious as to what she was actually talking about”. “She just describes it and so I don’t actually see or understand what she’s talking about”. (2)*

Several focus group participants associated entering the museum with entering a physical space, using vocabulary of space, for example:

> *“Erm, well, OK, so you come in, and I like and I remember, like, messing around with the mouse and you looked up and there was sky” (2).*

> *“There was a big red dress in the middle [of the entrance hall]” (2).*

Several participants discussed the content of the Entrance Hall in relation to how well it communicated themes within the museum; their comments are analysed in the next chapter. Several noted the simplicity of the Entrance Hall and discussed its effectiveness/non-effectiveness with regard to user behaviour, for example:

> *“It was very simplistic so it was good if you want like, cos of the focal point. So it made you straight away want to go to that, cos you wanted to see what it was. So straight away you went for the thing in the middle” (1).*

In the initial Entrance Hall, one participant went to the map first, but the majority of users reported navigating by looking around the 3D space and clicking to go to different areas. One user reported falling back on the menu:

> *“That [menu] helped me quite a bit. I was like, ‘phew, oh yay!’”*

Several users detailed steps involved in deciding where to go (e.g. noting the method of navigation, looking for focal points, finding points of interest to click on, and looking for user controls or instructions).

The majority of participants talked about their recollection of different exhibition areas, citing areas such as "the three ages" and the "Creating Couture" video. Several gave reasons about the content as to why they enjoyed different parts of the 3D resource, for example:

> *"I thought that video… I thought that video clip was really interesting to see how they were like the first people that put music in their fashion shows and how it like developed" (2).*

Several participants highlighted the dresses, discussing their visual impact in positive descriptive terms, for example:

> *"Researcher: So, what particularly did you like about, for example, the dresses?*
>
> *Speaker 1: Pretty.*
>
> *Speaker 2: They were like nothing you've, you've like ever seen before, cos you don't normally see people walking down the street with sort of feathers hanging off of them.*
>
> *Speaker 3: And it's like the message behind it was just how like beautiful it was" (1).*

When speaking of their interactions, several participants spoke about the provision of information, often in the form of mixed-media resources. For example, one participant comments on the viewing photographs while watching or listening to a video clip:

> *"In the interview room actually it was really cool where you could still listen to him, but you could look around the room, and you could look at photos, but you could still carry on listening to him, but it was just um different than just watching him." (1)*

Another participant commented on how she could click on a virtual image to see a photograph or "real" image:

> *"And also there are like some more real pictures like, like instead of like the virtual ones. So you could actually see it but like when you clicked on something". (1)*

Another example, below, was one of several which could be analysed for how content could relate to either affective or cognitive responses:

"Researcher: What did you like about the fashion shows?

Speaker 1: I don't know like… Its like you're there, and like. You don't just see the dress, you see like different, all the parts, the collection, you see how it's worn". (1)

The visual impact of the museum scenery was described as "simple", "grand", "modern", "smart" and as conforming to Valentino's expected branding. Some participants thought that the colour scheme was too plain, while others stated that it was effective since it was bold and did not detract from the dresses.

A minority of participants stated that they found it hard to distinguish between the rooms, which resulted in unintentional repeat visits to some rooms. Among these, suggestions that colour coding, 3D design differentiations, or a map could act as effective guides. A minority of participants also suggested motifs outside each room to indicate to them what was inside. An example of these discussions is given below:

"Speaker 1: Or maybe just like in the corner, a sort of, a map, showing where you are and what the room is called. So then you could just tap.

Speaker 2: And you can go back to it if you want to.

Speaker 3: And maybe you could like tick off where you've been.

Speaker 4: So you could still go there again, but you don't accidentally.

Speaker 5: But the floor was like red if you've been." (1)

A minority of participants described their trying to reach certain parts of the system while navigating in 3D, for example:

"Yeah, there was like, there was like, cos how to go to the runway, cos it was like you had to like, you had to go like, you to click on the dress and then go to 'more', and then to the runway thing, and I didn't know how to get there, so I had to ask someone." (2).

A minority noted the challenge of finding specific information, for example:

> *"The only thing is, it's like, it's difficult to actually get specific information, cos when you walk round the museum you're just looking for stuff that would interest you. But if you're trying to find something that you really need to learn about I think that might be difficult unless there was like a search". (1)*

> *"Like it was quite hard to find things as well if you didn't go round everything, because, like to find a certain video. It was quite hard". (2)*

In addition, some users tried to explore specific 3D areas to find more information but they were prevented by the affordances of the system.

> *"Speaker 1: And some of them, there was one dress and you couldn't see the front of it….*
>
> *Speaker 2: I know! That was really*
>
> *Speaker 1: ….I tried turning round and it turned with you. I was like 'come on'" (1)*

A second example:

> *"Speaker 1: It wouldn't let us go down the steps.*
>
> *Speaker 2: Yes, yes, on the!*
>
> *Speaker 3: It really, really frustrated me. I spent five minutes trying to go down the steps!" (2)*

Participants made associations with other resources or cultural referents. Comparisons were made to a library, a museum, online shopping and real-life exhibitions. A significant minority of participants compared VG to a museum. These comments referred to the layout of the resource, similar appearance, the variety of media and the fact that minimalistic design facilitated focus on the objects as features that made them compare it to a real life museum.

One participant spoke about the limitations of 2D fashion websites, which are less "realistic", do not allow you to "go round" and directly "experience" fashion, but another noted that she could often see clothes more closely on a fashion website.

Two participants compared VG to real life dress exhibitions that they have attended: Prada at Harrods, London, and Valentino at the Victoria & Albert Museum, London. The Prada exhibition was considered "really similar", while the participant who had attended the real life Valentino exhibition made a comparison, stating that there was more content in the digital museum. Several users discussed the comparative merits of either the resource or visiting a real-life exhibition. The relevant dialogue is given below:

> *"Speaker 1: But I went to, this isn't online obviously, but I went to, um, this Prada one in Harrods and it was quite, it was really similar! Like, I think it was good, like the online one really, it literally…*
>
> *Speaker 2: I went to the Valentino one at the V&A and the online one shows like a lot more than the V&A.*
>
> *Speaker 3: Yeah.*
>
> *Speaker 4: Yeah, cos you can, if you're in a like a museum you don't see it all.*
>
> *Speaker 5: You can't see all the detail." (1)*

One user also noted the added value of the resource in relation to a 2D fashion website, because of the 3D experience:

> *"On fashion websites it's never like realistic. It's always like you have to look at stuff, pictures and things. But you can never, it's never like going round a museum and like experiencing it, so I really liked that." (2)*

A significant minority used vocabulary evoking "being there", for example:

> *"Speaker 1: It was really nice how it was set out like a museum, and like you were really there.*
>
> *Speaker 2: Yeah, and it, it really felt like you were there" (2).*

A minority of participants referred negatively to the fact that the museum contained no "people", which led to suggestions from several participants about the use of avatars and their perceived advantages.

Several participants discussed game-like or "educational" features of the system, implying positive or negative connotations to each, for example:

> *"The other two were more like lessons". (2).*

A second example:

"Researcher: So do you feel that this wasn't like a lesson then?

Speaker 1: Not at all, which was good." (2)

A third example:

"Speaker 1: No [it was not like a lesson], cos it was more like you're doing it, because you feel...

Speaker 2: Almost like a game of something.

Speaker 3: Cos you like it." (2)

A significant minority of participants commented favourably on writing in the system, for example:

"Speaker 1: There wasn't too much like writing.

Speaker 2: Yeah.

Speaker 3: There was like necessary writing, but not too much so it was really boring". (1)

"Speaker 1: I think the writing could've been condensed on some sections, because it was quite a lot.

Speaker 2: Because it was quite a lot.

Researcher: Do you remember which section in particular?

Speaker: Well when writing about the dresses, you're more likely to read it all if there's less". (2)

The steps involved in navigating in a walkthrough environment challenged a minority of participants, according to their reports. Several comments relating to slowness in navigation expressed frustration at forming an intention to go somewhere and it then taking some time to get there, or not being able to navigate to the desired point with ease, for example:

"Speaker 1: *When it showed the time periods it was quite good how you had all the different dresses, but it was actually quite hard to get to some of them.*

Researcher: *Why was it hard to get to them?*

Speaker 1: *I don't know. It was like I'd click and it just, something else would be in the way and it wouldn't move." (1)*

The method of navigating with the mouse was difficult for a minority of participants. They expected their actions to result in moving in one direction, but they in fact resulted in the opposite movement, for example:

"Speaker 1: *And also, like the mouse clicking – it went the wrong way! I got really confused.*

Most of group: *Yeah!*

Speaker 2: *Yes, that exactly. On my thing.*

Researcher: *So do you mean that you expected something different?*

Speaker 3: *Yeah because so, on like most computers of tablets or whatever, if you click here and bring it that way, it swipes it as if you're picking it up and moving it, but on that one it was if you click here and bring it that way". (2)*

A significant minority participants noted that the videos could not be paused, rewound or fast forwarded and this is a specific feature of the system that several participants did not like, for example:

"Yeah, and also for the famous people, like, I kind of wanted to like stop and see the actual dress, because it was like going really quickly, and I couldn't see it. Like some of the sections were really long and then some of them were really short so if there was like a play button or something then you could like put it on which bit you wanted." (2).

A minority of participants imagined using a similar resource again in the future in the case that they had a specific research need – i.e. if it was perceived to be useful. They went on to discuss the broader application of 3D digital resources for a range of learning needs, such as history or science. In this example, hypothetical future use of the resource was predicated on its curricular relevance:

(Responding to the question "Would you use it again?") "Yes, if it was something I needed to know about, like, erm, I don't think, you know fashion, unless I was doing textiles would be my sort of first call of duty. But um, if it was something like say, maybe something like say maybe something to do with science I needed to find out about that." (1)

A minority of participants noted that seeing the dresses in real life was appealing to them as well as seeing them in the resource format, for example:

"I wouldn't say use it all the time, though, because it would be quite good to see them in real life as well". (2)

A minority of participants cited wanting to see the exhibits again, in order to better absorb the content – "take it all in" – as a motivation for going back to the system.

"Speaker 1: To have a closer look at everything, cos now you've sort of seen it, like you can look at it in more detail.

Speaker 2: It's like when you re-read a book, there's some things you've missed as well." (2)

Giza Summary

Participants had an initial interest in the subject matter which guided their choice of resource to look at. The novelty and perceived fun nature of the system also had an initial appeal for a minority of users. One group participant had been to Giza before and this formed a part of her initial inspiration for choosing the system.

It was noted in pilot trials that Giza required the user to wait initially while the system loaded. The experience of waiting formed part of the first impression for a significant minority of users of the system, for example:

"Mine was really slow. It, it was, it took a while to actually load the system".

However, a minority of participants said that they found the loading screen quick, or they tolerated the wait because the music was entertaining, or they found the wait "worth it".

Users navigated through the museum both by using the 3D aerial view and by using menus and guided tours as introductions to each section. A minority of participants stated that they decided where to go by selecting on the menu the name of the historical area that was of most interest to them. One participant's choice was inspired by prior interest in the subject:

"Speaker 1: I went to the Sphinx temple first, you know, the Sphinx. I'm not sure why.

Researcher: Do you remember why?

Speaker 1: Um, well I've always really liked Egyptian mythology and, um, especially buildings like the Sphinx and things, so I guess I just went for it, and had a look around."

Another user took the approach of viewing the Pyramid areas complex using the aerial view, and then exploring a particular area that took their interest:

> *"Um, I went to actually, um, look at the general thing first, just to get myself, sort of, you know, erm, sort of acquainted with what everything is, erm, but then after, erm, I wanted to know more about the Great Pyramid because I'm really interested in all the traps and all of the things they put in there. Erm, they, they didn't give, er, too much about all the different passageways. They just, they showed, I think, the King's room and the Queen's room, um, and a couple of other things, but, er, in the interactive mode it was really fun just zooming through the corridors".*

Several participants commented positively on the usefulness for the "interactive tours", for example:

> *"The little introductions where you click on the different thing were really useful, cos they just took you round it and then I just did the interactive tour after it and you could just see different things that you thought were interesting".*

A second example:

> *"Yep, because once you'd got the piece of information on that thing then it, they told, referred to something else that was of understanding, so you could like go and see that".*

A third example:

> *"Also like the guided tour bit wasn't too long so you weren't bored with that and you could go and explore it yourself".*

In the instances where some of the guided tours did not have an audio component, a significant minority participants felt that this detracted from the purpose of the guided tour because they could not tell what was happening without the aid of an audio commentary. A minority of users also found the narrator's accent hard to understand when he spoke.

A significant minority of Giza users spoke favourably about the fact that the system contained figures who moved around areas of the Giza complex. Among these, participant quotations called these figures "more believable", "really interesting" and said that it made the experience feel more realistic because it added a believable historical dimension.

Several participants reported exploring information in the system. Of these, a minority of participants stated that they liked the possibility of clicking on objects to obtain contextual information.

> *"Another thing that was really good when you were on the interactive bit if you went around the thing it had a little sort of those Google map things and if you clicked one it told you a little bit about the thingy. Well, that was in the Sphinx. I'm not sure if it was anywhere else, but".*

A second example:

> *"Cos it sort of, I don't know. It just gave you a little insight more into the thing you were looking at itself. It was sort of a little bit further than the general introduction, and so that was useful".*

One user appreciated how the provision of contextual information in Giza also extended to the co-location of objects that were not so grouped in the real world:

> *"It was quite nice to kind of see like everything all together. When you're actually go there they wouldn't all be there like that, cos it said that on the website. It was kind of quite nice to see them in their former glory, as it really, kind of, were. And then, when you actually go there you can see what they're like now and you can kind of compare and…"*

A significant minority of users reported having new information needs as a result of features within the system. Among these, participants were curious to find new information about the aspects such as the people and the historical images sparked curiosity. Some users accepted that these information needs would not be satisfied within the system, while others cited areas where they thought that more information should have been provided within the system, as the citations below indicate:

"Speaker 1: I was thinking about what it would've looked like now. Like, with all the pyramids I was thinking, wait: what, would they be, still a pyramid shape, or are they collapsed, or like, half worn away?

Researcher: OK, and did you find anything to give you an answer on that?

Speaker 1: Not really.

Speaker 2: Well the, yeah, the picture library.

Speaker 3: Yeah, you had to go into the picture.

Speaker 4: Oh, I didn't find those, yeah."

Two users tolerated not being able to find the information that they were curious to find:

"Speaker 1: The scroll.

Speaker 2: Yeah, the scroll, and so I like, sort of went through the man and tried to read the scroll, but I couldn't read it.

Researcher: What did you think when you couldn't read it?

Speaker 2: Erm, well, I thought it was kind of normal. I mean, like, it, it, I mean, ain't no one got time to like just look at writing. [Laughs]

Speaker 3: To go through ancient Egyptian scrolls!"

On occasion, a minority of users reported wanting specific information in the 3D environment but not being able to locate it contemporaneously:

> *"I thought, you know with the viewpoint thing, where you could click on it to zoom in and out and things. I thought they should've maybe put a picture of what it looks like now should've come up, or something, cos a lot of it was animation, so I know there was a picture library…"*

A second example:

> *"I was, kind of like, when I was like, I zoomed in on the bit with all the men in because I was like "what are they doing?", cos I wanted to learn more about what, like, the actual lives, so I thought like you could click on it, but you couldn't."*

A significant minority of users spoke about appreciating having the choice of where they wanted to go rather than being made to go to certain places and having the pace of that visit determined, for example:

> *"Being able to move around and look at the things that actually interested you instead of being dragged around like, 'great, there's a pyramid, now we'll move on'.*

A second example:

> *Yeah, you had a lot of choice about what you wanted to do, where you wanted to go."*

A significant minority of users stated that they liked the graphics and visual scenery of Giza, for example, describing aspects of the scenery as "pretty" and "beautiful", with two users noting the role of details in the overall visual impact, below:

> *"Speaker 1:* *I also liked the little details that they put into it, like, the boats, the sails had sort of markings and… They even had a little eye of Horus just on the front. I don't know if anyone saw that, but it was really nice. I loved the boats. They were really cool.*
>
> *Speaker 2:* *And also the cat inside the temple."*

Several participants made comparisons to other types of resource such as a video game, *Google Maps*, an interactive guide book or a digital resource developed by a real-world museum. Among these, a minority made the association between Giza and a video game – either an educational game or a commercially available shooter game, *Assassin's Creed 2*, and stated perceived benefits of this format, as seen below:

> *"Yes, it felt like a sort of educational game thing, it was quite fun".*

A second example:

> *"Speaker 1:* *It actually, um, reminded me of Assassin's Creed. [All: laughs].*
>
> *Researcher:* *Why was that?*
>
> *Speaker 1:* *Well, because in Assassin's Creed 2, if you're wondering around and you come across an important building, there's an icon which comes up, and if you press "back" then it will actually give loads of background information about it, and so, it's actually, kind of interesting.*

In the case of the user who compared the system to *Google Maps*, a resource which allows users to zoom into and walk around a photographed built environment, she favoured Giza because, according to her, it contained much more information.

Several participants associated Giza with a guidebook, but one going beyond the bounds of a traditional guidebook as it allowed them to feel "there" and as if they "were stepping into a brochure", with the implication that this could precede a real-world visit, for example:

> *"It felt like you were about to go. You were stepping into a brochure about it so you were learning all this information, and it's fun to just look around and hear what it has to say and stuff, so it's not exactly it, but it's still really fun and really interesting to go around..."*

A second example:

> *"It was quite a good starter, almost, like, "oh I should go and see it".*

One user felt that she learned more using the resource than she would have done in real life, because there were fewer distractions when using the resource. Three users perceived the resource to be more comfortable than a real-life visit, e.g.:

> *"I feel that, actually, I learnt more on the thing than I would have in real life, because in real life I think I'd have been, I don't know, distracted by the heat, or, erm, itching a mosquito bite or something [laughs] erm, and, er, whereas here you actually could listen to everything he had to say, and there weren't as many distractions, and you know, it, yeah, it was quite good".*

Of course, one value of this resource over a real-world visit was the fact that the resource represented a historical recreation:

> *"It was really nice seeing what it would have looked like, not, sort of, what it looks like now. You got both on the insides as well, which was good."*

In a discussion involving the majority of participants, they anticipated similar resources in other historical periods, such as the Industrial Revolution. They would use such resources as they would be useful and also fun and convenient.

Two users expressed the desire to find out more about the Pyramids of Egypt after using the system:

> *"Yeah, I think I'd look at more of the people. Because, they didn't – I don't know, I didn't see the whole site - but they didn't give too much information about you know, the average person, so I think I'd do a bit more research on that".*

A second example:

> *"I'd quite like to study the magic or the culture or the reason why the buildings were built and, you know, how they were built and the motives for things that were done in those days".*

The majority of users said that they were inspired to want to visit the Pyramids of Egypt in real-life as a result of using the resource:

> *"Researcher: Do you feel any differently about the subject having used it?*
>
> *Speaker 1: I'd like to go there.*
>
> *Speaker 2: Yeah, definitely.*
>
> *Speaker 3: See what it was, and it is.*
>
> *Speaker 4: I'd like to go there again.*
>
> *Speaker 5: What it was, and what it looks like now. It sounds really interesting".*

Two participants stated that they sometimes struggled to distinguish objects from each other in the 3D space or to distinguish one pyramid from another.

Two users stated that the flyover feature allowed them to reorientate when they lost their bearings:

> *"If I ever got lost I flew up into the sky and looked where I was and then…"*

A second example:

> *" I was, kind of like, when I was like, I zoomed in on the bit with all the men in because I was like "what are they doing?", cos I wanted to learn more about what, like, the actual lives, so I thought like you could click on it, but you couldn't. So when I was doing that, I was just getting completely lost all the time. But then I, like came down, and I was like "I get where I am now".*

One user stated that the menu was useful and helped her orientation in the system:

"Speaker 1: Oh, actually the menu was really useful because it was actually really well made, I think, because, I mean it was easy to get around. I mean, as far as I [inaudible].

Speaker 2: Yeah.

Speaker 3: I didn't get lost and I didn't, um…"

One participant highlighted good layout of the system which they said allowed them a good view of what they were doing.

"It was a really good format. It's quite comfortable on the screen and easy to see everything that you were doing".

One participant highlighted specific steps involved in 3D orientation that she could not work out how to do.

"I couldn't work out how to do that [zoom through the corridors]. I got so confused about how to work it".

A significant minority of participants described the experience as calm and relaxed, for example:

"It was quite peaceful as well. I mean…"

A second example:

"… so like you said, it was really relaxed and really calm so it was easy to take things in, and… It's like the perfect rhythm".

A third example:

"Yeah, it was really relaxing and you had sort of a lot of freedom and a lot of wandering and you just felt quite relaxed in the whole thing".

A further example:

"Also, you could hear the sound of the wind when you had the headphones on, and I found that really relaxing, the sound, so it was just calm".

A final example:

> *"Yeah, it was really relaxing and you had sort of a lot of freedom and a lot of wandering and you just felt quite relaxed in the whole thing."*

A significant minority of participants made comparisons between the system and their notion of "learning", for example:

> *"It kind of seemed, like, less like learning as it were…"*

A second example:

> *"Speaker 1: You still learnt stuff.*
>
> *Speaker 2: Yeah, more like you were doing stuff.*
>
> *Speaker 1: …and you were finding stuff out but it wasn't actually learning."*

This user contrasted learning by doing with, presumably, learning with texts or through classroom instruction.

8.2 Stage Two

Seven months after the initial focus groups, the researcher returned to the school to conduct the follow-up focus group interviews.

It was projected that volunteers would be organised into two focus groups, of those who had used VG and those who had used Giza. In practice, unforeseeable changes to the school timetable resulted in two "mixed" groups comprising some participants who had used VG and others who had used Giza. As a result, on the recordings verification is made of which resource the participants are talking about at each venture and tallies taken of different responses to each variable. In addition, the dynamics of the groups were potentially altered by the fact that the majority of participants used VG.

The sizes of the focus groups was not ideal, due to unforeseen changes taking place within the school. The first focus group involved 14 participants – larger than planned. 12 had used VG and 2 had used Giza. The second focus group involved 3 participants, 2 of whom had used VG and 1 who had used Giza.

The larger size of the first group still generated good data and the researcher observed that the participants seemed relaxed and were willing to share their experiences, compared to the smaller group of 3, although transcription contended with a high level of cross-talk. This concurs with the findings of Hyde *et al.* (2005) who noted that in a group of 12 participants in a study about teen sexual health, groups were more "relaxed" and had the same level of engagement as smaller groups, but the downside was that there was more rapid conversation and interruptions between participants, making transcription more challenging.

The number of participants in the second group does not reach the minimum number of 4 recommended for focus groups (Bryman 2008). It was the researcher's observation that the size of group resulted in fewer instances of new codes in the data and this may have been due to number of participants, as well as the hypothesised reduction in conversational dynamics resulting from the smaller group. Although the group size does not qualify as a true "focus group", the results are given because they contain instantiations of data of interest.

The focus groups went as planned, with all the foreseen questions asked. 35 mins was allocated to allow focus groups to take place. The researcher asked further questions based on their responses, to clarify and ask for reasons, and at other times to take a tally of how representative the different views given were. In the second focus group, the researcher went on to ask what aspects of the system they liked and did not like – a return to the contingency questions, due to the other questions having been exhausted.

After the focus groups were over, the researcher presented the resources to a group of schoolteachers from the History and Art departments, over a working lunch. There were three Art teachers and two History teachers present. The researcher recorded a short (14 mins) group interview involving the five teachers where the planned questions were asked. This interview was shorter than expected, due to the later arrival of participants than scheduled, and so does not qualify as a focus group for analysis.

In the focus groups, it is borne in mind that panel conditioning is a methodological scenario which can negatively influence results. According to Cantor (2008), this is a scenario whereby participants' participation in the study influences their responses. This is an issue because a longitudinal element requires advance consent, and presumes ongoing engagement with the resource, and the raised consciousness among participants may influence their behaviour. In this investigation they may feel influenced to over-estimate the extent of their information seeking activities. However, the nature of the responses, most of which do not report further information seeking activities, or which report very specific instances, does not appear to indicate that this has been the case.

8.2.1 Demographic Questionnaires

Group 1

The first group had 14 participants. 50.00% aged 14 and 50.00% aged 15. The median answer using the Likert scale for time spent online per day was "up to 3 hours". The mean percentage of time that respondents reported using the Internet for social networking was 52.14%, for academic study 22.50%, for other personal use 23.57%, and for gaming 1.79%. When it comes to expressed interest in the subjects of the libraries, the Pyramids had a median score of 3, Iraq had a score of 3, and high fashion design a score of 5.

Group 2

The second group had 3 participants, 2 of whom were 14 (66.67%) and 1 (33.33%) was 15. The median answer using the Likert scale for time spent online per day was "up to 4 hours". The mean percentage of time that respondents reported using the Internet for social networking was 13.33%, for academic study 78%, for other personal use 8.33%, and for gaming 0.33%. For interest in the subject of the libraries, the Pyramids had a median score of 4, Iraq had a score of 3, and high fashion design a score of 6.

Below, we consider the data from the demographic questionnaires, split by users of VG and Giza.

Valentino Garavani users

Of the 17 questionnaire respondents, 14 (82.35%) were for those who had used VG (the figure in the initial laboratory test was 86.57%), six of them 14 year-olds and eight 15 year-olds.

2 (14.29%) respondents reported spending up to one hour online per day, 4 (28.57%) selected up to two hours, 4 (28.57%) selected up to three hours, 3 (21.43%) selected up to four hours, and 1 (7.14%) selected up to five hours. The median was three hours reported online activity per day.

The mean percentage of time that respondents reported using the Internet for social networking was 49.29%, for academic study 28.14%, for other personal use 20.71%, and for gaming 1.86%. This compares to the initial demographic of VG users of percentage of time of 55.29% for social networking, for academic study 20.55%, for other personal use 20.43%, and for gaming 3.72% - broadly speaking, we see a slightly greater proportion of time reported for social networking and a slightly lower proportion reported for academic study among the 7-month VG cohort.

For the 14 VG users, the median value of 6 was given on the Likert scale of 1 to 7 to indicate interest in "high fashion design"; a median of 3 was given to "the Pyramids of Ancient Egypt"; a median of 2.5 was given to "cultural artefacts of ancient Iraq". Compared to the demographic questionnaire given before the laboratory experiment, the figure for high fashion design is the same, while this time a slightly lower median figure is given for the other two subjects (the previous medians were 4 and 3 respectively). The preference for high fashion design is given by this group as a whole, as before.

Giza 3D users

Of the 17 questionnaire respondents, 3 (17.65%) were for those who had used Giza (the initial laboratory test figure was 15.79%) and all were aged 14.

1 respondent (33.33%) reported spending up to three hours online per day; 2 (28.57%) selected up to four hours (the median response).

The mean percentage of time that respondents reported using the Internet for social networking was 26.67%, for academic study 51.67%, for other personal use 21.67%, and for gaming 0%. This reported use corresponds to the reported use in the initial demographic questionnaires in the laboratory session whereby Giza 3D users were found to spend a lower percentage of their time on social networking, compared to the VG users, and to on average allocate a greater proportion on academic study.

When asked about prior interest in the subjects covered by the 3D digital libraries, a median of 4 was given to “the Pyramids of Ancient Egypt”; a median of 4 was given to “cultural artefacts of ancient Iraq”; the median value of 3 was given to “high fashion design”. Compared to the demographic questionnaire given before the laboratory experiment, the figure for high fashion design is the same, while a higher median figure was initially given to the Pyramids of Ancient Egypt and the cultural artefacts of ancient Iraq (6 and 5 respectively). Nevertheless the preference for Egypt above high fashion design is asserted among this group, as before.

8.2.2 Valentino Garavani Focus Group Responses

Focus Group 1 (VG)

2 of 12 participants stated that they had looked for information related to the resource since using it. Their responses are summarised in the table below.

Table 17. Post-use information seeking on the subject at 7-month interval for VG users (Focus Group 1).

Table showing post-use information seeking on the subject at 7-month interval for VG users (Focus Group 1)		
Information looked for (number of participants)	**Where did they look and did they find anything?**	**When did this occur?**
Information on one of the photographers featured in the resource (1)	Instagram - could not find information sought	Several months afterwards, prompted by finding old notes
Looked at "stuff to do with fashion", dresses, and designers (1)	Google Images, browsed images	Immediately afterwards

In the course of the focus group, hand-counts were taken at junctures when one or more participants stated a reason for not seeking further information. The number of participants counted for each reason were arrived at by the researcher asking a direct question based on participants' input, and taking a headcount. These responses are given below.

Table 18. Reasons given for lack of post-use information seeking on the subject at 7-month interval for VG users.

Table showing reasons given for not seeking further information post-use, and hand-counts taken when participants identified reasons (VG, FG1)	
Reason for not seeking further information	**Number of participants (highest to lowest)**
Thinking that the information contained within the resource gave them a complete enough appreciation of the topic	12
Lack of interest in the subject matter	1

Some citations given below indicate instances where participants gave further explanations for these reasons.

Reason 1: Thinking that the information contained within the resource gave them a complete enough appreciation of the topic

> *"I felt you didn't need to look into much more because there was quite a lot on there already."*

A second example:

> *"Um, well, as well as there being lots of things it was very visual, so like if you wanted to see a dress or something like you already could see it, walking around."*

A third example:

> *"It was really clear having them all, like, near each other."*

At this part of the focus group, a minority of users compared the experience to a real-world exhibit and preferred it due to being able explore information by clicking on objects of interest, and having greater control over their actions in the environment.

> *"It was like better than actually being there. Like in a clothes thing."*

A second example:

> *"It was better than it cos you could click on it and like find out stuff about it."*

A third example:

> *"And there was slightly more control."*

One participant recalled wanting to find out more during the process of exploration, although they did not then go on to explore this information need after using the resource.

"Researcher: And do you remember thinking that there was anything where you thought that I'd like to find out more?

Speaker 1: Pictures.

Speaker 2: Just the…

Speaker 3: I went into the gallery and looked at all the pictures.

Researcher: OK, so you did that while you were using it, you like maybe, clicked on the dress, looked for information?

Speaker 3: Yeah."

Reason 2: Lack of interest in the subject matter

One participant gave this reason. When a hand-count was taken, she was revealed to be the sole participant who identified with this reason and her explanation is given below:

"Not particularly interested in the various, um Valentino, I'm not really interested, and the pyramids, cos I did both. I had time to do both."

For the next question, when asked whether they had returned to the system again, 12 of 12 participants had not done so.

Table 19. Returns to the resource at 7-month interval for VG users (FG1).

Table showing returns (if any) to the resource after use for VG users (FG1)	
Returned to: yes/no (number of participants)	**When did this occur?**
No (12)	N/A
Yes (0)	N/A

The reasons given for not returning to the system again are visualised below.

Table 20. Reasons given for not returning to the resource again at 7-month interval for VG users (FG1).

Table showing reasons given for not returning to the resource post-use, and hand-counts taken when participants identified reasons (VG users, FG 1)	
Reason for not returning to the resource	**Number of participants (highest to lowest)**
Having more pressing priorities	11
Subset of above: navigation slow – would find other resources faster	Uncounted
Participants would only access resource if they had a specific "reason" (interest or subject research need)	12
Not having time to explore that kind of resource	12
Not having a link to the resource	7

At this juncture, a minority of users expanded on the reasons given for not visiting the resource again, and their responses are grouped into thematic reasons below.

Reason 1: having more pressing priorities

When asked to explain what they meant by having other priorities, a minority of participants said that they felt **navigation would be time-consuming**, or that **they would need a specific research question or to be studying the topic in school**. These dual reasons are cited in exchanges below.

"Speaker 1: I think because it's not like the first thing that comes into my mind. I always think about something else before.

Speaker 2: Like, even though it's to do with art, like, we can do it for art, it's quite like a specific subject.

Speaker 3: That's like.

Speaker 4: It's easier to access other stuff as well.

Speaker 5: Cos it, it's quicker.

Speaker 6: If it was more accessible.

Speaker 7: If it had more variety I think it would be a really useful kind of thing to do…

Speaker 8: *Like not just for dresses.*

Speaker 7: *…not just for dresses and stuff, but if you had it for a subject, that could be really useful."*

Frustration about navigation falls under the category "other priorities", because upon clarification from the researcher, it became evident that navigation was not the reason, *per se*, for their not wishing to experience the system again, but that given time constraints, navigating through a system was perceived to be a barrier to wanting to go back:

"Researcher: *But you didn't [go back to the site again]?*

Speaker 1: *I found it so, like, I found it hard to navigate myself and I got quite frustrated, cos I kept like thinking 'OK, I've gotta, now'.*

Speaker 2: *Cos you've been into that room.*

Speaker 3: *Yeah, and then, and then you like, think you've gone the wrong way.*

Researcher: *So did that mean, because you were frustrated about navigating did that mean that you didn't want to go back to it again?*

Speaker 4: *No, not that I just…*

Speaker 5: *Didn't have time.*

Speaker 4: *…like, in my spare time I'm more likely to go on other stuff and it was, I dunno."*

Reason 2: needing a specific reason to go back

In the above section, some participants indicated that they would only go back if they had a specific "reason". The researcher attempted to clarify this point at a later juncture during the focus group. Some responses are given below:

"Speaker 1: *I think I'd only go back on it if I had like a good reason for it.*

Speaker 2: *So let's say for art.*

Speaker 3: *Yeah, especially to look at art.*

Speaker 4: *Yeah, you could look at it for art.*

Researcher: *So if you wanted to find out about something, like a research question?*

Speaker 5: *Yeah, particularly about something, like, if for the pyramids you can use it for like history or something, you could. I'd go back on it if I had a reason for it and needed some information but otherwise I don't think I would".*

A second example:

"So I think once I'd browsed something, like, already, so I spent about an hour browsing that in the lesson, what we were doing, I'd kind of like looked through everything and so I didn't really have a reason to go back and do it again, unless I was looking for something specific, hence I'd kind of need a reason to go back again".

A third example:

"Speaker 1: *Other topics people would have more reasons to go back.*

Speaker 2: *I think it's a really interesting way though to learn about the topic.*

Speaker 3: *I think if it was more broad then it would be really good for that.*

Speaker 4: *It was memorable.*

Speaker 5: *It was really interactive and...*

Speaker 6: *Like one of those for geography would be really helpful… I don't know what but for something.*

Speaker 7: *Something like that.*

Speaker 8: *Or for Hampton Court.*

Speaker 9: *That would…*

Speaker 10: *That would be really cool".*

Reason 3: navigation slow and quicker to look on other resources.

The researcher attempted to clarify why a minority of participants had indicated that the navigation was slow and the responses indicate that some participants made a comparison between the slowness of the resource compared to other resources for looking up information.

"But like, and also it was a really cool website but it wasn't that quick. You could just find a link which had, I dunno, had like a page of writing. It takes so much time to get from one room to the other.

It can be really long-winded if you're searching for something".

A second example:

"Yeah so, if you were just going to look up a particular dress, [yeah] I'd rather type it up on Google rather than scroll through the whole thing looking in the whole, on the website".

Reason 3: not having time

Examples of relevant quotations are given below:

"Speaker 1:	*If you had a lot of time then that would be nice, but the thing is that it takes quite long to actually log on to it and to do a whole bunch of stuff, you know to actually get to the place that you wanted to do. If you have like, a really broad, you know, time then you could just sort of get lost in it and just like.*
Speaker 2:	*And take your time.*
Speaker 3:	*Yeah, exactly".*

Reason 4: not being given a link to look it up again.

The citations below indicate how not being given a link and the consequent effort of searching for the resource online was a reason stated by a minority of users for not returning to the resource.

"Speaker 1:	*We weren't given a link.*
Speaker 2:	*So I didn't.*
Speaker 3:	*Yeah we didn't have.*
Speaker 4:	*I found it really aggravating.*
Speaker 5:	*If someone had told us there was a link we probably would have looked at it.*
Speaker 6:	*It would have looked it up again.*
Speaker 7:	*I would have looked it up again".*

A second example:

> *"Like Facebook is really easy to get into because it's just Facebook but that you just have to look for it".*

A third example:

> *"You'd have to spend the time looking for it when you can just put something into Google".*

Focus Group 2 (VG)

Neither of the 2 participants who identified as having used VG in the second focus group stated that they had looked for information related to the resource since using it. Their responses are given below.

Table 21. Reasons given for post-use information seeking on the subject at 7-month interval for VG users (FG2).

Table showing reasons given for not seeking further information post-use, and hand-counts taken when participants identified reasons (VG, FG2)	
Reason for not seeking further information	**Number of participants**
Doesn't enjoy game-like environments	1
Remembered a visual experience, rather than information	1
Didn't think about it unless prompted	1

Neither of the participants who had used VG in FG2 went back to the resource in the 7 months elapsed since the initial use of the resource. Their responses are summarised below.

Table 22: Reasons given by VG users (FG2) for not returning to the resource.

Table showing reasons given for not returning to the resource post-use, and hand-counts taken when participants identified reasons (VG, FG2)	
Reason for not returning to the resource	**Number of participants (highest to lowest)**
They would only access resource if the subject came up in school	2
Navigation slow – would find other resources faster	1

Further data from Focus Group 1 (VG)

After the 7-month focus group questions had been discussed, any remaining time was used by the researcher to revisit the questions asked in the initial focus groups. Some of the data is repeated and corroborates that from the initial focus groups, but other data is new at this stage.

Several users were enthusiastic about the system, and especially its "uniqueness" and novelty.

> *"Speaker 1:* *Variety.*
>
> *Speaker 2:* *Sort of unusual.*
>
> *Speaker 3:* *Yeah, impressive.*
>
> *Speaker 4:* *Really unique.*
>
> *Speaker 5:* *I'd never been in a museum like that".*

As in the initial focus groups, a significant minority of participants suggested uses of labelling to indicate where they were in the system/museum, such as written texts and colour coding, in a manner which aided navigation without detracting from the other elements of the design of the system.

A comment which began "you were standing in the room" suggests that this user conceived of herself as participating in a virtual environment.

A minority of comments pointed to limitations in the capability of the system, for example:

> *"Speaker 1:* *And not with all the dresses, some of them you could go quite close to but when you're looking at them from a gallery, you couldn't like, from just standing in the room.*
>
> *Speaker 2:* *Standing in the room!*
>
> *Speaker 3:* *Yeah, you know what I mean. You couldn't go all the way up to them and look at them in detail. Like, it would be good if you could click on a dress and get like a profile, then you can turn it round and things.*
>
> *Speaker 4:* *Could zoom.*
>
> *Speaker 5:* *Yeah, some of them were a bit glitchy.*

Speaker 6: Some of them, but then you went into a gallery and you couldn't look at every single one".

In the words of a minority of participants, positive comparisons were made between using the system and more "traditional" ways of learning such as museum trips or reading a book:

"Speaker 1: I felt like I learnt more doing that than I probably would have had I been there.

Speaker 2: Going on the website.

Speaker 3: Or like reading a book or something".

In 7-month focus group, three users indicating that "going where you wanted" was a positive feature of the user experience:

"Speaker 1: Or like you could go straight where you wanted to straight away so you didn't have to like. In a museum you kind of [people] go past things you aren't really interested in.

Speaker 2: You can go to what you want to see.

Speaker 3: You can go to this, you can say, I don't really want to see any more of that, I'll go back in another room".

An interesting new finding in this focus group was that in a group discussion involving several participants they stated that they enjoyed the fact that they used the system as an individual user which two users described as feeling "exclusive":

"Speaker 1: More focussed.

Speaker 2: Yeah.

Speaker 3: And it was just you. It's just you, so it's.

Researcher: What do you mean by that?

Speaker 4: So you're the only person going through the museum.

Speaker 5: You feel exclusive.

Speaker 6: Yeah, you're exclusive. You're the only one there. So like, I dunno.

Researcher: *So you liked that?*

Speaker 6: *Yeah.*

Speaker 7: *And then you can talk about it, cos you've been, instead of like travelling there and back you can talk about it straight afterwards cos you don't forget it.*

Speaker 8: *You're not influenced by being taken different places by different people. If you go with a group of people, or one person, you might be outvoted to go and see something else instead of going to see something you personally want to see.*

Researcher: *Is that what you meant by "it's more exclusive"?*

Speaker 9: *Yeah".*

Further data from Focus Group 2 (VG)

One participant used immersive language such as "you walked in".

Two participants stated that the revelatory nature of the system involving both progressing towards objects in walkthrough 3D and multimedia information was something that they liked:

"Speaker 1: *I liked that there were some things, like, that you could just see when you walked in, and some things you had to like access, like, click on them, to find out more, so you see the general picture and then like go to something you want to find out more about.*

Speaker 2: *Yeah, I did that. I liked that, that you could see it and then you clicked on it if you wanted to know more, you just moved on. That was nice".*

One participant stated that she liked the videos in VG, and two preferred the videos to navigating in 3D:

"The videos were, like, really interesting, because they were like well structured".

A second example:

> *"Well, when, um, looking at the dresses and the things, it was kind of then, like, everything was quite different to your eyes, and, like, then you clicked on it and then you actually had an image or you had a video, and that was, like, much easier to look at and to take in. I think it was more detailed and more sort of, what we're used to, I guess, cos I'm not really used to this kind of stuff".*

A third example:

> *"Also, I liked clicking around like sort of places it was quite, like, distracting, when you were moving, to like concentrate on all the information, cos you were like moving around and, whereas if there was a video and stuff, you could kind of just like look at it".*

In a group discussion, several participants suggested that the use of colour, especially contrasts, could make orientation easier in the system, since "confusion" was raised as an issue by one participant:

> *"Speaker 1: It was a bit confusing, like how you click, like, I dunno, like maybe, out of the place, or like I just found it a bit confusing.*
>
> *Speaker 2: I think like the colours, not the colours, but I remember going through, like, a corridor and it being like dark or something, and then like the arrow, or something, like, blended in. So maybe, like, the colours between them, the kind of difference…*
>
> *Researcher: Could have been more contrasting?*
>
> *Speaker 3: Yeah, more contrasting. And like, in the rooms, some of the things kind of blended in so you didn't see them as well, like the wall.*
>
> *Researcher: So you couldn't spot the difference between things?*
>
> *Speaker 3: Yeah, like the perspective, it was quite hard with the colours.*
>
> *Speaker 4: And I think you could make it easier to get back to like a central point so you could find your way around.*
>
> *Researcher: Going back to where you'd already been?*
>
> *Speaker 4: Yeah".*

8.2.3 Giza 3D Focus Group Responses

Focus Group 1 (Giza)

0 of 2 participants who used Giza stated that they had looked for information related to the resource since using it. One reason given for not seeking further information post-use, and is visualised in the table below.

Table 23. Reasons given for lack of post-use information seeking on the subject at 7-month interval for Giza users.

Table showing reasons given for not seeking further information post-use, and hand-counts taken when participants identified reasons (Giza, FG1)	
Reason for not seeking further information	**Number of participants**
Forgot.	1

In this sole case, the exchange took place as follows:

> *"Researcher: Anyone else, did you think that you'd like to find out more about anything after visiting it?*
>
> *Speaker 1: Well, when I was, so I went inside the kind of chamber underneath the ground, cos I was doing Giza and I saw a bunch of paintings, well not paintings, but you know like the painted hieroglyphic thingies, um, that I quite liked, and I thought that I should do some research about it later, and then I kind of forgot".*

When asked whether they had returned to the system again, 2 of 2 participants had not done so.

Table 24. Returns to the resource at 7-month interval for Giza users (FG1).

Table showing returns (if any) to the resource after use for Giza users (FG1)	
Returned to: yes/no (number of participants)	**When did this occur?**
No (2)	N/A
Yes (0)	N/A

Focus Group 2 (Giza)

There was just one participant who used Giza, who said at the beginning of the focus group that she had largely forgotten about her use of the system. She had not sought further information on the subject post-use and did not give a reason why.

This user did not return to the resource post-use, either, giving the following reason:

> *"Speaker 1: I think maybe because I wasn't doing anything really about the um, Giza, so I didn't really look back.*
>
> *Researcher: You mean that you weren't studying it in school?*
>
> *Speaker 2: Yeah and I thought, I like, yeah".*

Table 25. Reasons given by Giza users (FG2) for not returning to the resource.

Table showing reason given for not returning to the resource post-use (Giza, FG2)	
Reason for not returning to the resource	**Number of participants**
Wasn't studying the subject of Giza	1

Further data from Focus Group 1 (Giza)

Giza users in both focus groups gave responses when the questions of the initial focus groups were repeated after having covered the new question. Their responses, which largely corroborated findings from the initial focus group, are given here.

One participant found that the navigation was challenging.

> *I found like the navigation quite hard. So, it was just like, um, I sometimes like, to move the camera around was kind of tough. Once I got stuck in like a corridor that I don't think I was supposed to be in. It was really, really long and both sides were closed off and I would go really, really fast, just like, and I didn't know how to just get out. So, yeah, maybe the navigation, um, yeah.*

One participant stated that due to Giza 3D being a "relaxed" environment with fewer "distractions", she thought that she had learned more by using the system than by actually visiting the historic site of Giza.

"Researcher: You said that you felt that you felt that you learned more by using it than by actually going there.

Speaker 1: Yeah, cos like, for instance, you know, there are often great big crowds of people in these really touristy places, and then you have to sort of jump, you know, to be able to see what's going on. It's just like, so it was kind of a more relaxed environment, and also you know, there would have probably been loads of distractions had I been there, for instance, so, there's a mosquito on my arm : quickly kill it. I don't know, I just felt like…

Speaker 2: More focussed.

Speaker 3: Yeah".

Further data from Focus Group 2 (Giza)

The sole participant stated that the resource was most memorable where it communicated visually, and this was the only further data gleaned from this group.

"Researcher (to VG user): It was the visual sort of strikingness that drew your attention? (To Giza user) Would you say it was the same for Giza too?

Speaker 1: Yeah, it was the same for Giza, because there was some information but I don't remember. I just remember the videos that were on there and that was all, the objects".

8.2.4 Group Interview with Teachers

Five teachers took part in a group interview lasting 14 mins, after a presentation of the resources. Unfortunately, due to delays in the school timetable, the slot allocated was much shorter than would allow a valid focus group interview. The length of interview and quantity of data means that the teachers' comments are indicative and cannot form a part of the same analysis as the data gathered in the students' usability questionnaires or focus groups. The content of the interview is summarised below.

1 of 5 teachers noted a change in the pupil's behaviour after using the resource. This teacher noticed the pupils talking about VG excitedly, one week afterwards when she asked them in the art class.

"Speaker 1: Yes, they did, they definitely talked about it, and they talked about… they were excited about the fashion because they did come back chatting about the fashion. Nobody came back talking about Giza. They were talking about you know how gorgeous, and they kept going on about… They did… they carried on.

Speaker 2: It was all about how gorgeous it was. It was how, you know, the dresses were beautiful, they were really interesting. They didn't talk so much about the designs, but they did talk about how they'd been used in films, or, there was that kind of element to it."

Of those who did not notice any change in the pupil's behaviour, three were not teaching at the school at the time, so could not have noticed, while one said that they did not notice because they were not directly involved at the time:

"No, but I'm not sure I could tell you exactly when it was, and therefore and if I would know. Because I wasn't directly involved – I sort of knew it was happening – I therefore would not have been thinking about it."

When the teachers were asked why they thought that some pupils would be so positive at the initial stage and in the focus groups and then perhaps not follow things up afterwards, the following opinions were given by the teachers themselves.

- Pupils' school lives mean they quickly move onto the next thing.
- Looking up information requires too much effort.
- The technology itself may encourage a feeling of immediacy.

The conversation then digressed as the teachers discussed their viewpoints on the 3D digital libraries they had observed and their potential use in education.

One teacher stated that digital technology encourages immediacy and rapid engagement with information. Another teacher thought that digital technology encourages dabbling in different things, and can be superficial. A further teacher stated that digital technology does not encourage further efforts to seek information, while a fourth referred to the kind of learning with 3D digital libraries as surface-level learning. The responses of teachers are based on their opinions rather than on the research findings. As Druin (2002) points out, one's own memories of childhood, as well as pop culture portrayals of teenage life (Dahl 2004) may unintentionally bias practitioners.

On the other hand, all of the teachers stated that they would like to explore a 3D digital library themselves. One teacher stated that the 3D digital libraries appealed because they were novel. Two teachers stated the benefit of the 3D digital libraries would be to view something they would ordinarily be unable to see in the real world – such as artefacts of the Museum of Iraq which are inaccessible due to war and looting, and the dress designs of Valentino which are not all on public display. Three of the teachers discussed the resources' usefulness for accessibility for the disabled or economically disadvantaged. One teacher stated that visiting a 3D digital library would appeal because she would find it less tiring than in real world museums, but another stated that it would not appeal to her because she liked visiting real world museums and disliked looking at a computer screen.

When asked if they would use a similar resource in the classroom, excluding practical considerations, 5 of 5 teachers agreed that they would do so.

All of the teachers stated that they would like to use 3D digital libraries in their classroom. One teacher stated that a benefit would be that a 3D digital library would make learning more tangible and add context for the learners. One teacher stated that a 3D digital library could support individual learning or project work. Another teacher stated that she would ask the students to use it freely and then relate it to what they had learned, and two teachers termed this use as encouraging more "ownership". One teacher stated that he would use the resource as a "way in" or as a "hook" to attract the students to the subject at the start of a topic, while another teacher stated that she would use it as a motivational tool to be used at the end of a lesson. One teacher said that he would also potentially set resource use as a homework task and ask the students to navigate independently.

PART III: ANALYSIS AND CONCLUSIONS

Chapter 9: Analysis

9.1 Summary

The chapter is structured by analysing the data collected for VG and Giza in turn, by analysing the relationship between usability/usefulness criteria and user information seeking behaviour, and then between architectural design and user information seeking behaviour. After the analysis of each resource, common trends and unique trends are summarised.

For each library, data on usability from both usability questionnaires and focus groups has been pre-coded using the thematic HCI heuristic codes identified in Chapter 2. Focus group data has been coded according to architectural thematic codes identified in the literature review in Chapter 3. User behaviour has been coded according to the thematic codes in Chapter 5.

The relationship between HCI heuristics and user behaviour, and architectural principles and user behaviour are analysed in turn. This approach enables the identification of user behaviours associated with specifically 3D aspects of the user experience, enabling us to make conclusions, inferences or suggestions as to the effects of 3D architectural criteria on the user experience.

Common trends across both libraries, where 3D architectural criteria influence user behaviour, are then summarised. Trends unique to each library, by virtue of their different design approaches are then identified. Although these results cannot necessarily be universally extrapolated to all 3D digital library archetypes, this allows the research to indicate which aspects of the 3D architectural design of digital libraries may be effective or ineffective in other scenarios in providing a positive user experience.

A diagram showing the process of analysis is given below, and demonstrates how the chosen process of analysis allows for the isolation of relationships between the user experience and HCI, and then architectural, aspects in turn.

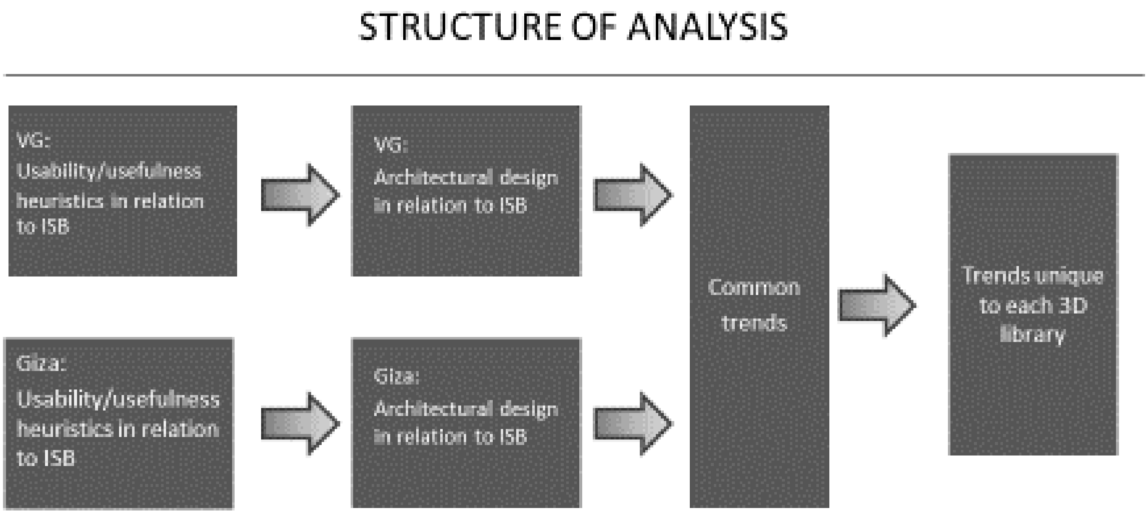

Fig. 43.. Structure of analysis

9.2 Demographic Comparisons

The user group comprised all-female subject group aged 13-15 (22% were aged 13, 75% were aged 14, and 3% were aged 15), enrolled in a southern English private school. They are from an academically selective school, and mostly from wealthy socio-economic backgrounds due to it being a fee-paying school, although some pupils may have received bursaries up to the full cost of fees. The users were at a transitional age between early and late adolescence. Poole and Peyton (2013) suggest that early adolescence takes place roughly from ages 10-14 and late adolescence from roughly 15-19. During early adolescence, the age bracket to which most participants belongs (mostly 13-14 with a small number of outliers aged 12 or 15) cognitive development takes place, with characteristics of this age group including deferring to group opinion, sensation seeking and risk-taking behaviours (Dahl 2004).

The median response of “up to 180 mins” reported online per day for by the user group exploring the Valentino Garavani Museum compares to a reported median response of “up to 120 mins” online per day by the Giza 3D users. These figures are plausible when compared to Ofcom (2013) figures which cite that 12-15 year olds spend on average 17.0 hours online per week (a mean of 146 mins online per day). We can also assume that the young people in question have access to digital technology with none reporting no use. When figures extrapolating the average reported time (following a calculation of each person's reported time on each activity [total reported time online X percentage reported for specific activity] spent doing various online activities per day [calculated using the overall reported time and the percentages given for each activity]), it becomes clear that much of the additional activity online reported by Valentino Garavani users is spent social networking. There may, therefore, be a correlation between interest in fashion and social media use.

The figures given for time spent gaming are lower than Ofcom's (2013) reported figures for 12-15 year olds (7.5 hours per week). The VG participants' 7 minutes per day corresponds to 49 mins per week, and the Giza participants' 3 minutes per day correspond to 21 mins per week. In fact, the figures reported by the participants for time spent gaming, calculated from the percentage of time they cited for this activity X total time they reported online, generate such low averages that the group can be said, as a whole, to only spend a negligible amount of time gaming. Ofcom (2013) reported in 2013 that children aged 5-15 in households from social classes A and B are estimated to spend less time gaming per week (7.3 hours vs. 8.7 for the age group as a whole). This result is also lower than recent research findings that state that boys play video games on average for 1 hour and 37 minutes per day and girls for 49 minutes per day (Kaiser Family Foundation/Rideout *et al.* 2010). Even though girls are expected, according to the cited data, to play video games for less time per day than boys, this figure is still low in comparison to the expected times in the literature. It is also worth bearing in mind that another factor in the reported figure may also be because of the self-reporting required of participants. This may have led to their reporting higher or lower figures, with a lower reported percentage a possibility in the case of gaming: since participants were required to report their time spent gaming as a percentage of their overall time online, if gaming was the activity that they spent least time on, then the reported figure may have been understated.

9.3 Valentino Garavani Analysis

9.3.1 User Behaviour in Relation to HCI Heuristics

The analysis is structured using thematic codes from the HCI literature review. Instances of user behaviour are coded using the thematic codes from the ISB literature review. The applicability of the analysis to all or part of the group is designated using the descriptions "the majority" and "a minority" of participants in either the laboratory scenario, or 1-week or 7-month interval focus groups. In the case that the analysis generates from the data of only one or two participants, this is also indicated.

Efficiency

Petrelli (2008) stated that time spent on task completion was a suitable metric for efficiency. The usability questionnaires indicated that users spent an average of 33.26 mins out of a possible 36 using the resource. However, as discussed in Chapter 2, when this metric was considered, this may not be a suitable metric for a resource where exploration was encouraged.

In the usability questionnaire, the median rating for "the system responded quickly, without delay or error" was 6 on the Likert scale of 1-7, indicating that VG was usable in this respect. A minority of respondents made extra comments which indicated that the group was split when it came to evaluation of the quickness or slowness of the system. As for responses relating implicitly to delays or errors, two stated that the resource was responsive/did not lag, while one noted "lags" at some points.

Loading was referred to as sufficiently speedy by three users while two noted rooms or photographs that had a slight lag on loading. One user said that the system "crashed briefly", another referred to "a few glitches", while another stated that she noticed no errors.

Further data in the usability questionnaires from the "free" responses added context. In trying to execute exploration tasks, one user stated that she kept going "past" objects – or too far, indicating hyper-responsivity of the mouse. Two users also referred to malaise – feeling sick or dizzy as a result of using the system.

We now consider data from within the focus groups that may shed more light on efficiency in relation to the exploration task.

One user considered that VG was more convenient than visiting a real world museum, because access to the resource was associated with being able to talk about it straight afterwards, and because she stated that she was able to remember due to not having to journey to the resource. This coincides with Wilson's (1997) observation that access can influence information behaviour – in this case, immediate interaction with peers to discuss and easier recall of material was enabled by accessibility of the resource in comparison to a real world museum visit.

Another user in the focus groups equated the digital format to less effort expended than within a real world museum. In this case, efficiency is associated with the digital format which reduced the need for the user to make an "effort" (although it is not clear from the context whether that effort involves physical or cognitive effort). As in the example above, digital access is inferred to influence behaviour since it enables easier exploration and may have effects such as more immediate responses to the material.

The focus group data suggests that individual use of the resource was related to a feeling of exclusivity, and to choice and personalisation, and that this resulted in a greater productivity or sense of productivity, as indicated by the following examples. One user associated use of VG with having greater control than in a real exhibition. Here, the resource is said to encourage control, a concept linked by Fisher and Landry (2007) and Weisz and Cameron (1985) to motivation, because it is said, in their work, to increase both the confidence to find out information for oneself and the ability to provide information to others. This factor may hence also be at play in the case of the user, above, who experienced greater convenience with the resource compared to a real world museum visit. She did not have to make a journey and there was no cognitive load experienced with having to hold the discoveries in her head for a long time – both aspects that gave her greater control in relation to her response to the environment, and which precipitated immediate interaction with peers. It would need to be investigated how much perceived competence could have been augmented by the resource.

In a minority of other cases, users made statement that led in the analysis to their being associated with a cluster of themes in the information behaviour literature around empowerment, control, and self-efficacy. Indicative quotes are given below. In one instance, the resource was associated with being able to realise one's own intentions about what you wanted to see – an example of productivity in relation to the user's "motivated intention" (see Nahl 2007) of intending or "wanting to". In another instance of contrast with a "real world museum", user productivity – going where one wanted straight away – was contrasted with having to go past things that were not of interest, another apparent example of productivity in relation to the user's motivated intention. In another instance of contrast with a "real world museum", one user felt that she was able to see what she personally wanted to in VG rather than seeing what the group wanted (which was not necessarily what she wanted as an individual) – an element of control and self-efficacy.

> *"Speaker 1: You can go to what you want to see.*
>
> *Speaker 2: You can go to this, you can say, I don't really want to see any more of that, I'll go back in another room" (7-month focus group, VG)*

"Or like you could go straight where you wanted to straight away so you didn't have to like. In a museum you kind of go past things you aren't really interested in." (7-month focus group, VG)

"Speaker 1: And it was just you. It's just you, so it's.

Researcher: What do you mean by that?

Speaker 1: So you're the only person going through the museum.

Speaker 2: You feel exclusive.

Speaker 1: Yeah, you're exclusive. You're the only one there. So like, I dunno.

Researcher: So you liked that?

Unidentified speaker: Yeah.

Speaker 3: You're not influenced by being taken different places by different people. If you go with a group of people, or one person, you might be outvoted to go and see something else instead of going to see something you personally want to see." (7-month focus group, VG)

All of the above instances suggest that the user perception of control can be influenced by source attributes (see Wilson 1997) such as accessibility (in comparison to real world museums) and the facility to explore as an individual, and that this increased control could better allow the user to accomplish what they want to and perhaps also influence their feeling of self-efficacy and ability to pass on information to others.

Productivity in accomplishing exploration tasks was frustrated by going somewhere unwanted in a significant minority of cases in the focus groups. While not so much a "delay or error", the sensitivity of the system or the difficulty in translating user input to the precise orientation envisaged clearly does impinge upon efficiency and navigation. In three cases, frustrations in orientation related to the user's going in a different direction to where she wanted to go. For them, the lack of efficiency in orientation style is thus related to frustrated information behaviour. Examples of this in the focus groups include four examples of a user's clicking somewhere, which resulted in going somewhere unwanted. In a further example related to orientation, a user was not able to see objects that were off screen as a result of the orientation style, thereby clarifying that efficiency in exploration was reduced and the usability frustrated the user's viewing intention. Two users in the focus groups stated that the resource kept moving even when they wished to remain still. In the focus group data, going "too far" led to a feeling of "annoyance". Finding yourself where you did not want to be was related in two instances in the data to an affective experience of confusion.

It is therefore suggested that the lack of efficiency in orientation in VG related to frustrated information behaviour, and sometimes also to affective accompanying emotions such as annoyance and confusion. The role of orientation was not explicitly addressed in the original thematic tables compiled to identify aspects and mitigating influences on user information behaviour, but it is suggested that in a 3D walkthrough environment this is an important intervening variable on the exploration of information and user enjoyment. This is an important consideration because enjoyment can affect the motivating intention (Nahl 2007) and increased or reduced enjoyment may affect time spent searching (Zillman 1988).

Other elements of orientation appear to have resulted in counter-intuitive or unexpected outcomes for users. In the system, clicking resulted in going, whereas one user noted that in other programs, such as *Google Maps*, clicking can be expected to result in dragging an object – clicking to go thereby resulted in a user frustration, which indicates the role of usability aspects in mediating the information seeking experience in the VG environment. This unexpected element of input and resultant movement was related by one user to feeling disorientated. The challenges associated with efficient exploration were not associated with clicking on the dresses, since this aspect was regarded as unproblematic, but rather to orientation through the 3D space. As an alternative to clicking, one user suggested that using the keyboard as an input device would be "easy". Preference for keyboard navigation over mouse navigation was also stated by one respondent to the usability questionnaire. The users above cite unfamiliarity with orientation system. As McCreadie (1998), Nahl (1998), Wang and Tenopir (1998), and Wilson *et al.* (2002) indicate, experience level with steps involved in search may affect motivation.

In summary, the examples above suggest that familiarity of orientation style may also effect the user's motivation and enjoyment of the system. Fitzmaurice *et al.* (2008) suggest that difficulty using navigation tools can arise either from users' lack of knowledge or from poor design of the tool itself. It is also known from previous research that when users have less experience with the steps involved in navigating, their motivation may be effected (McCreadie 1998; Nahl 1998; Wang and Tenopir 1998; Wilson *et al.* 2002). For a minority of users for whom 3D orientation caused unpleasant physical feelings, reduced enjoyment may also have occurred, which would also probably have influenced their desire to explore. It is perhaps unforeseen in non-3D navigation that productivity could be mitigated by unpleasant feelings related to dizziness, as it did in two instances in the data. Agosto (2002b) suggests that physical discomfort may influence a user to cease information seeking, although the data here does not suggest that this occurred – only that a minority of users found 3D navigation physically unpleasant.

As another consequence of 3D navigation, the system could be perceived to be slow, which resulted in a delay in the execution of user intention, albeit one which was deliberately built into the system, as the following examples indicate. Movement (walkthrough) was considered slow by three users. A hypothetical quicker website was preferred by one user. The perceived slowness with which a user was able to progress in this way through the system was related to their impression of taking a long time to move through the system and, in one case, to going slower than was desired. One user related going too slowly feeling of frustration. Progression through the system was related to a long time investment by one user.

The role of the slow progress through a system associated with 3D walkthrough orientation is not explicitly addressed in the compiled themes influencing information seeking, but the examples above indicate that it is an important variable for a minority of users in VG. This is important because the success of interactive design elements such as “play, interactivity, control, narrative and flow” may affect enjoyment, and as has been previously stated, enjoyment may affect time spent searching (Zillman 1988). The speed of progress which was related to an overall longer time investment by one user is also relevant, because Wilson (1997) suggests that the cost of the value of time may, citing Stigler (1961) affect effort spent in searching. This could represent an interesting paradox for 3D digital library designers, since effectiveness is defined as the degree to which an interface helps users to achieve tasks as they were intended (Rubin and Chisnell, 2008), and it is arguably the case that the “inefficiency” associated with 3D exploration is sometimes intentional as the means of accomplishing the intended task of 3D exploration of the space and information contained within.

A number of examples below contain indicative data about how the presentation format (see Wilson 1997; Bettman and Kakkar 1977) can influence information acquisition strategies (Bettman and Kakkar 1977). One user stated that the manner of display of dresses in a gallery configuration gave them an experience of clarity. The visual nature of the content and large quantity of contents was related, by another user, to her being able to see whatever she wanted to see *in situ*. Another user said that this was an interesting way to learn. This cluster of examples, representing a minority of users, may suggest that the manner of displaying "all at once" had successful outcomes for the cognitive experience of information seeking.

For one user, wanting to look at and experience everything was weighed against the consideration of the time required to do so. For another, the quantity of content within the system did not allow her to see it all within the classroom session. In another instance, the experimental time limitation was related to not being able to look around everything that was desired, despite trying. Following three examples in the focus group data, above, the quantity of information in the system resulted in the system taking longer to explore, and this was weighed by these users against the consideration of time limit expiration (see Agosto 2002b; Wilson 1997; Cameron *et al.* 1994), an effect of the experimental conditions.

Clickable objects which allowed access to further information (as opposed to an ordinary museum where the objects cannot usually be interacted with to generate further information) were related by one user to curiosity and to exploration, and by another to feeling "involved" and interested. This example of interactivity within the system suggests a number of things. Interest is thought to precipitate curiosity (Silvia 2006, 2008). Exploration, too, which Bruner (1973) relates to the process of connecting ideas, is also thought to precipitate curiosity. The user's indication of "involvement" may implicate the notion of active learning (see Sharp *et al.* 2007). Hence, in this small gobbet of data, there are suggestions that interactive clickable information is a form of active learning which encourages exploration behaviours. Both the cognitive process of connecting ideas and the stimulation of interest may relate to increased curiosity.

Effectiveness

In the questionnaire, effectiveness related to the question "when looking for information during exploration, I was able to find what I was looking for". Effectiveness is implicitly related to how well the system facilitates information goals.

A minority – 17% - affirmed that they had tried to look for specific information while browsing VG in the usability questionnaire. The median figure of 5.5 on the Likert scale of 1 to 7 indicated no problems for these users in finding what they were looking for.

A significant minority of users described effective cognitive information seeking processes. The visual mode of communication of the resource was related by one user to visual cognition, and one user described the visual mode as appropriate to the subject matter. This form of display would seem to correlate to a browsing search behaviour (see Sharp *et al.* 2007; Ellis *et al.* 1993; Ellis and

Haugan 1997; Bilal *et al.* 2008), since it does not neatly fit with Wilson's (1997) descriptions of the categories of passive attention, passive search, or active search.

Use of colour played a communicative role when the user entered the system, with use of the colour red related to two users' recognition of Valentino's branding. A user that did not have prior knowledge of the prominent use of the colour red in the designer's branding was unable to identify significant information to identify the content of the museum at the entrance.

As well as browsing, information seeking behaviours were evident among a minority of users. In the usability questionnaire, one user said that she found it easy to find out who wore the dresses and when, reporting that she found it easy to locate this information. This user conducted an "active search" (Wilson 1997). Users thus describe browsing behaviours with visual cognition and recognition, combined with instances of active searching (Wilson 1997) punctuating the browsing search.

A minority of users sought information when using the system by moving towards an object but they were unable to – an HCI limitation. For example, the display of dresses in the galleries also related to an instance of a user wanting to get closer and see detail, to click for extra information, or for another to rotate the dress, but being unable to do so – since these facilities were only available for select dresses within the system. Another participant stated: "When I tried to look at the back of a certain dress, sometimes the model would 'turn around' to face me again so I could never see the back of the dress". In the examples above, the motivated intention (Nahl 2007) was frustrated by a system attribute that limited the provision of choice (Brophy 1986), which, we suggest, conflicts with the curiosity induction (Brophy 1986) brought about by the associated component.

Two further examples also suggest that presentation format (see Wilson 1997; Bettman and Kakkar 1977) can influence information acquisition strategies (Bettman and Kakkar 1977). For one user, clicking was associated with going towards the thing she wanted to see. Her experience combines both display and an interaction technique. The presentation format of objects in a gallery set in train a strategy of moving towards objects of interest, while the action itself corresponds to Mackinlay *et al.*'s *point of interest (POI)* interaction technique, whereby the user must first choose a destination point, before the camera starts to move towards their chosen point.

In another case, dresses presented as objects with dialogue boxes with extra information when clicked was related to a process comprising the following steps:

(1) walking in and perceiving the object,

(2) wanting to know more,

(3) a clicking action,

(4) finding information,

(5) moving on.

This elicited a positive response from the user who undertook these steps. This feature was compared favourably to being an exhibition (where information format would not be as closely associated with such information seeking processes).

The process described by the user who interacted with the dresses with clickable information appears to indicate: "walking in" as a first person symbolic act of presence (Dickey 2005) before perceiving the object. This 3D exploratory interactive experience seems to most closely equate to the notion of "browsing", whereby the user "browse[s] through information, allowing it guide [her] attention to interesting or salient items" (Sharp *et al.* 2007). The user then experienced a "motivated intention" (Nahl 2007) to know more which led to an engagement. Once information was encountered, it is implied that the user experienced a feeling of satisfaction, which Kuhlthau (2004) associates with the search closure. "Moving on" implies that the process is then repeated with possible encounters with further information artefacts. (An information artefact consists of "a conceptualisation of objects in the experienced world which has the purpose of revealing some information about the underlying objects to some users" [Benyon n.d.].)

In another case affirming the notion of browsing, one user stated that she looked around to see what there was, in a fashion she described as "random".

The encounter of information in the system appears to have brought about discoveries on the part of users. For one user, the grouping of dresses into three chronological periods (arrangement by subject) was related to the user's recall of the information according to this categorisation. In another case, the presentation of information on a timeline, with pictures of dresses in context, was related to "seeing how" and learning. Another example in the data citing noticing, clicking, and visual exploration, led to the user's "realisation" of changes over time – this providing an example of discovery (Tieben *et al.* 2011; Korhonen *et al.* 2009). We suggest that these examples of "discovery" involving realisations thus involve making patterns, as is key to the theory of Bruner (1973).

New discoveries are suggested by Tieben *et al.* (2011) and Korhonen *et al.* (2009) to play a role in precipitating further curiosity, and we suggest that the data does indicate that discovery may have precipitated further curiosity. Seeing the content of the library was related by one user to wanting to see more and know more. For another user, exploration of the system was motivated by the wish to experience all the content. The layering of information such as dresses with interpolated drawings and close-ups was related by one user to "actually" seeing, to knowing more, and to increased interest.

The first two examples above report a motivated intention to see and know more, brought about by encountering or exploring the 3D digital library. This suggests that motivated intention not only implicated curiosity as an unlearned factor (Morgan and King 1971), but that processes involved in exploring the library may have precipitated curiosity. Both "exploring" and "discovering" are associated with spurring curiosity by Tieben *et al.* (2011) and Korhonen *et al.* (2009). The third example associates discovery with "interest" which is thought to precipitate curiosity by Silvia (2006, 2008). Interestingly, Berlyne's (1960, 1967, 1971) distinction between "sensory" curiosity, for novel sensations, and "cognitive" curiosity, a desire for more knowledge, suggests that both may be implied in the curiosity posited at this point of exploration.

Some information was communicated textually, and while text style is discussed under "aesthetic appearance", the effectiveness of text as communicator of information was discussed by a minority of focus group participants, mostly in relation to quantity of text. The quantity of text was thought to be acceptable by a minority of users, with one user in the usability questionnaire stating that she encountered "short, informative and interesting sentences". One user thought that there was "quite a lot" of writing and expressed a preference for less. Not having "too much" text to read was received positively by one user and it was related to a lack of boredom by one user. Additionally, in the usability questionnaire, one user said that they found the limited quantity of text made her less likely to be distracted or bored. For one user, less text related to a higher self-assessed likelihood of reading the content.

The above examples suggest that in the VG 3D digital library, less text was more effective since in one case it related to interest, in two cases to lesser boredom, and in another case to a higher likelihood of reading. Boredom, which relates to not finding a site engaging (Agosto 2002b) can be related to the decision to cease information seeking. Agosto (2002b) also states that "information snowballing" (being overwhelmed by information presented) can also be associated with stopping information seeking.

In contrast, for one user, visual elements were more associated with holding the user's attention than text. For another, pictures and movement, rather than written information, were associated with remembering. For another user elements such as photographs, dresses and videos were associated with looking and remembering. One user associated videos with high memory retention.

Visual communication, such as pictures, objects and videos were associated by three users with remembering, and by one person with greater attention than encountering a text. This may relate to Wilson's (1997) and Kari's (1998) notion of "passive attention", whereby listening or watching activities may result in information acquisition" (Wilson 1997). According to Heinstrom (2006), attention may affect motivation.

A significant minority of participants recalled watching videos in the Interview Room during the 1-week interval focus groups. A minority of these recalled watching the video entitled "Creating Couture". For one user, the video title sparked an interest while browsing through the video options, leading to the selection of that video to watch. The display of information about the design process in "Creating Couture" was related to progressing through the information and media content. One user considered that the video was well-structured, and this related to her interest. One user related this to a feeling that they were "going into" the information, and a feeling of the video being "personal".

"Creating Couture" was an effective video resource. The title of this video prompted cognitive curiosity (Berlyne 1960, 1967, 1971) for one user. Visualisation, while only commanding "passive attention" (Wilson 1997) nevertheless created an encounter (Tieben *et al.* 2011; Bruner 1973) involving the use of narrative (Sharp *et al.* 2007), which would therefore have involved a cognitive experience of discovery (Tieben *et al.* 2011; Korhonen *et al.* 2009). The success of this video may have been due to effective source characteristics (Wilson 1997), such as structure, and angles which suggested a "first person symbolic presence" (Dickey 2005), which may have correlated with interest and even "self-concept" (Wigfield and Karpathian 1991) in the sense that the viewing experience was described as "personal".

A significant minority of users wanted controls on the videos allowing them to start, stop and skip to a new part of the video. Lack of controls on the videos were associated with two users being unable to realise the intention to go forward or back to a desired point in the video, or for another to stop. For one user, the hypothetical provision of controls on the videos were associated with the user's ability to choose to which point they went in the video. Motivated intention was thus frustrated by lack of video controls, and provision of controls associated with control (see Fisher and Landry 2007; Weisz and Cameron 1985).

In one instance where efficiency could be said to impinge upon effectiveness, one user stated that moving around the system was related to difficulty in concentration on information. Another user thought that video information was related to ease of viewing and absorption of information more than 3D visualisation or movement. Finding specific information was related by one user to the necessity for the actuation of a specific series of steps. One user sought a specific video while in walkthrough mode and had difficulty in finding the specific information. Another user related finding specific information within an area of the system to a long search, and to the experience of uncertainty in how to get there. One user in the usability questionnaire stated that she was looking for the collection "Rosso Valentino" but she was unable to locate it immediately, instead having to go through all of the collections to find it. Two further users did not know how to go to a specific area ("Catwalks"), with one user asking a fellow pupil for instructions. One user stated that in a search for specific information, a search engine was preferred over the resource. A minority of users suggested the addition of a search box to retrieve a specific object. For one user, lack of search box was related to difficulty in retrieving specific information from the system.

The 3D navigation in walkthrough mode was related by one user to reduced attention, which according to Heinstrom (2006), can affect user motivation. This is contrasted with the success of videos in commanding the user attention (see above). As a system attribute, this may come about because of the necessity of actuating steps in the physical space in order to locate information. "Active search" (Wilson 1997) was therefore harder when the user had to take steps to navigate in the 3D space. This experience related to spending longer searching and delayed search closure, or satisfaction (see Kuhlthau 2004; Bilal *et al.* 2008), and may relate to the negative emotion of uncertainty. In one case, this experience of uncertainty was connected with taking steps to resolve the negative emotions (i.e. asking a peer), a typical response noted by Tieben *et al.* (2011) and Kuhlthau (2004).

Aesthetic appearance

In the usability questionnaire, users were asked to rate their level of agreement with two statements relating to traditional HCI notions of aesthetic appearance: "Text type and font size are engaging and readable" and "Colours, graphics, and icons have been used appropriately".

When asked to rate the text type and font size as "engaging" and "readable" the questionnaires yielded a median answer of 6, indicating system success for this metric. Although the usability questionnaires indicated that the text was readable, in the extra questionnaire comments, one user indicated that the italics were harder to read. A minority in both usability questionnaires and focus groups stated that text size in VG was considered small and was disliked. The focus group data shows that in one case text that was too small was related to physical strain in trying to read it, and for this user this strain was related to an affective experience of frustration. In the usability questionnaire, one user stated that the small font size meant that the text was unreadable, while another stated that the small font size resulting in her having to “walk” closer to read it.

The font size, which a minority of users found too small occasioned a variety of responses to the difficulty in reading. One user experienced physical discomfort and frustration, which, Agosto (2002b) asserts (in other cases) may go on to influence ceasing the activity. The decision by another user to move closer to see the text may have been influenced by other intervening factors of motivation, such as, but not limited to, perceived ability or information need.

Eight users in the usability questionnaire referred positively to graphic aspects of the font style: five made positive comments, one stating that the colour was good, another that it was clear, two remarking on the good effect of font style, with one of these stating that it was stylish, and one stating that the font was appropriate to the branding of the system. Two users in the usability questionnaire considered that while the font size was readable, it was “not engaging”. In the focus groups, one user disliked the use of white writing on a black background. By another user, dark text on a white background was (hypothetically) related to readability. One usability questionnaire respondent related the colours to a feeling of boredom, along with two other users who cited lack of engagement with the text may have influenced the decision to engage with the written work in the system (see Agosto 2002b).

In the usability questionnaire, the median rating of 7 in response to “Colours, graphics, and icons have been used appropriately”, indicates that VG was very successful on this metric. One user stated that the system was beautiful, while five stated that use of colour was effective. One participant thought the atmosphere of the whole resource was futuristic, and another that it was elegant and classy. Two users stated that they loved the dresses, one of whom stated that this made the system more life-like. One user stated that the red colour throughout the system “stood out” and this was related to the user’s noticing it. This is an example of “attention” which may increase motivating intention (Heinstrom 2006).

Appreciation of the aesthetic elements of the system suggests enjoyment, which may also increase motivation (Wilson 1997). Furthermore, the use of vocabulary such as “elegant”, “classy” and “impressive” could suggest a degree of “gratification” involving values reinforcement or association with personal interests, which could also increase motivation (Wilson 1997). In addition, "novelty" or uniqueness may also precipitate curiosity (Tieben *et al.* 2011; Garris *et al.* 2002). The word "lifelike" could indicate a sense of presence or narrative, all of which notions come together as ideas associated with enjoyment, curiosity and motivation.

Terminology

The questions measuring terminology in the usability questionnaire were: "The terms used to label the menu functions are understandable" and "The menu functions are logically related". All of the data for this question comes from the usability questionnaires since data relevant to terminology was not found in the focus groups. The median answers for both questions were 6, indicating that the terminology was successful.

One user stated that the understandability of the headings made it easier for her to find specific information. One user stated that every room was labelled clearly. However, two users thought that the descriptions on the menu were not fully explanatory. One user stated that the terms used were only understandable to people with prior knowledge of Garavani, which meant that she did not understand them.

System configuration, in this case involving terminology successfully applied, relates to the user behaviour of selecting resources to be used (Choo 2000). However, the user who did not know much about Garavani suggested that the labelling hindered her identification of possible resources (Choo 2000). The case where menu labelling was felt to be not fully explanatory equates to an experience of ambiguity (Gaver *et al.* 2003). This may set off steps to resolve the negative emotions associated with uncertainty (see Tieben *et al.* 2011; Kuhlthau 2004).

Navigation

Navigation was probed in the usability questionnaire by asking users to rate agreement with the statement "Orientation is straightforward", with a related metric of "steps required to complete" tasks in navigation. The median rating for this question was 5, which indicates a navigable system but with a score that is comparatively lower than for other usability questions.

Navigation and movement through the system was described by one user as similar to a video game such as Minecraft. One respondent in the usability questionnaire liked this feature, as she wrote "I like walking whilst also being able to look round at the same time! Like minecraft [*sic.*]!" Game-like navigation was associated by a minority of users in the focus group with difficulty of use and of comprehension, for example:

"Speaker 1: *I think I didn't link it back to this as much because it find it quite hard. I'm not very good on like a computer when you're looking at these things – I find like, not perspective, but I find it quite hard just to look at. My brother's quite into like gaming and lots of things like that and I just find it quite hard to look and like understand. So I think I don't, I didn't really, it's not something that my brain really settles that well with.*

Researcher: *So you meant that the fact that you felt it was a bit like a game it didn't really connect with how you, maybe, would learn?*

Speaker 1: *Yeah, I find it quite hard to look at like a screen. Like, you know, I'm not sure if you know, my brother plays* Minecraft *quite a lot, and he's like "[name], look at this" and I don't enjoy like the whizz of here and of being there. I found it was a bit too similar to that." (7-month focus group, VG)*

Walkthrough navigation was a source characteristic (Wilson 1997) of VG. The comments of a participant who was familiar with *Minecraft* on the one hand, and the difficulty in use and comprehension associated with video games by two users, may warrant investigation as to whether familiarity with the type of navigation – and therefore experience level with the steps involved in search in the terminology used by McCreadie (1998), Nahl (1998a), Wang and Tenopir (1998) and Wilson *et al.* (2002) may have affected users' motivation. Lack of experience with computer games, which was also evident among the demographic as a whole, may also act upon information seeking success.

In VG, 3D orientation relied on using the mouse to click to navigate. Six responses in the usability questionnaire referred to difficulty in getting around in general with one user stating that she did not like walkthrough, and another stating that the mouse navigation was difficult. Moving to the focus group data, navigation was associated with a feeling of frustration by one user and a feeling of tedium by another. One user in the questionnaires stated that it was very easy to get around, on the other hand.

Orientation was not always straightforward, as respondents in the usability questionnaire indicate. A significant minority of responses in the usability questionnaire noted that the system did not do what she wanted it to do or they had difficulty in doing what they wanted to do. Two users stated that it was difficult to turn and change directions. One response noted getting stuck: "I would find myself looking up and at the museum with a wonky angle and I didn't know how to get out of it". One respondent in the usability questionnaire reported a similar instance of "getting stuck".

Difficulties in 3D orientation were associated with frustration in executing the motivated intention. The associated experience of frustration and tedium may have impacted upon motivation or further information seeking.

Two users in the usability questionnaire found it hard to get back to different points in the system. One user stated that she felt confused when she tried to return to a place that she had been to before. The entrances to the rooms were associated with taking a long time to exit by one user. In the 7-month interval focus group, difficulty in navigation was cited by one user as a reason for not going back despite wanting to. Another user stated that they would have a preference for going back to watch the videos but not to navigate through the rooms. In another instance, difficulty in navigation was related to user acceptance insofar as it was considered not to make the whole experience negative.

Navigation style (walkthrough by clicking the mouse) was associated by two users with a rather cumbersome experience of, for example, exiting a room or getting back to a place previously visited. This introduced “complexity” (Garris *et al.* 2002) to movement through the 3D system, and was related to an experience of confusion. After the initial use, this degree of complexity frustrated the motivating intention to go back since it resulted in the user deciding not to re-engage with the resource. 3D navigation is therefore posited as a mitigating factor in motivation to use VG. However, another user seems to have striven, or persisted (Nahl 2007) in her use of the system despite recognising the difficulty, and this may be because other factors had a positive influence on her motivation.

The menu tool was evaluated as “helpful” by one user and was associated with a feeling of relief. One respondent in the usability questionnaire stated that this tool made it easier to get around. One focus group participant stated that the menu tool nevertheless resulted in going where she did not want to go. For one user, the menu tool enabled the location of sources (see Choo 2000) and a feeling of relief. We therefore associate it with the sense of relief and feeling of satisfaction associated with search closure (Kuhlthau 2004). Potentially, a map has the effect of reducing the negative emotions associated with uncertainty during 3D navigation by providing a means of search closure which ends the process of information seeking (see Kuhlthau 2004). For one participant, using the map brought about a closure but not a successful location of the information required, a situation that Kuhlthau (2004) associates with a feeling of disappointment.

A significant minority of users went on to suggest that map tools, or alternative ways of navigating as a supplement to 3D navigation, would be effective. One user suggested different navigation tools to ameliorate the orientation experience. A hypothetical "reset" button that would allow the user to go back to the entrance was suggested by one user in order to ease orientation through the system. Two users suggested that the interface could include a map tool for navigation while another suggested an alternative function whereby the rooms that the user had already visited were highlighted using colour coding. One user compared existing list navigation unfavourably to the provision of a hypothetical map tool. One user related the provision of a hypothetical map in the corner to being able to tap, and to actualising the intention to go back to an area already visited or to going straight to a section. The hypothetical provision of a map was associated by another user with increased ease of use and quicker access. Two users suggested colour coding for the rooms so that they changed colour if the room had already been visited. The colour coding of rooms would be related to improved location awareness in one users' estimation.

Learnability

Learnability was measured in the usability questionnaire by asking the participants to rate their agreement with the statement "steps I took during exploration were understandable". In the usability questionnaire, the mean rating was 6, indicating that the system was usable in this respect.

In the usability questionnaire, one user stated that "sometimes you get mixed up which way to move the cursor". Two users stated that the response of the system to their movement went the opposite way to that which they would find intuitive. Three users in the usability questionnaire found steps during exploration confusing and hard to understand. Specific challenges to learning how to orientate through the 3D space included, for a minority of users, use of the mouse as input device and the movement achieved by clicking. In the usability questionnaire, one user stated that 3D exploration was difficult to get used to. In the focus group, cognitive learning of the steps required in orientation "took a while" for one user.

A minority of users tolerated the time required to understand steps required for exploration. In the usability questionnaire, one user stated that steps during navigation were easy so long as one learned how. The acceptance of minor navigational challenges was, in another instance in the focus groups, related to tolerance of the time needed to learn how to navigate. Learnability investment was tolerated in another instance: it was cited that the steps required in orientation would not impact on the decision to return to the system.

Learning how to orientate was related to an affective experience of confusion. This adds to an emerging insight on the relationship of HCI to ISB, whereby orientation can introduce uncertainty which may militate against motivation in the information seeking process. Time investment was also a factor in learnability, but three users stated that learning to use the system was an acceptable use of time, and in one case the assertion was bolstered by a declaration that it did not affect the motivated intent to use the system again.

Relevance

Relevance impinges both on the relevance of the resource to its purpose and to whether users would use the resource, or similar resources, in practice.

Relevance of the resource to purpose was discussed by a significant minority of people within the focus groups. For a minority, relevance related to interest in the subject matter. Several users stated that they found the resource interesting. For a minority of participants, having an initial love or interest in Valentino or fashion design was related to an expectation that the resource would be good. For one participant, knowing someone else with an interest in Valentino was related to having an interest in the resource. One user was motivated to use the system in the first place by curiosity about the visualisation of the content in the system. For another participant, having the highest degree of interest in that resource of the three offered during the experimental scenario was her cited reason for selecting the resource. One participant stated that she would not use the resource again because she had a low interest in the subject. The resource was received positively by one user because its content was said to differ from the learning subjects of the school curriculum. One user reported low initial interest in the subject of VG and relating this to their low motivation.

One user stated that she thought it was of interest because of the all-female gender of the user group. The lack of a comparison group of male participants in this study limits its scope to discuss the role of gender in resulting in the findings reported, but the statement about the initial choice of VG among the majority of participants may have some basis in observable trends. The largest number of questionnaire responses pertained to the VG user group, and it is suggested that gender as well as age may have influenced the group preferences. In a marketing study, O'Cass (2004) found that fashion clothing "involvement" is significantly affected by a consumer's gender and age – female and younger participants were more likely to be involved in fashion. The construct of "involvement" is defined as the "extent to which the consumer views the focal activity as a central part of their life" and as "a meaningful and engaging activity in their life" (O'Cass 2004).

Initial interest in the subject of the resource, indicated in the usability questionnaires, increased expectations of the resource. Original interest was determined by individuals' general interests, lifestyles and motivational states (Kracker and Wang 2002; Nahl 2005; Nahl-Jakobovits and Jakobovits 1985; Johnson and Macrae 1994; Wilson 1997). It is not confirmed but the initial choice of VG, by far the most popular in the girl's school, may have been influenced by factors such as gender (Knobloch-Westerwick and Alter 2006; Shamo 2001), femininity of the school environment

(Hofstede 1980), or the desire for approval or status (Morgan and King 1971). However, the choice of three resources created an experimental context which constrained the range of users' options which meant that not all users would have expressed an interest "in the wild". The choice is moderately true to life in the school context, although fashion represents a subject area where personal interests may overlap with curricular interests to a greater extent than in other fields. Low initial interest seems to relate to low motivation.

A minority of participants discussed the relevance of the resource, or similar resources, to learning. One respondent in the usability questionnaires stated that she learned a lot using the resource and thought that it was a useful learning resource about Valentino. In the focus groups, a hypothetical 3D digital history museum was related to being able to remember content and to learning by doing. Two users suggested that a hypothetical 3D digital library on "Hampton Court Palace" would support ease of use and improved learning. One user suggested that similar resources based on geographical subjects would be helpful.

Compared to non-digital resources, two users considered that they had learnt more using the resource than had they gone to an equivalent exhibit or read a book on the subject. One respondent in the usability questionnaires said that VG was more interesting than "just pictures and writing". One focus group participant indicated that after using the resource she knew more and was more engaged with the subject matter. Two users stated that they had increased knowledge after using the system and two stated that she had increased interest in the subject. One user stated that use of the system would influence her purchase interests.

Sharp *et al.* (2007) suggest that the design of 3D interactive systems, with guided pathways, and dynamic linkages of concepts, can support exploratory interaction and active learning. This is corroborated by the users' insights related in the above comments, with "learning by doing" clustered around other attributes such as visual historical or geographical learning scenarios. Furthermore, the resource is considered more engaging and interesting than written texts – a factor that may have spurred curiosity and motivation in the learning process. As Bekele (2010) and Jones and Issroff (2007) state, motivation is a factor which is crucial to the success of online learning environments.

Sense-making and knowledge construction are a key feature of several information seeking theories we have considered (e.g. Kuhlthau 1999; Dervin 1983). "Ease of use" and remembering (related to "attention" and possibly also the cognitive and affective value of the stimulus [Heinstrom 2006]) suggest that learning in such 3D contexts involves the "scaffolding" of learning materials in a contextual learning environment, to support sense-making. Scaffolding is defined by Sawyer (2006) as the support given during the learning process with the intention of helping the student achieve her learning goals.

One user indicated that the information content in the system was satisfying, resulting in not feeling the need to seek more information after using the system. For another user, a perceived sufficiency of the time allocated in the lesson for browsing was related to the user's satisfaction and hence not perceiving a need to go back. In these two cases, search closure was precipitated by a feeling of satisfaction (Kuhlthau 2004). For these users, not returning to the resource could have occurred because this satisfaction related to an ending of cognitive curiosity (Berlyne 1960, 1967, 1971) which reduced the motivating factor to return.

Several participants compared the resource to a traditional textbook, indicating that the learning style differed due to its 3D nature. For one user, the resource was differentiated from a textbook by virtue of its enabling moving through a space and "seeing". The fact that the resource differed from a 2D written experience was associated by one user with learning for its own sake, by another with immediate learning, and by another with the absorption of information, rather than with the extraction of information associated with homework tasks.

At the 1-week focus group interval, one user stated that she would return to the system in order to look at the content and absorb more information. The relevance of the resource as a tool prompting future information seeking (an indicator of ongoing motivation) was suggested in three instances in the data where users engaged in information seeking after using the resource, as a result of using the resource. One user was curious about photographers featured in the resource and sought this information on *Instagram*. Another user later sought information on fashion and dresses on Google as a result of using the resource. Another user made a note to herself while using the resource which prompted her to seek further information at a later date. For one user, information encountered while reading or flicking through magazines and seeing high fashion elsewhere prompted a remembrance of using VG.

The above three examples indicate the pivotal role of curiosity in ensuring ongoing motivation. The types of searches undertaken involved active searches (Wilson 1997) in two cases of actively seeking out information on *Instagram* or *Google*. In one case, the research behaviour of taking notes on facts and ideas, associated by Kuhlthau (2004) with pre-focus exploration, prompted a later search, which could be characteristic of an "ongoing search" (Wilson 1997), whereby an active search has set out a basic framework, but occasional continuing search occurs to expand the searcher's framework. Although only one instance in the data, this case indicates an ongoing process between taking the note during exploration and later searching to expand or settle the matter raised during exploration. The final example of flicking through magazines and serendipitously encountering relevant information could be indicative of Wilson's (1997) conception of the passive search.

A significant minority of participants also had views as to whether they would use the resource or a 3D digital library in practice. One user had a positive disposition to hypothetical systems containing content related to other fashion designers. The perceived suitability of 3D digital libraries to displaying chronological information resulted in one user expressing an interest in a hypothetical 3D digital library on a history subject. In the usability questionnaires, three respondents stated that they would prefer to see a real life exhibit, while another stated that she would not ordinarily choose to use such a resource.

Two users suggested that they would only use a 3D digital library if it had broader content and subject matter. Relevance of any resource to future use was, by two users, predicated on its containing information that the user needed to know about or with the subject being studied in school. One user stated that she would only use the resource again if prompted by a third party. A hypothetical return to the system was, by a minority, related to having a reason to do so, such as an information need, or, specifically for one participant, to an art-related information need.

The responses in the above paragraph indicate that without "relevance", an aspect of usefulness, no future use outside of a classroom scenario can be expected. Usefulness is related to a motivation to use the system, and this is predicated by a minority of users on an information need, an important influence on motivation according to Case (2012), Krikelas (1983), Shenton (2004), Shenton and Dixon (2003), Wilson (1997) and Bilal *et al.* (2008).

At the 7-month interval, a significant minority of users stated that they did not go back to the system again because she did not have a link. For another, time spent looking for this resource online was contrasted with the perceived ease of access of a search engine. For another participant, easier access of alternative resources, such as *Facebook*, a social network enjoying popularity at the time of writing, was contrasted with the decision not to go back to VG. One user stated that to access VG again would be a "hassle".

A minority of users stated that they would consider the resource "really good" if they had more time available to use it. One user stated that she did not go back to the resource because she lacked time. Another user expressed a preference for other leisure activities in her free time. For two users, prioritising other resources first was associated with not going back. For example, one user was more interested in the broad categories on *Pinterest*, a social network where users "pin" images to a board, tagging them with their chosen subject, while another preferred and more enjoyed looking at books by the photographer Tim Walker. For one user, her heavy use of a screen for leisure activities related to her aversion to going back to a resource for work.

According to Wilson (1997), lack of accessibility inhibits information seeking. For the users above, the resource was not inaccessible, but rather, it was not perceived to be easy to access (perhaps in relation to the value of time to be investigated in finding it) or to familiarity with other search tools such as *Facebook* or *Google* over accessing and using VG. The value of time (Wilson 1997) appear to have affected some users' decision not to return, and preference for other resources was also stated by a majority. Finally, for one user, physical discomfort at looking at a screen was a factor in not returning to the resource.

Reliability

Reliability, which refers to accuracy, dependency and consistency of information, related to the metric of "credibility". In the usability questionnaire, the mean rating for the statement "Information retrieved was from a credible source" was 6, indicating that users found it so.

A significant minority found the information detailed and highlighted aspects like interviews. For four users, information such as interviews, photographs and original designs of the dresses made the resource more credible. Three users stated that they were unable to tell if the resource was credible. According to Wilson (1997), credibility can influence the decision to use a resource.

Currency

The creation date of the resource and last citations within the 3D library were in 2012. Since the information content of the resource represents a retrospective of Valentino's work, much of it from a first-person narrative, it is likely that the information contained therein retains its currency at the time of writing in 2015. The speed with which digital technology develops is the factor most likely to contribute to the perceived "age" of the system. None of the users remarked upon the perceived datedness of the system aesthetics, although it is predicted that with time and improved graphics and technologies, the visual currency of the resource could depreciate and its appeal thereby wane with contemporary users.

9.3.2 User Behaviour in Relation to Architectural Principles

The analysis is structured using thematic codes from the architectural literature review. The data cited refers to encounters with the 3D environment that can be said to conform to architectural heuristics rather than being interpreted through the lens of traditional HCI heuristics. Instances of user behaviour are coded using the thematic codes from the ISB literature review.

Beauty

The statement "the visual scenery is attractive", which users were asked to agree or disagree with on a Likert scale on the usability questionnaire contains some indications of the beauty of the 3D design. The median answer of 6 for this question is indicative that the scenery was considered attractive by participants. As an overarching heuristic informing all the other principles in classical architecture, no particular indicators are sought for beauty from the architectural perspective although some answers from the focus groups pertain to this heuristic.

In the questionnaires, one user described the scenery as "beautiful", another as "attractive" and another as "appealing to the eye". One user referred to the scenery as "sophisticated and chic". "Beauty" played a part in a minority of users' aesthetic assessment in the focus groups, and played a communicative role: "The message was the beauty", stated one user. The dresses were called "stunning" and their display together was described as "really pretty". One user stated that she found the dresses attractive because of the novelty of seeing them that way.

Responses indicate that the resource presentation had high aesthetic and affective value. Statements such as "stunning" or recognition of the novelty of display may indicate the element of surprise, which precipitates curiosity (Garris *et al.* 2002; Zheng *et al.* 2007). The evaluation "sophisticated and chic" may connect with the user's prior interests, which can affect motivation. The communicative value of beauty, from an architectural approach where objective beauty meets the subjective appreciation of the beholder, points towards the classical conception of beauty as having an intrinsic and ultimate value.

In the usability questionnaire, two respondents referred to un-lifelike aspects of the visual scenery. One participant wrote that the scenery, although "pleasing to the eye" was "unrealistic". Another wrote "it's slightly computerised".

The above comments indicate that the challenges of achieving realism in digital design can impact upon the perception of beauty.

Symmetry

One user thought that the use of symmetry in the system meant that things looked similar and harder to distinguish, resulting in her lack of spatial awareness. In this comment, although the use of symmetry achieved a design that was proportional, the problem was that in this specific case, symmetry resulted in an impression of sameness. It is not certain whether this problem arose from the application of symmetry itself, or whether other factors led to the user being unable to distinguish where she was.

In this instance, user appeared to imply that either variation within symmetry or asymmetry would aid comprehension goals. This case aside, neither the focus groups nor the usability testing generated significant data where participants mentioned symmetry or linked it to information behaviour.

Proportionality

In the literature review, it was concluded that the application of proportionality in classical architectural design involves the use of stable figures, and the use of "reasonable" proportions.

VG contained stable figures that to the eye were reflective of real world structures, such as a museum. The sizes of entrances, rooms and pathways were not impractical for human exploration. Examining the visual interface did not evidence the structured application of specific ratios – in the literature review it was discussed that such ratios were cultural artefacts rather than necessary principles.

The data collected did not contain explicit references to proportionality. However, the users' acceptance of the system as reflective of a real-world museum may implicitly involve acceptance of reasonable proportionality. The limited data on proportionality and the relationship to user behaviour raises questions. The methodology may not be as effective as can be possible in exploring proportionality, without explicit user questioning as to its application and effects.

Ornamentation

Ornamentation can be used to achieve beautiful ends as well as for functional ends, and data suggests that ornamentation was both successfully and unsuccessfully applied for these ends.

One user in the focus groups considered the detail of a sky pattern on the ceiling to be "really cool". Another user "looked around" in order to see: "looking up" and noting aesthetic elements of the system such as the sky effect in the skylight. Two users mentioned liking the blue sky and its clouds in the usability questionnaires, too.

The design was called "simplistic" and this was related to a favourable opinion in one user, but to a negative response in another. One user in the focus groups related the simple style (e.g. minimal ornamentation) museum design which minimised distraction and focussed attention on the content and dresses. A respondent in the usability questionnaire stated that the simple colours made the dresses stand out more. However, four respondents in the usability questionnaire stated that the design was plain, which would seem to be a more negative emphasis than the descriptions of simplicity. Three users complained about the white background, and one about the plainness of the use of the colour red. Some of these comments related to first impressions on entering the system. The role of more ornamentation at this stage could be to create a stronger impression of the "beauty" which was to come on further exploring the system. Minocha and Reeves (2009), in their study of 3D virtual environments stated that "The initial impression of a system or environment greatly influences subsequent perceptions and attitudes, which then affects the quality of subsequent interactions", and this also corresponds to the principle of entrance in architectural design.

The sameness of colour was related by one user to difficulty in trying to differentiate between rooms to establish which ones had already been accessed, and another user said that the white colouring was related to her finding it hard to distinguish and navigate between spaces. However, a minority of users indicated that lack of "differentiation" (i.e. minimal ornamentation) was not effective. One user attributes "going where [she had] gone before" unwillingly to lack of differentiation between rooms. One user stated that a hypothetical differentiation in the colour of the walls would be her preference and that this would also relate to ease of use. Limited differentiation between colours and shades was associated by one user with difficulty in seeing perspective, by another with difficulty in distinguishing features, and by another being unable to distinguish the cursor. In the usability questionnaires, too, one user said that too much use of the colour white made them find it hard to distinguish walls from shadows, while another said that the amount of white meant they did not know if they were looking at a wall or a corner. These responses suggest that better application of the architectural principle of ornamentation in the system may have improved the user experience.

Ornamentation where successfully applied appears to have had a cognitive value (Heinstrom 2006) which affected attention. Ornamentation also appears to have visual appeal, which may impact upon enjoyment (Wilson 1997), an influence on motivation. Judiciously applied ornamentation could also be used to focus attention on salient parts of the system, directing the user's attention towards an information object. However, lack of ornamentation was thought be unattractive to several users, which may have made the website less engaging, which may result in boredom or ceasing information seeking (Agosto 2002b). Plainness could also contribute to the lack of distinction of parts, which inhibited success in navigation in the 3D space.

Propriety

Following the findings of the literature review, the key indicators sought for propriety are appropriate magnitude and sensitivity of buildings to surroundings. No implicit or explicit references to this principle were found in the data for VG, and nor could inferences be drawn between the principle and user behaviour. Magnitude was evident in the interface although no particularly striking examples were mentioned by users. Sensitivity of building to surroundings was not an applied principle, since the museum interior appearance characterised the totality of the virtual world as presented.

The lack of data for analysis may indicate that propriety was not an accented characteristic of the resource. It may also raise questions about the suitability of the methodology, where no metrics could be suggested for the principle of propriety. The suitability of the methodology and seeking further data would need to be verified by future investigations.

Arrangement

The key indicators sought for arrangement are use of centres of gravity, division for emphasis, use of inflection, and consistency.

The system was divided into rooms. A variety of videos were displayed in the Interview Room, and this was explicitly recalled in the focus groups by the majority of participants, the majority of whom liked this room within the system. Users were able to use the "room" interface to experience different media at the same time as watching the video and one user stated that she liked exploring in this way. The layout of the system in rooms related, for one user, to a process of browsing, recalling a favourite place and then going back. For one user, the display of objects in rooms was related to going into the area and to the user behaviour of clicking. The location of all of the dresses in a single area, or of pictures in a gallery area, was associated by a minority of users with the human input of clicking, to looking or viewing.

Therefore, the use of division for emphasis as a design strategy guided the users, supporting exploratory interactions (see Sharp *et al.* 2007). The behaviour of users within the rooms corresponds to browsing, with the user's attention guided towards salient items (see Sharp *et al.* 2007). While browsing, users undertook cognitive steps such as identifying possible sources and making contact with them (Choo 2000). The division into rooms also impacted upon the presentation of information, since rooms corresponded to different subjects, much like learning zones, and this related to the users' cognitive absorption of the subject presented.

Commodity

The key indicators of commodity are design for a particular use, and use of motif. The system was designed in a way that denoted a particular use, and in the data was compared to a museum by a minority of focus group participants. The museum comparison was related to “feeling like you were really there”, said one user, and to pleasure for another. Hence commodious museum design can correlate not only to recognition of a known 3D environment but this can also increase a sense of presence. The illusion that the interacting human is “in world” is cited as evidence of good virtual world design by Bartle (2003). The array of information in a museum-type configuration was contrasted with use of a search box by one user, who stated that the museum design led to her browsing and to exploration. The realism of the museum (as opposed to 2D resources) was related by another user to exploration and to learning while doing. This seems to correspond to the notion of “experiential learning” advanced by Kolb and Fry (1975) who implicate the learner as a “creator of learning” in contrast to just being a “passive recipient”. The presentation of information on the dresses in 3D related to feeling “like you’re there” and to learning by another user. Furthermore, the multi-layered display of information, which was facilitated by the 3D environment, was appreciated by one user because it allowed her to hear, see and watch simultaneously.

In Minocha and Reeves’ (2009) study of 3D virtual environments, they found that “Visual realism, that is depicting objects and spaces as they are in the real world (e.g. lecture rooms with tables, chairs and a podium) helps to support existing mental models of the learners of what to expect” and thus has a key role in the user experience. Since it corresponds to existing mental models of environments, commodious design may have some bearing on the notion of “credibility” since a realistic or credible recreation is one indicator of credibility in a 3D environment.

Some instances in the data correspond to the notion of motif as an aspect of commodity. In the Entrance Hall, there was a dress. One user stated that the dress indicated to her what was in the system and that as a result she recognised the content. Another user stated that were it not for the dress, she would not have known what was in the system. In the two examples above, the use of motif played a guiding role in the system, with possible relations to knowledge construction (see Dervin 1983), whereby the user was given the information needed to understand the gap between the existing situation (walking in) to new information (the content of the museum).

In one case, the inclusion of steps in the room design led to the user expecting that she would be able to walk down them, and when she found this was not possible she was frustrated in not being able to go where she wanted. This indicates that motifs carry user expectations of affordance in the 3D virtual environment and in this one instance, a motif that did not offer the affordance expected led to stopping information search and in the experience of frustration, which may have affected motivation.

Wayfinding

The key indicators of wayfinding features are sensory elements (light, view, touch, hearing, smell), doorways, circulation spaces, vias, crossroads and milestones. A metric that would indicate poor wayfinding would be getting lost or not being able to hold a cognitive map of the environment, with inverse examples indicating a narrative progression through the system.

Users experienced a range of views on orientation through the system. 3D orientation around the dresses was associated with a positive visual way of exploring by one user. Initialising the programme was related to spatial language, such as coming in, as well as awareness and initial use of the mouse as input device.

The lobbies which served as a doorway to each gallery, described as “boxes”, were related to the user not seeing all content of the rooms at once, and this “unknowing” was related to her turning in order to see. The use of doorways led one user to associate the system with a museum. Initial realisation of this design configuration is associated with one user’s proceeding to navigate through the system. In one case, the first entrance perceived was the first that the user clicked on. Another user proceeded to click on each room in the order in which they were displayed. The users did not indicate it explicitly but both of these behaviours may relate to the fact that the doorways all looked the same.

The combination of “simplistic” design in the entranceway and a central dress, which was described as a focal point, related to one user’s movement towards the object and to her curiosity to find out more. The dress was therefore an example of a milestone.

The above comments indicate that the user’s first entrance into the 3D digital library environment was significant in creating an impression and in determining what kind of orientation would occur next. These findings concur with Minocha and Reeves’ (2009) recommendation that 3D virtual environments employ “design to orient the user at the landing or entry point”.

The data from the focus groups indicates that a minority of users experienced disorientation (feeling lost) within the 3D environment. In the usability questionnaire, one user stated that they could not tell where she was, and another said that she was unaware of which areas she had already visited. One user stated that she forgot which rooms she had already been to, while two users stated that they got lost when orientating between rooms. One user said that she got lost when entering the library. For another user, movement to the central hall was preceded by unintentional arrival at a room which the she did not intend to enter several times.

While there is not an evident majority experience, the responses of participants paint a rich picture whereby wayfinding experiences characterise exploration through the system, with features such as entrances and milestones influencing user behaviour, although some cases of disorientation potentially relating to lack of or ineffective wayfinding features.

9.3.3 Enjoyment

Enjoyment is but one variable influencing the motivating intention to explore (Wilson 1997) yet it was posited as key to the use of a game-like system (see Sharp *et al.* 2007), with a possible role of prolonging search behaviour (Zillmann 1988).

On the Likert scale, the large majority of users indicated that they enjoyed using the resource. A significant minority of responses to the question about enjoyment in VG related to the novelty and the creativity of the resource: e.g. “I have never experienced anything like it! The concept is brilliant!”, and “It was really creative”.

Five respondents referred to finding the resource interesting, while three further respondents referred to the resource as simultaneously interesting and fun. One user stated “I enjoyed viewing all the different dress styles and information surrounding them”. Two respondents found the resource enjoyable or positive but not interesting.

One user said that difficulties in movement through the system lessened her enjoyment.

The question about enjoyment allowed us to note that the majority of users did express enjoyment, which may affect motivation (Wilson 1997), but that other variables such as interest or intervening design variables (such as orientation style) are also important. This question is therefore not as indicative as anticipated, because the complex relationships between design and user behaviour have already been mapped, where possible, elsewhere.

9.4 Giza Analysis

9.4.1 User Behaviour in Relation to HCI Heuristics

Efficiency

As in the analysis of VG, “completion” and “productivity” are viewed in relation to the exploration task. Data related to whether the system responded quickly to the task, without delay or error is also relevant to this question. The response to the statement “the system responded quickly, without delay or error" received a median answer of 5 on the Likert scale used in the usability questionnaire. This indicates that the system was successful in this usability measure, although the rating is not as high as for other ratings of usability. In fact, this is the only question for which VG recorded a higher mean score than Giza. For this group, the mean time spent using the resource was 35.67 minutes of a possible 36.

One user described her behaviour in relation to the content of the system as "doing everything". One user returned to the system again after the session in order to explore once more. One user stated that the "rhythm" of the system was perfect. The user's aim to "do everything" implies an active search (Wilson 1997), orientated towards exploration of the whole information content of the system. For one user, motivation to return to the system in order to actively explore was present. The narrative flow of the system, considered "perfect" by one user, may correspond to enjoyment (Sharp *et al.* 2007). These three examples, although representing a small sample indicate that enjoyable source characteristics and the active exploration of information occurred during the participants' use of Giza.

The system was considered slow by a significant minority during the focus group but quite fast by two others. This variation in delay experienced between initial loading, on the one hand, and the system once loaded, on the other, could also account for the variation in reported subjective slowness or fastness of the system. Time taken to load on the initiation of the system reported as a slow element by a minority of users. Three respondents on the usability questionnaire noted that loading the system was initially slow. One usability questionnaire respondent stated that elsewhere in the system loading was fast, while another stated that the speed of the system improved with time. One focus group participant indicated that she tolerated the initial slowness in loading because the system worked faster after that. It is also notable that one respondent in the VG questionnaires stated that she chose to explore Giza 3D, but gave up after it took a long time to load, and this was the reason she chose to explore the Valentino Garavani Museum instead, indicating that loading time led one potential Giza user to abandon the task. This may be because excessive loading times relate to boredom (Agosto 2002b) and this can influence task abandonment. One user's toleration of the initial delay may be attributed to the user's higher motivation or the action of a combination of motivational variables. Faster speeds after loading may have influenced users' motivation to continue to use the system.

Three respondents in the usability questionnaires referred to errors in Giza, namely, the system "freezing". These respondents did not report information seeking cessation as a result of the errors, but it may have interrupted the exploration process.

Effectiveness

We continue the theme of considering the primary indicator of effectiveness as how well the system facilitates the exploration of information. The responses reported below indicate that information was explored in a number of ways, including flythrough navigation, "wandering" at ground level, selecting and watching videos, menu-based navigation, and comparing multimedia. In the usability questionnaire, one user stated that "it was easy to find what [she] wanted to see", while another stated that she found it "easy to find information". The effectiveness of the different exploration methods are considered below.

Flythrough navigation was related by one user to the action of zooming in was described as "cool". In this case, flythrough navigation facilitated a browsing approach, and when the attention was guided towards items, more active behaviour occurred as the user zoomed in. The user does not state whether she was engaged with information in the process of flying over and zooming but if she was then browsing could be seen in relation to locating items of interest, and zooming to a form of active search (see Wilson 1997). "Coolness" describes user gratification (see Wilson 1997) and this could affect motivation.

The majority of users explored information by watching videos. One user stated that watching a video involved being "taken round". Two users appreciated the ability to start and stop videos. One user related being able to stop a video and go to another part of the system to being able to do what she wanted to do depending on what interested her the most. One user said that watching a video initiated a process of her seeing information, understanding and then going to see something related elsewhere in the system.

Another user noted that being able to stop a video and look at something else was related to a feeling of not being "forced" to do anything, and said that this reduced her "suffering". Watching videos was mostly correlated to "passive attention" (see Wilson 1997) but it appears that starting and stopping videos using controls reflects an interaction with the resource to find desired information (see Choo 2000). The controls on the videos enabled the "intending to" or "wanting to" part of motivating intention (Nahl 2007) to be actualised by the user. Curiosity was induced by a process of exploration and discovery ("seeing" and "understanding") (see Tieben *et al.* 2011; Bruner 1973). The system attribute of controls on the videos facilitated the user's being able to make a choice even before the whole video had been completed – i.e. at the point when curiosity prompted further exploration. Reduced "suffering" in the user's description may be related to her sense of empowerment, control and competence (see Fisher and Landry 2007; Weisz and Cameron 1985) in this situation.

A significant minority of users stated that after watching an introductory video, they accessed and watched the interactive tours associated with the introductory videos. This structure – introductory video first; interactive tour second - was thought to be useful. One user thought that the introductory videos contained a good amount of information and content in a short time. One user related the brevity of the guided tour to not feeling bored and going on to explore further afterwards. Two users found the narrated pace of the guided tours too fast and as a result one of them stated that she found it hard to absorb the information. One user disliked the voice of the narrator on the guided tour. One user found the American accent of the narrator hard to understand, while one user wanted subtitles.

Two users referred to the effectiveness of interactive tours in combination with list menu items which one person related to going around and clicking for more information. Being able to go to different parts of the complex was appreciated by one user. One user stated that clickable menu items were related having more insight, to “going further”. The arrangement of information into three levels within the complex was related to ease of exploration and to actualisation of information needs by one user.

Comments above indicate that the structure of information in the system, and the guidance of the user through the system had a role in supporting interaction with the information in the system. Style of transmission had the potential to decrease enjoyment. The use of the menu allowed users to actuate their intention to explore and allowed the user to regulate steps in the exploration process – both steps taken in relation to a motivating intention, according to Nahl (2007). This process of exploration may have been equated to “going further” because it allowed for the discovery of new information and perhaps also to cognitive processes such as recognising and making connections (Bruner 1973).

While the majority of users above appeared to have browsed menu items, in the case of one user, beginning to use the resource involved going straight to a particular area - the Sphinx Temple. This user explained this step in exploration by stating that it reflected a prior interest in the Sphinx. The same user appreciated how miniature icons explained the history of the boats coming for the King’s funeral. She made use of the clickable icons around the Sphinx to click and to see what the Sphinx looks like today. This user indicated high initial interest in the system, which may have influenced her evident motivation to understand and compare information when using the resource.

The majority of users reported instances of not finding specific pieces of information that they sought or desired at a point in exploring the system. Two users wanted to be able to click on the figures in order to obtain more information. One user wanted to compare multimedia but was unable. This user wanted to see more contemporary pictures to compare with the visual scenery and animation. This user therefore desired more layering of information. This was also supported by one respondent in the usability questionnaires who wished that the "animations" could be combined with the objects and photographs more, to enable the user to click on the information and make comparisons between the historical site and the site today. Two users noted instances of limited information content. One user experienced a feeling of not knowing what was happening in the object gallery. Another user wanted more information about the objects in the object gallery. The lack of detail and information in the object gallery was lamented by one respondent in the usability questionnaires. One user wanted the picture library to be integrated with the 3D visualisation so that she could see the two types of information – photographs and 3D scenery – simultaneously. A significant minority of users did not like the introductory tours when they contained no audio commentary. One user stated that watching an introductory tour without audio resulted in her not understanding, while one described it as "pointless".

"Wanting to" or intending to explore information indicates motivation to know (Nahl 2007), as well as indicating users' desires to make connections or see patterns (Bruner 1973), and therefore indicates that users experienced "cognitive curiosity" (Berlyne 1960, 1967, 1971) while using the system. However, sometimes the motivating intention was frustrated by lack of information in the system, or by limitations in the dynamic linkage of ideas or interactive elements within the system. Developing these features could potentially support exploratory interaction and active learning (Sharp *et al.* 2007).

Aesthetic appearance

As in the analysis of VG, our consideration of aesthetic appearance impinges upon readable and engaging text, and appropriate use of colours, graphics and icons. The usability questionnaires indicate that text was engaging and readable, as users ranked this statement with a median rating of 6.

In the usability questionnaires, one user stated that the contrast of the text colour to background made the text readable. One user stated that some of the text was too small. Also in the usability questionnaires, one user stated that the text looked uninteresting to read, while another stated that although the text was readable it was not engaging. Lack of engagement with the text style may, if we follow Agosto's (2002b) reasoning, have influenced the decision to engage with the written work in the system.

Colours, graphics and icons were given a median rating of 7 in the usability questionnaire, which indicates that these were very successful. Two users in the focus groups said that they thought the graphics were really good. One respondent in the usability questionnaire stated that the graphics were “vivid” and “clear”. Pixelated graphics were tolerated by one user in the focus groups, and according to that user they did not result in diminished sense of “being there”.

Graphics probably correlated to the enjoyable user experience, which may have affected motivation and prolonged use of the system. For one user “vividness” and “clarity” are equated with aesthetic success. Graphics could be affected by limitations in the system’s ability to achieve the highest definition without pixilation, but one user still noted that she felt in some way immersed in the system.

Terminology

The questions measuring terminology in the usability questionnaire were: “The terms used to label the menu functions are understandable” and “The menu functions are logically related”. These statements received median ratings of 6 and 7, respectively, on the usability questionnaires.

One user’s comment: “When looking through all the complexes you can get information in a logical manner 1) Guided intro 2) Object gallery 3) photo etc.” This statement expresses a cognitive synergy between terms used and user understanding, which appears to have supported exploration.

Navigation

As in VG, navigation was investigated in the usability questionnaire by asking users to rate agreement with the statement “Orientation is straightforward”, with a related metric of “steps required to complete”. The median rating of the statement in the questionnaire was 6, indicating that orientation was straightforward for the users of the system. Relevant instantiations of the heuristic are also found in the focus group data.

One user noted that going to a desired destination took a long time, while another stated that it was sometimes difficult to see something she wanted to see. This delayed or frustrated actualisation of the motivated intention to advance to an object or area could be attributed to a number of factors depending on the type of navigation taking place. A number of specific instances are discussed in the paragraphs below.

Orientation during flythrough was characterised by one user as sensitive. One user associated it with going to an unwanted area. Two users stated that they became disorientated when in flyover mode. However, one of these was able to rectify the situation and another user reported not getting lost. One questionnaire respondent stated that “sometimes, because you're viewpoint was changing, you could not tell which pyramid you were going to", while another wrote "it was nice that it kept revolving, but sometimes you could not tell where individual pyramids were". The association between getting lost and flyover was related to one user's desire for a reset button.

Flythrough mode and especially its sensitivity to user input could act as a frustration to the user's intentions. Disorientation was sometimes caused by constantly changing viewpoint which may have resulted in a lack of cognitive connect with steps to be taken in the exploratory process. This experience of uncertainty can lead to the user's taking steps to resolve negative emotions (Kuhlthau 2004).

One user considered the menu be good quality, namely: readable and facilitating orientation in the system. Another user found the menu useful. One user related the provision of a list menu to being able to do what she wanted to do depending on what interested her the most, while another user said that having the option to select which chamber she wanted to go to from a list resulted in her not feeling "completely lost". The menu connected to the 3D visualisation by highlighting a part of the virtual world when a user selected its name on the menu. One user noted that she was able to identify what she was looking at because the relevant area matching the label was highlighted when she moved her mouse over it. The pyramids changed colour when you hovered over them and so did the text.

The menu appears successful in the comments listed above since it appears to have supported the encounter with areas of the system. It is related to the user's being able to actuate their intention to go to a particular place, thus facilitating the motivating intention. The menu may have increased a feeling of control and self-efficacy (see Schunk 1991; Wilson 1997; Bandura 1977). In one instance above, the menu as a supplement to 3D orientation facilitated location awareness, and colour coding, too, also facilitated the user's cognitive map of where they were.

Interactive mode was associated with "zooming" through the corridors of the Pyramids, and with fun, by one user. In Interactive mode, two users experienced travelling through a long, enclosed corridor and wanted to escape but did not know how. Interactive mode was associated with enjoyment by one user, a factor which Wilson (1997) states may affect motivation, and which Zillmann (1988) states may prolong searching behaviour.

Learnability

Learnability was measured in the usability questionnaire by asking the participants to rate their agreement with the statement "steps I took during exploration were understandable". The median rating given for this statement was 6, indicating no usability problems related to this metric.

In two reported cases, beginning use of the resource was related to surveying the main interface in order to get acquainted with the system. A significant minority of users said that they used instructions in order to learn how to navigate in Interactive mode. One user could not find the instructions and this was related to not knowing how to navigate at first. One respondent in the usability questionnaire stated that the instructions were limited. Some users did not experience success when trying to use the instructions. The instructions were considered difficult. One user wished that the instructions could have more specific advice about steps required in navigation.

Users used a mixture of observation and instructions to acquaint themselves with how to use the system. Limited or unsatisfactory instructions resulted in difficulty in navigation, which caused users to need to learn through trial rather than by relying on the information about steps in navigation. One user said that navigation was easy once she had "got the hang of it", indicating that she tolerated having to learn how to explore in the system, while another respondent in the usability questionnaires stated that while it "took [her] a while to understand how to use it", once she "got used to it", she "had a lot of fun".

The above users striving or persisting to learn how navigation worked through trial and experience. Striving or persisting are both steps associated with motivation (Nahl 2007). While more extensive or clearer instructions could have resulted in increased control and competence (Weisz and Cameron 1985), motivation was high enough among users to continue to strive to master the steps required in navigation, and using the system having overcome this obstacle was associated with enjoyment.

Relevance

The first sense of relevance considered is the relevance of the resource to its purpose. Secondly, we consider whether users would use the resource, or similar resources, in practice.

Several focus group participants reported that they thought the resource was useful for learning. Three users contrasted notions of "learning by doing" with a traditional concept of learning. Among these, in comparison to other notions of learning, one user stated that using Giza "seemed less like learning". Another student furthered this notion of contrast with traditional learning by stating "it was more like you were doing stuff" (in comparison to learning). Another stated "you were finding stuff out but it wasn't actually learning".

As for the potential application of the resource, two users said that the resource was useful as a brief introduction to the subject. One user said that the resource would be useful to somebody doing a project. One user said that it would be useful for a person studying the culture as well as for general interest. One respondent in the usability questionnaire stated that she would "definitely use it to research", while another stated that the resource was useful for learning. One user said that the resource would be useful for someone who wanted to visit Egypt. Another user compared using the site to "stepping into a brochure" and that in thus looking around and hearing about the site, she felt as if she was preparing for a visit to the real life site. Another user stated that the website was "like a mixture of a guidebook and being there". The comments above indicate that Giza was successful in encouraging exploratory interaction and active learning with potential relevance to a variety of scenarios such as formal learning, lifelong learning and engagement with the actual tourist destination in Egypt.

A significant minority of users compared Giza 3D favourably to other ways of learning about Giza and ancient Egypt. One user thought that learning about history online was more enjoyable than other ways of learning about history. Two users stated that they learned more using the system than they would have done reading a book while another user said that there was more detail in the system than in a guide book. One user compared the system to *Google Maps*, but thought that this system contained more information. One respondent in the usability questionnaires stated that the resource had given her "a better insight into Egyptian life". Two users said that there was more information or they could see more in the system than in a real life trip to Giza.

The above comments indicate, using a limited number of examples from the data, that the system was relevant in relation to alternative resources such as an analogue resource, due to enjoyment, and to *Google Maps*, due to better information content. Enjoyment can affect motivation and prolong searching behaviour (Zillmann 1988) and the encounter with informational content within the system ensured that sufficient exploration to enable discovery.

Four users decided to use Giza because they considered it more interesting than the other two 3D digital libraries presented to them in the laboratory session. One user opted to use Giza because she had visited Egypt and was therefore curious. Speaking of heritage activities, McDonald (2011) found that people are motivated to engage in heritage activities that they find directly relevant to their own specific interests.

The resource was successful insofar as it was reported to have increased users' interest in both the subject and in the location in Egypt. Users may have expressed initial interest in choosing Giza above the other 3D digital libraries offered, but interest can also be increased in an instructional context, by curiosity induction and interest induction (Brophy 1986; Schiefele 1991), and this appears to have occurred as a result of the activity as well as after a component of the exploratory process in one reported instance. Use of the system also correlates with increased curiosity and new information needs which would need to be fulfilled beyond the system. Interest can precipitate curiosity (Silvia 2006, 2008) and this can increase the motivation to seek information.

The majority of focus group participants reported increased interest in the subject after using a part or all of the system. One user reported increased interest after seeing an introductory tour. One user wanted to learn about the pyramids through time as a result of using the system. As a result of using the system, one user said that she now wanted to know more about ancient Egyptian culture. Two users wanted to learn about the lives of ordinary Egyptians as a result of using the system. In one case, wanting to know more about the culture and lives of individuals was associated with the fact that some of this information was not available within the system. Three users were interested in comparing the historical recreation in the system with contemporary images as a result of using the system. Three users stated that as a result of using the system they would like to go to Egypt.

A minority of users discussed the application of 3D resources to other subjects. One user thought that a hypothetical 3D digital library on the subject of the Industrial Revolution would facilitate exploration and would be useful. One user thought that a hypothetical resource on Ironbridge (a World Heritage Site in England related to the Industrial Revolution) would facilitate both exploration and study and would be fun. One user stated that this type of resource would allow her to "actually stand on the iron" (i.e. give her a sense of physical presence). Two users liked the option of being able to explore a place such as Ironbridge on their mobile device.

When asked whether they would or had used the resource again, one user bookmarked the system after using it, indicating an interest in accessing it again. One user said that they would enjoy the resource if they had sufficient time to use it. One user stated the desirability of just "losing herself" in the site if she only had sufficient time to do so. Two users said that she would only go back if she had an historical information need. Two users said that their reason for not returning to the resource was that she was not studying Giza in school. For another user, returning would need to be related to an information need – a key variable in motivating intention (Case 2012; Krikelas 1983; Dervin 1983; Shenton 2004; Shenton and Dixon 2003; Wilson 1997; Bilal *et al.* 2008), while for another a relevant curriculum context (a "purpose") would affect their motivation (Nahl 2007).

Reliability

Reliability, which refers to accuracy, dependency and consistency, of information, was measured by asking the user to rate the credibility of the system in the usability questionnaire. The median answer given was 6, which is suggestive of adequate reliability.

One user cited the provenance – Harvard University and Dassault Systèmes, while another stated that she would have used the website as a resource. The user's assessment of system credibility, as Wilson (1997) states, can affect the user's decision to use the resource.

Currency

Creation date of the resource and last citations were in 2012. As in the case of VG, this is unlikely to impact upon the information currency of the resource since it details a period in history. Nevertheless, it may now or at some point cease to represent the most up-to-date knowledge of ancient Egypt. As in the case of VG, visual currency of the computer graphics and the technology used are likely to depreciate rapidly through time, as has been the case with most emergent computer and digital design developments in the last decades. None of the participants indicated that the resource content or style was perceived as out-of-date.

9.4.2 User Behaviour in Relation to Architectural Principles

Beauty

A significant minority of users in the focus groups found the visual scenery attractive. In the usability questionnaires, users rated the visual scenery with a median rating of 7, indicating that the resource was highly successful in relation to this metric.

In the usability questionnaires, one respondent stated that the resource was visually "fantastic". In the focus groups, one user liked the specific areas of the temples and the Sphinx. Another user liked the appearance of the colourful rooms and the boats. The above comments indicate that the visual engagement and impressiveness of the resource, and engagement is said to have an influence on increasing information seeking (Shenton 2004).

Symmetry

The data gathered from usability testing and focus groups for Giza did not contain any explicit or implicit references to symmetry, and hence it is also not possible to draw any conclusion about symmetry's links to user behaviour. Symmetry was observable as an architectural heuristic at several places in the system and was an integral part of the architectural design observed in the pyramid complex. Since the effects of symmetry on user behaviour are not evident from the datasets gathered, further validation would need to be sought to ascertain if any measures can be used or relationships drawn between symmetry and behaviour.

Proportionality

Giza contained stable figures that to the eye were reflective of the real-life pyramids. The sizes of structures and corridors resembled structures that were practical for human exploration. Examining the visual interface did not evidence the structured application of specific ratios save those which were replicated from the real-life pyramids.

The data collected for Giza did not contain explicit references to proportionality. However, the users' acceptance of the system as reflective of the pyramid complex may implicitly involve acceptance of reasonable proportionality. There is limited data to verify the role of proportionality in the user experience, and either further verification must be sought, or the methodology reconsidered to consider whether measures or metrics can be devised for proportionality as a design principle.

Ornamentation

Ornamentation can be used to achieve beautiful ends as well as for functional ends and data suggests that ornamentation was both successfully and unsuccessfully applied for these ends.

Three users appreciated the details within the visual design, with one user liking the detailed rendering on the boats and another the addition of a cat in the temple. One user said that the detail on the boats, marshlands and forests, gave them a sense of surrounding. The comments above indicate that the details in the system resulted in user engagement and also increased the user's sense of symbolic presence within the environment.

One user stated that the lack of differentiation in the colour of the pyramids was linked to her becoming disorientated. The above example indicates the role of contrast and differentiation in supporting the user's cognitive awareness of their location in the system.

Propriety

As stated in the literature review, the key indicators sought for propriety are appropriate magnitude and sensitivity of buildings to surroundings.

One user had a sense of scale when using the system – she could sense that the site was big because of the length of time it took to scale the walls. This impression of magnitude depended on the navigation speed as relative to the scale of a part of the environment. In the HCI literature, Fitzmaurice *et al.* (2008) point out the expedience of different navigation speeds according to scale, but what is of interest here is how navigation speed as an aspect of interaction interacts with magnitude as a design element drawn from architecture, to create an overall impression of propriety in the user experience.

One of the comments above indicates that appropriate magnitude was conveyed through the speed of progression through the system – a revelation of the complex interaction between architectural and HCI design. In the "real world" we make calculations about distance of areas according to the length of time it takes to traverse them, as well as judging visually by the eye. It would therefore seem that a virtual world which sets a pace to the user's movement through the system has a similar effect on the user, and hence the relationship between speed, time and distance is applicable in the virtual world too. This relationship may be borne in mind by designers of virtual worlds as they seek to convey magnitude.

Arrangement

The key indicators sought for arrangement are use of centres of gravity, division for emphasis, use of inflection, and consistency.

The chamber containing hieroglyphics was explored by one user: she went in, saw inside, liked what she saw and made a decision to do some further research about it at a later date. This is an example of how division into rooms is able to structure an information seeking experience. One user contrasted the resource favourably with actually visiting the pyramids in Egypt, because the resource allowed them to go inside the pyramids and see the chambers, which a tourist in Egypt could not do.

The above comments, though few, indicate the success of the division of the environment into rooms. They allowed for thematic encounters with the information content. Entering a room involved an encounter (see Tieben *et al.* 2011, Bruner 1973) which resulted in enjoyment (Wilson 1997) and provoked cognitive curiosity (Berlyne 1960, 1967, 1971).

Commodity

The key indicators of commodity are design for a particular use, and use of motif. One user compared Giza to an "online museum" and liked being able to access it remotely. One user stated that she liked seeing the historical recreation. One user found the site very informative and easy to use and another user said that Giza 3D was a resource that would give her "visual knowledge".

One user said that in comparison to going there, it was more possible with Giza 3D to view all aspects of the complex at once. One user stated that in comparison to a 2D book or website, Giza 3D enabled her to explore more and to physically go round the site. Another user said that an advantage of the site over going there was that it allowed her to see the site in its "former glory". However, one student who had actually visited Giza in real life stated that there were advantages to actually going there, such as experiencing the weather and having more of a feeling of "real life".

Commodity in Giza seems, from the above comments, to have equated to a resource that was successful in achieving a design that served as a museum and a visual communicator of information.

In comments that overlap with relevance, the role of all these features, which could only be achieved in the complexity of an interactive system, was to give added informational and exploratory value to the resource compared to a real-world resource. The design enabled a “bird’s eye view” as well as a walkthrough effect, and also achieved an historical recreation. Despite the commodity of the system as an online museum, the environmental effects of being in a real world scenario were not exactly reproduced by the system.

A significant minority of users compared the resource favourably to a real world visit to Giza, mostly due to comfort. Two users said that Giza 3D was more fun and relaxed than a real life visit to Giza. Two users said that they associated actually going to Giza with discomfort and stress. Four users noted the inconveniences associated with guided tours in real world scenarios and compared the site favourably to such instances. Three users said that the site had fewer distractions than in real life and one of these said that this enabled her to focus on the narrated content of the guided tours.

The virtual Giza resource was architecturally designed, and yet accrued benefits compared to the real world sites due to the comforts associated with a virtual system over a visit to Egypt. Reduced physical discomfort has been related to information seeking activity (Agosto 2002b). Real world guided tours were related to distractions by the users, whereas the online tours were said to command their attention, an aspect of the user experience that can affect motivation to explore (Heinstom 2006).

A minority of users compared the resource to other popular and successful exploration experiences. One user compared Giza 3D to an online resource which clickable maps which they believed they had seen on the British Museum website. A significant minority of users compared the system to a game. One of these compared it to an educational game, while one user compared it to the popular video game *Assassin’s Creed 2* because that game contains building with icons which yield background information. In that system, the user related an experience of wandering around, coming across objects, clicking, and feeling interested.

As well as comparing the resource to the real world, the comparison of the resource to a game or interactive 3D resource is relevant in understanding the design attributes that can underpin it, such as “play, interactivity, control, narrative and flow” (Sharp *et al.* 2007) that can make using the 3D digital library a unique experience. These observations, and observations made throughout the analysis, demonstrate that the role of 3D digital design which resembles the built world in sparking interest and curiosity, both factors encouraging motivation to explore; this warrants serious consideration and investigation.

In the walkthrough mode, the presence of walking figures of Egyptians in the system was remarked upon. One user found the figures more believable. One user related period dress to historical realism. One said that the presence of figures made it feel more like she was there. One user said that she learnt what people would wear and how they would behave from the figures. One user wanted to have their own avatar within the system. The role of figures in the system design therefore appears to have increased the user's sense of presence. They played a role in providing a visual narrative of content, with the potential to increase this function through more interactivity or a user avatar.

Wayfinding

The key indicators of wayfinding features are sensory elements (light, view, touch, hearing, and smell), doorways, circulation spaces, vias, crossroads and milestones. A metric that would indicate poor wayfinding would be getting lost or not being able to hold a cognitive map of the environment, with inverse examples indicating a narrative progression through the system.

9.4.3 Enjoyment

The lower response rate to this question may be explained the layout of the paper documents that participants were given to complete, where this question was the only one on the fifth page of the five-page document and may have been missed by some participants.

The median rating for enjoyment of the system was 7, indicating that using Giza was a very enjoyable experience. One respondent referred to the resource as "engaging". Another said that she would definitely recommend the resource. In the focus groups, the overall impression that the system gave was related to a feeling of surprise by one user, when she compared it to the prior user expectation of a 2D website. Another user related the resource to novelty and to enjoyment. These comments cite both surprise and novelty which are said to precipitate curiosity (Garris *et al.* 2002).

9.5 Common Trends

9.5.1 Information Seeking Behaviour and Interaction

On the basis of indications from both 3D digital libraries, it is possible to propose a common framework for information seeking in a 3D digital library. Both 3D digital libraries give preliminary indications that information seeking in such environments involves a process as follows:

- Browsing;
- Noticing objects;
- Where motivation to engage was sufficient an active exploration of the object ensued;
- Exploration of the object was brought to a conclusion, and browsing continued.

A diagram of the process is shown below.

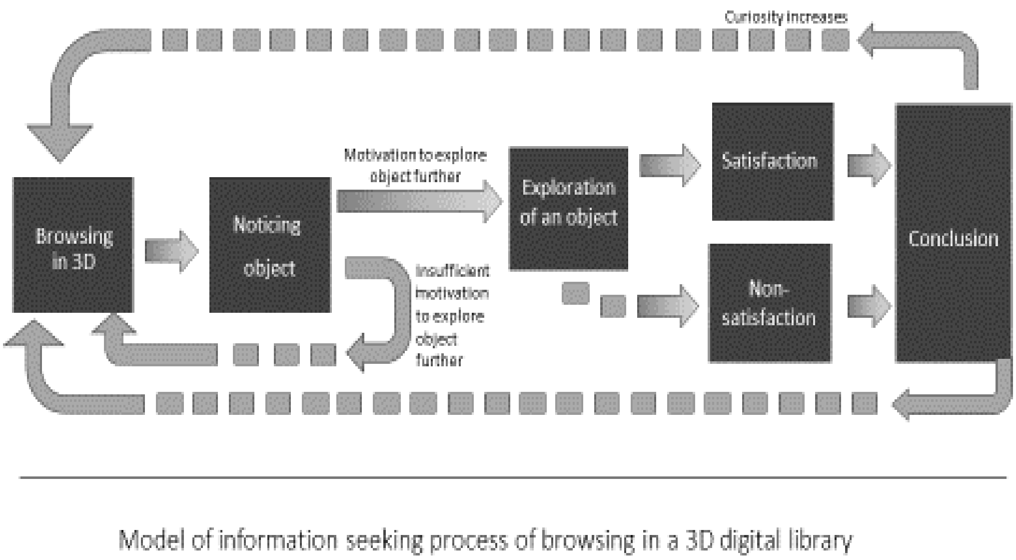

Fig. 44. Model of ISP while browsing in 3D.

This ISP in 3D implicated symbolic acts of presence (Dickey 2005) such as “walking in” or “flying over”, depending on the affordances of the environment. According to findings from both 3D digital libraries, it was then found that the user’s attention was guided towards objects or information artefacts, with users then perceiving the objects. The model illustrates how Sharp *et al.*’s (2007) description of “brow[sing] through information, allowing it guide [her] attention to interesting or salient items” is true of the user’s visual encounter with objects while moving through the 3D space.

Further interaction with the objects depended on the user feeling motivated enough to explore them. A "motivated intention" (Nahl 2007) to know more leads to an engagement or active searching intention, which in the HCI is represented by clicking to explore or advance towards the object. Once information was encountered, it is implied that the user experienced a feeling of satisfaction. This is mirrored in the literature when Kuhlthau (2004) associates satisfaction with the search closure. In the model, satisfaction relates to an ending of cognitive curiosity (see Berlyne 1960, 1967, 1971) with respect to a particular component of the system which reduced the motivating factor to return to the object, and ultimately marks the cessation of the cycle of browsing. The user then "moves on", repeating the 3D browsing process, with the potential to perceive and explore other objects in the system. This continuation of browsing behaviour is also driven by curiosity, with an ending of curiosity usually resulting in the cessation of the whole cycle.

The findings indicate that during this process, the motivation to explore can itself be stimulated by the system. In VG, both "discovering" and "exploring" through interacting with the system result in increased interest and curiosity.

Intervening factors can also influence the information seeking process while browsing in 3D. One of the clearest to emerge from this research is the challenge of navigation in 3D walkthrough or flyover mode. The navigation style introduces "complexity" (Garris *et al.* 2002) to movement through the 3D system, due to the necessity of actuating steps in the 3D space in order to locate information. In the case that navigation induces uncertainty or delayed satisfaction, it can affect motivation to use the system, although other positive factors of using the system can boost motivation to the extent that the user persists in browsing.

Disorientation in 3D digital browsing is also an issue which can result in a lack of cognitive connection with the user's location in the system and an affective experience of uncertainty. The provision of tools which enable steps to be taken to resolve disorientation are welcomed by users.

A variation on the ISB model for 3D digital browsing concerns the activity of watching videos. In the case of video media, findings indicate that the user would select a video and passively watch the content, absorbing the narrative. Successful narratives involved a well-structured story and effects such as close-ups which enhanced the user's sense of presence. In the case that watching the video sparked the user's curiosity to explore other content relating to the subject of the video, they would seek controls on the video that would allow them to explore information elsewhere. The role of controls on the videos was to enhance the user's sense of control and to facilitate a way for the motivating intention to explore elsewhere to be realised. Exploration of a related part of the system would lead to a feeling of understanding and result in satisfaction. The user would then end this part of the search or continue to watch the video. If no controls were available, the user would experience a feeling of frustration and continue to watch the video until the end.

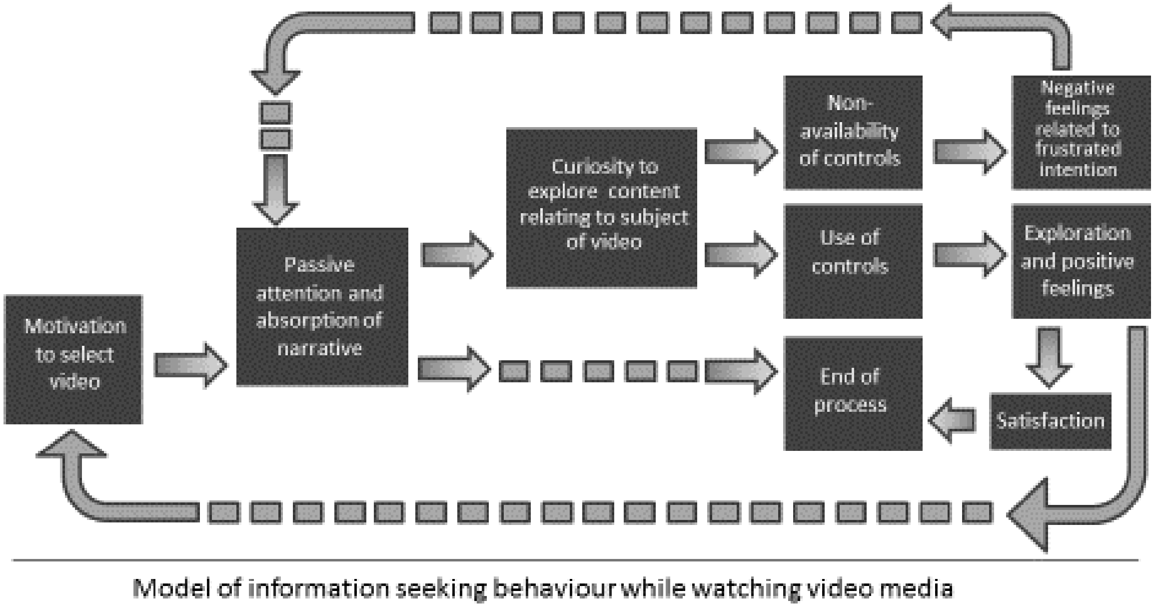

Fig. 45.. Model of information seeking behaviour while watching video media.

Focussing in on a specific part of this model, the non-availability of controls in the video scenario presents a circumstance whereby curiosity is induced, the user experiences motivation to explore, but is then not satisfied because the system does not facilitate that kind of exploration.

Curiosity → Motivation to explore → Interaction to advance towards object → Intention not satisfied (affective frustration)

Fig. 46. Diagram showing non-satisfaction of a motivated intention while using a 3D digital library.

Non-satisfaction of a motivated intention may result in reduced motivation to explore. The associated experience of frustration and tedium may have impacted upon motivation or further information seeking. Fewer instances of non-satisfaction may correspond to a cognitive appreciation of the narrative flow and to enjoyment. In VG, more instances of frustrated intention were experienced in relation to 3D navigation – for example, not being able to access a part of the system, or terminology resulting in lack of clarity. In Giza, the motivated intention was more often frustrated by lack of information in the system, or by limitations in the dynamic linkage of ideas or interactive elements within the system – for example, after clicking on an object and expecting more information.

The above examples of trends in information seeking behaviour support the role of the system in stimulating curiosity and allowing this curiosity to be satisfied through the exploration of information. Successful models which support information exploration without the user experiencing a "frustrated intention" can be said to successfully "scaffold" (Sawyer 2006) access to learning materials in a contextual learning environment to support sense-making. Interactivity, provision of information content, freedom to leave as well as enter an area or media experience, and terminology can all be harnessed to support a successful learning experience.

Relevant citations from the focus groups:

"I liked the going through, ev… like the years. And when it started. So you could see how like the designs had changed. I didn't actually realise until I looked. And then, and then, once you noticed it was quite good, because you could see the different fashions, like cos you clicked on the dresses you could see what who were the models then. So it was, it was really well done." (VG)

"I liked it when you were in the pyramids. You could choose which chambers you wanted to go to so you weren't completely lost, and also when they gave you the brief introductions before it, it wasn't just the perfect time, but they managed to get, sort of, all the right sort of information that you wanted to hear about it and how it links into all the passages and temples leading to the different ones, just in that sort of brief time, which was really good." (Giza)

[Speaking of clickable icons with further information] "Cos it sort of, I don't know. It just gave you a little insight more into the thing you were looking at itself. It was sort of a little bit further than the general introduction, and so that was useful." (Giza)

The use of terminology within both systems prompted the user behaviour of selecting resources to be used (Choo 2000). Where the menu tool enabled the location of sources we associate it with the sense of relief and feeling of satisfaction associated with search closure (Kuhlthau 2004). The use of the menu allowed users to actuate their intention to explore and allowed the user to regulate steps in the exploration process – both steps taken in relation to a motivating intention. The provision of a menu could also support the learning process by facilitating the encounter with information. The menu may have increased a feeling of control and self-efficacy (see Schunk 1991; Wilson 1997; Bandura 1977).

Cases where menu labelling was felt to be not fully explanatory equate to an experience of ambiguity (Gaver *et al.* 2003). Ambiguity was experienced to a greater extent in relation to terminology in VG than in Giza, which in some instances led to the non-satisfaction of a motivated intention, and hence to frustration and feelings of disappointment.

Further investigation on the influence of a map or similar device on the intelligibility of a 3D environment could be warranted. VG users supported the inclusion of a spatial map or of highlighting pathways to facilitate locations awareness – feature that were not present in the system. There is precedent for effective map design for 3D virtual environments. For example, Darken and Sibert (1996) proposed the following principles for map design: show major landmarks and areas and always show the observer's position, orienting the map to the navigator's position.

In Giza, the menu coordinated to colour coding of the complex, which facilitated the user's cognitive map of where they were in the system. The concept of colour coordination has been tried and tested, too. For example, Ruddle (2005) explored the use of trails in a virtual world as a navigational aid. White lines indicating where a user had already been were found to halve the time it took users to find target objects in a virtual world.

9.5.2 Usefulness

Both resources were thought to be useful for their ability to support "learning by doing", which was thought to be transferrable to other visual historical or geographical learning scenarios. Learning by doing was contrasted with more traditional forms of learning in school in both VG and Giza.

Both VG and Giza users indicated that the resources had beneficial elements compared to real world visits. They both achieved a design that served as a museum and a visual communicator of information but that, due to its digital nature and interactive features, was advantageous. In the case of VG, the advantage of viewing an exhibition online was that it could contain much more content and detail.

In Giza, interactive elements added informational and exploratory value to the resource compared to a real-world resource. The design enabled a "bird's eye view" as well as a walkthrough effect, and also achieved an historical recreation. Giza users also considered the resource more comfortable and relaxing than a real-world visit to Giza, an aspect which increased user attention.

VG users stated that the resource was better than a 2D resource. Giza users indicated that the system was relevant in comparison to alternative 2D resources such as a written resource due to enjoyment, and to Google maps due to better information content. VG and Giza users indicated the relevance of the resource over alternative resources especially in relation to exploratory learning, enjoyment, a sense of presence, as well as to accessibility.

VG and Giza users weighed their potential future use of the resource against relevance to an information need, or to its relevance to the subjects that they were studying in their school curriculum. This finding reflects Hong *et al.*'s (2002) study of the determinants of user acceptance of digital libraries, where relevance was the main determinant of perceived usefulness and the main influence on uptake.

9.5.3 Aesthetics

The authority on museum architecture, Giebelhausen, in *The Architecture of Museum: Symbolic Structures, Urban Contexts* (2003) describes the typical museum of Enlightenment modernity which displays all content in a linear fashion, representing the normative aim to curate all knowledge, and making a statement about man's capacity to acquire all knowledge. Both VG and Giza participate in the museum paradigm, with information about a subject constrained within a system and arrayed in a linear fashion. The user is guided by the system through the information contained therein – she is neither pre-eminently co-curator nor is she seeking information "in the wild". Consequently, the VG and Giza users aimed to "do everything"- to explore all of the information within the system; to progress through and ingest information about the subject contained within. The division of the environment into rooms allowed for thematic encounters with the information content. Entering a room involved an encounter (see Tieben *et al*. 2011, Bruner 1973) which resulted in enjoyment (Wilson 1997) and provoked cognitive curiosity (Berlyne 1960, 1967, 1971).

VG and Giza users described the resources using vocabulary which conveyed an impressive encounter with an aesthetic environment, often in relation to stylishness or novelty. "Beauty" and "prettiness" were common perceptions in the user experience. Appreciation of the aesthetic elements of the system suggests enjoyment, which may also increase motivation (Wilson 1997), and make more positive other aspects of the user experience through a "halo effect" (De Angeli *et al.* 2006). Meanwhile, the "novelty" or uniqueness noted by a minority of users may also precipitate curiosity, according to Tieben *et al.* (2011) and Garris *et al.* (2002).

The aesthetic appeal of ornamentation differed between systems. Ornamentation of the environment was perceived to be sparse in VG and this was thought be unattractive to several users, which may have made the website less engaging, which may result in boredom or ceasing information seeking (Agosto 2002b). In contrast, the extent of detailed ornamentation in Giza was appreciated and enjoyed by Giza users. This indicates the role of ornamentation in contributing to the aesthetic experience. In both VG and Giza, the challenges of achieving realism in digital design can impact upon the perception of beauty.

As well as participating in attractiveness, the findings indicate that ornamentation, in both VG and Giza, had a cognitive value (Heinstrom 2006) which affected attention, as well as contributing to spatial awareness. This suggests that judiciously applied ornamentation could be used to focus attention on salient parts of the system, directing the user's attention towards information object. For example, in VG, the use of motif played a guiding role in the system, with possible relations to knowledge construction (see Dervin 1983), whereby the user was given the information needed to understand the gap between the existing situation and new information.

In both VG and Giza, users found it difficult to distinguish between parts of the design, due to lack of distinctiveness and contrast in the design. This was related to their lack of spatial awareness. This corroborates the assertion of Vinson (1999) that landmarks in virtual worlds should be sufficiently distinctive both in their own right and in relation to surroundings, as well as visible.

The notion of experiential learning in an immersive environment could be connected to the fact that encounter, discovery and sense-making take place within a virtual environment – a reality describing a type of "immersion" appropriate to a 3D interface on a 2D screen. Minocha and Mount's (2009) synthesis of the literature of virtual environments found that there was ambiguity surrounding the term immersion. Yee (2007) notes that "immersion" can be used differently depending on source characteristics: "whereas immersion used in the context of VR most commonly relates to Steuer's (1992) ideas of telepresence, the immersion associated with MMOs [massively multiplayer online game] and virtual worlds is more closely aligned to notions of engagement". Both user groups included participants who referred to presence in the system through the notion of symbolic presence, feeling like they were "really there". In the case of Giza, "stepping into" the system was said to bring about an increased sense of immediacy.

In both VG and Giza, users reported lesser engagement with the text compared to the 3D objects. The text was also reported to be unengaging. In VG, but not so much in Giza, the small font size made reading difficult and uncomfortable, causing users not to read, or prompting them to make adjustments.

9.5.4 Psychological Aspects of the User Experience

Source attributes such the facility of the resources to allow users to explore individually rather than as part of a group appear to have increased the users' sense of control and freedom. In both VG and Giza, this appears to have occurred because increased control could allow the user to accomplish what they want to and perhaps also influence their feeling of self-efficacy.

Furthermore, the Giza data suggests that the user's control within the system related to a sense of diversion, escapism or emotional release, the contents of the transcripts corresponding to these three notions as found in McQuail (1972). Control resulted in a calmer experience, with fewer instances of the frustration as related in the diagram showing non-satisfaction of motivated intentions. The most common descriptor used by Giza participants themselves was "relaxing". There were more instances of Giza users' referring positively to control whereas VG users related more instances of frustrated control in comparison.

It is notable that the teachers stated that a benefit of the resource would be for individual project work or homework learning, and would encourage more "ownership" of a learning task. If the resources were used in this way it would represent a pedagogical harnessing of the ability of the resources to enhance individual discovery and exploration.

Both VG and Giza users enjoyed using the resource, a factor which Wilson (1997) states may affect motivation, and which Zillmann (1988) states may prolong searching behaviour. The role of enjoyment or fun is regarded as a key adjunct of usability criteria for children's games by Baauw *et al.* (2005) and Bekker *et al.* (2007).

VG and Giza users both reported increased interest in the subject matter as a result of using the respective resources. This indicates that regardless of the users' initial interest in the subject matter, interest was also increased in the context of the 3D digital libraries.

"I know more about it now. Like, before, it was just sort of a name that you hear, but you wouldn't really take it in very much. And now you just sort of think "oh, well he's been around since then" and stuff." (VG)

Giza was successful insofar as it was reported to have increased users' interest in both the subject and in the location in Egypt. Users may have expressed initial interest in choosing Giza above the other 3D digital libraries offered, but interest can also be increased in an instructional context.

Use of Giza also correlated with increased curiosity and new information needs which would need to be fulfilled beyond the system.

9.5.5 Learnability

Learning how to orientate was related to an affective experience of confusion in both VG and Giza. In VG, time investment was also a factor in learnability, but some users stated that learning to use the system was an acceptable use of time. Both VG and Giza users strove and persisted to learn how to navigate. In Giza, while more extensive or clearer instructions could have resulted in increased control and competence (Weisz and Cameron 1985), motivation was high enough among users to continue to strive to master the steps required in navigation, and using the system having overcome this obstacle was associated with enjoyment.

9.6 Trends Unique to Each 3D digital library

9.6.1 Aesthetics

In Giza, the role of figures in the system design appears to have increased the user's sense of presence. They played a role in providing a visual narrative of content, with the potential to increase this function through more interactivity or a user avatar. The lack of figures was noted in VG.

"Researcher: What did you think of the people?

Speaker 1: They were really great.

Speaker 2: I thought it made it more interesting.

Speaker 3: It made it more believable.

Speaker 4: It made it feel more like you were there.

Speaker 5: And they were wearing traditional sort of clothing that would've been.

Speaker 6: You were more like in the old days." (Giza)

"Speaker 1: It was really empty. I think it was a bit eerie. I mean it, was it, was great.

Speaker 2: I think it would've seen a lot less plain, per se, if there were people walking around." (VG)

Ibáñez and Delgado-Mata (2011) have summarised some ways in which virtual humans can be programmed to provide a more interactive experience for users. They cite how virtual humans can give directions or transport users to locations (van Dijk *et al.* 2001). Virtual humans can also serve to orientate the user by pointing out objects or pathways (Wernert and Hanson, 1999). They also cite examples whereby characters can also act as presenters of information (Nijholt 2006) or as storytellers (El-Nasr *et al.* 2008).

However, while the addition of virtual humans is very common in virtual environments (Ibáñez and Delgado-Mata 2011), both Norman (1994) and Dehn and van Mulken (2000) caution that users can have exaggerated expectations of virtual humans, since they assert that humans tend to anthropomorphise and attribute intelligence to the slightest human-like action. This reality can result in the problem of generating wrong expectations (Ibáñez and Delgado-Mata 2011). They therefore suggest that populating a virtual environment with animals can be a more secure way of improving the user experience and improve realism (Ibáñez and Delgado-Mata 2011). If human figures are used, then consistency is important, they insist, so as not to generate too high expectations of realistic behaviour where it cannot be achieved (Ibáñez and Delgado-Mata 2011).

9.6.2 Psychological Aspects of the User Experience

A unique component of Giza was the reports of a "relaxing" or "calm" user experience. One reason for this aspect being unique to Giza may be user responses to the ambient music. Whereas in Giza sensory elements such as the music were helpful in creating a pleasant and relaxing experience, music was disliked by significant numbers of VG users in the usability questionnaires. Pleasurable feelings in response to the music may have contributed to an experience of gratification (see Wilson 1997), which is defined as providing diversion, escapism and emotional release (McQuail 1972). This in turn can affect motivation, and perhaps the motivational state in which the user is approaching the task (see Kracker and Wang 2002; Nahl 2005; Nahl-Jakobovits and Jakobovits 1985; Johnson and Macrae 1994; Wilson 1997).

A second reason why a feeling of relaxation may have been uniquely mentioned in Giza was that the users reported fewer difficulties in going where they wanted to go during the focus groups, using a range of tools to navigate, including the menu. This may have increased the users' sense of control, and this sense of control may explain users' association of relaxation and freedom. One user stated that the system was relaxing because she had "freedom" and could "wander". The 3D system was associated, by one user, with going round "yourself" (i.e. in a self-directed fashion). The system was associated, by another user, with looking around according to interest, and this was associated to freedom of movement and lack of constraint whereby the user experienced choice as to where they went and what they did.

9.6.3 Usability Problems

Excessive loading times were present at the initiation of Giza. In one case this lead directly to stopping information seeking, by switching to VG instead. Excessive loading times relate to boredom (Agosto 2002b) and this can influence task abandonment. One user's toleration of the initial delay may be attributed to the user's higher motivation or the action of a combination of motivational variables.

9.7 Conclusion

The analysis of the research findings of laboratory trials and a qualitative research methodology involving focus groups has yielded potentially valuable findings in the investigation of 3D digital libraries through an analytical perspective of both 2D and 3D design approaches in relation to the user experience.

Although the results are limited to a fairly homogenous group of users and a single educational application of just two emergent 3D digital libraries, their unique contribution emerges from the design and application of a methodology which is capable of addressing the 3D reality of 3D digital design, which HCI from a 2D perspective, even when considering the 3D interface, has hitherto not been addressed. The consideration of user information behaviour in relation to a defined list from a combined model of HCI and architectural principles allowed analysis to focus precisely on the role that 3D design can play in the learner experience.

The findings represent only an emergent picture, and it is expected that the methodological approach can be effectively replicated in different circumstances, with perhaps different 3D digital libraries, user groups, and with refinements to the task as presented in the educational setting. The precise contribution of the findings to knowledge of the role of 3D design on the user experience is discussed and evaluated in the following Conclusion chapter. In this subsequent chapter we also consider how further research could build upon these conclusions to begin to form a new body of design and behaviour research in relation to 3D digital libraries and their users.

Chapter 10: Conclusion

10.1 Introduction

The study set out to explore the applicability of classical architectural criteria to 3D digital library design and the influence of design and user behaviour. It has identified the principles from architecture and HCI which are relevant to analysing the design of a 3D digital library, and the theoretical approaches from information seeking behaviour which are relevant to the analysis of user behaviour with 3D digital libraries. Through a methodological approach which is capable of taking into account these interdisciplinary design principles, the study explored their role in the user experience with 3D digital libraries. It has thus identified the nature of the user experience with 3D digital libraries in the school context with 14-15 year-olds including the types of information behaviour occurring during and in the 7 subsequent months after use of a 3D digital library, and the role of design in the user experience and information seeking in the 3D environment by identifying examples from the data and suggesting implications for further study.

The study inserts itself within the existing theoretical and industry literature addressing 3D digital design and virtual worlds which considers the role of architectural principles (e.g. Gibson 1986; Darken 1995; Bridges and Charitos 1997; McGregor 2006; Minocha and Mount 2009; Pratschke 2011; Hernandez Ibanez and Naya 2012; Jones 2012). Meanwhile, the outlined research context (see 1.2) pointed to the emergence of 3D virtual worlds and their potential relevance in the learning environment. This situation raised several questions. Firstly, it was opportune to clarify assertions in the literature as to the role of architecture in the design of virtual worlds by, after selecting and defining the parameters of a 3D digital library, asking RQ1) What are the key criteria relevant to the design of 3D digital libraries?, through a review of design literature emanating from HCI and architecture. Secondly, having established a design framework for investigating 3D digital libraries, the experimental methodology incorporating a usability trial with qualitative exploration of the user experience in focus groups with 14-15 year old school girls yielded data for analysis of three further research questions: RQ2) How do 3D digital libraries encourage exploration and curiosity?; RQ3) What types of information behaviours take place with 3D digital libraries?; RQ4) In what ways do 3D digital libraries deliver benefits to the learning experience? The experimental methodology, in turn, allowed us to further clarify RQ1, by concluding which principles from HCI and architecture were truly operative in the selected environment, and to further explore the relations mapped in *Fig. 5* the Model showing the association of HCI and architectural principles for the design of 3D digital libraries. In this chapter, we draw together the analyses of the data and reach conclusions to the research questions.

10.2 Conclusions

Research Question 1) What are the key criteria relevant to the design of 3D digital libraries?

The literature reviews yielded a framework of principles for exploring 3D digital libraries from a design perspective. The conclusions we propose for research Question 1) are therefore central in the research, since findings can either validate the model advanced in *Figure 5*, or challenge it. In answering this question, we therefore revisit the model, then summarise the main research findings in relation to this question, and finally revisit the model to suggest the strength of relationships laid out.

The model (*Fig 5)*, repeated below, at *Fig. 47*, proposed a generic validity of the Vitruvian principles of beauty (*venustas*), fitness for purpose (*utilitas*) and robustness (*firmitas*) (Vitruvius 1966) as top-level considerations driving the application of more specific architectural and HCI principles in 3D digital libraries, with the main contextual consideration being that robustness has specific applications to the 3D virtual space which is navigable by users, and so robustness is constituted by principles facilitating the user´s movement through the 3D virtual space.

In turn, the key criteria from classical architecture and usability/usefulness and user interface design literature reviewed at the beginning of the study are summarised below.

Principles from classical architecture making a 3D digital library aesthetically pleasing:

- Beauty
- Symmetry
- Proportionality
- Ornamentation
- Propriety
- Arrangement

Principles from usability/usefulness and user interface design making a 3D digital library aesthetically pleasing:

- Text
- Graphics
- Scenery

The full list of principles making a 3D digital library fit for purpose is given below, with all emanating from usability/usefulness literature primarily, apart from “commodity”, which is a principle of classical architecture and whose role as a key criterion will be summarised later in the chapter.

- Commodity
- Effectiveness
- Relevance
- Reliability
- Currency
- Credibility

The list of principles relating to “robustness” of the 3D digital library, and thus concerning how the 3D digital library is designed for navigation and especially to facilitate movement through the 3D space, are listed below. All of these principles emanate principally from the usability/usefulness literature, with “wayfinding” being an architectural concept.

- Efficiency
- Terminology
- Navigation
- Learnability
- Wayfinding

From these groupings of principles it can be seen that the proposed classical architectural principles, referring mostly to dimensional design, are most operative in the realm of the aesthetics of a system, creating a 3D visual experience that goes beyond the defined criteria from graphic interface design. The HCI principles remain salient especially in the matter of the “robustness” of a 3D digital library, since the overall navigability of a system remains very important in the user experience and it can be argued that aspects such as “efficiency” and the effectiveness of terminology in the user experience clearly impinge upon the user´s navigation through the system. The addition of “wayfinding” as an architectural conception to our existing ideas of tools and techniques that make navigation in a 3D space more user friendly demonstrates how the different tenor of 3D aesthetics and dimensionality in architecture are also operative in the 3D space. For example, an architectural wayfinding feature such as a crossroads or an archway can insert themselves into the user exploration of the 3D space in a way that guides and creates a narrative user experience that goes beyond the realms of more functional HCI navigation tools.

Our model of combined 3D architectural and HCI criteria frames existing discourses by proposing a combined function of interdisciplinary design principles in the 3D reality. It is anticipated that while the model is open to future refinement, it successfully encapsulates the speculative angle of the research into the dual operation of architectural and HCI principles and so is a departure point for the discussion which follows. Framing design research into 3D digital worlds in this way is original and salient – supported in the literature – and thanks to the research findings can now be further interrogated as to its applicability.

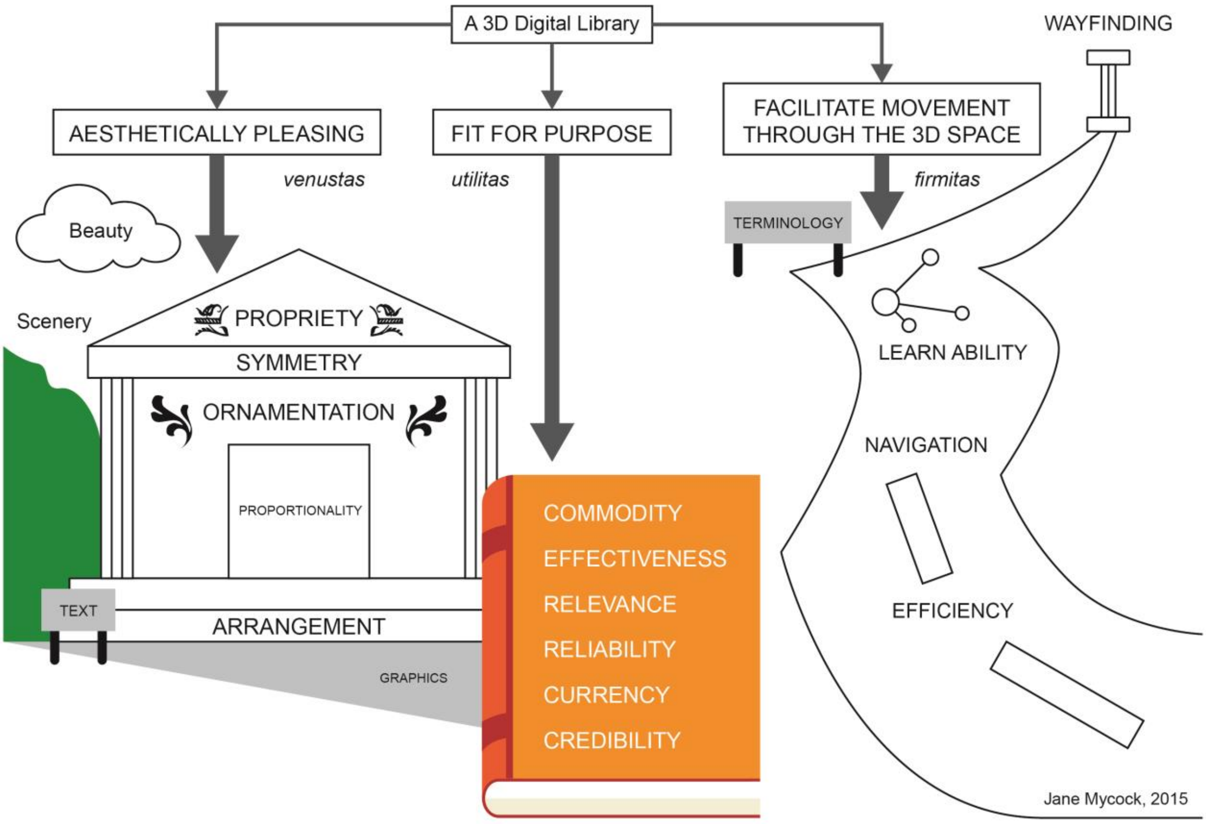

Fig. 47. Model showing the association of HCI and architectural principles for the design of 3D digital libraries.

We now go on to summarise the main conclusions of the research in relation to Research Question 1 in relation to the model. Following the conclusions, we revisit the model and ask whether it is applicable to the 3D digital libraries investigated in the experimental research. The most novel relationships brought to light by the model are arguably:

> the role of "commodity" as an aspect relating closely to usefulness principles - how is this defined and how is it distinct?;
>
> the importance – if any – of visual aspects such as ornamentation, especially if one is used to a more functional approach where such aspects might be assumed to have a communicative role restricted to the merely decorative;

and finally the notion of wayfinding and how it relates to navigation – again, are architectural features truly salient or merely superficial in the user experience?

The findings are capable of addressing these three points in turn. Firstly, the findings indicate that 3D digital libraries were conceived as resources that users "visit", giving them a sense of exploring an environment, and on first appearances this reflects the architectural notion of "commodity". If in the architectural literature, a "commodious" environment is one that conveys a specific purpose - in the case of a 3D digital library, we argue that it essentially and quintessentially facilitates a user visit and encourages exploration. The research suggested that users conceived of resources as places to be "visited" and consistently had a sense of exploring the environment. Some of the most positive examples of engagement with the resources were driven by indications that users experienced a sense of presence. When users compared visiting the resources to real-world visits and to school trips they did so both favourably, esteeming the real-world antecedents and the advantages of using the 3D digital libraries over the inconveniences of the real-world environment. On this basis, we conclude that user engagement was positively related to whether the resources effectively conveyed either an exhibition environment (VG) or an historical site (Giza). Although the experimental design did not investigate this relationship for its statistical significance, we are able to conclude from qualitative study and from reviewing the literature that having a sense of a meaningful, accessible environment to explore, was an important driver of the positive user experience. We suggest that the user response to a commodious 3D digital library evokes mental maps (see Minocha and Reeves 2009) of real world experiences, yet harnesses the affordances of digital technology to co-locate content and create new interactions with it. Our research indicates that visual realism may also relate to credibility, since we argue that credibility of a 3D virtual environment depends not only on information content but also the quality of the visual interface.

Furthermore, the use of lifelike figures or avatars within the system can be pinned to this concept of commodity, since the findings indicate that users found that they added realism to the environment. The findings suggest that figures or avatars can make the resource seem more lifelike to users and add historical realism. When comparing findings relating to the use of VG over Giza 3D the contrast emerges between users who noted that the system felt barren without figures or avatars on the one hand, and users who were highly engaged and showed curiosity about the figures when exploring the system, and started to formulate independent questions about the subject matter of the resource as a result of interacting with them. We consider the role of avatars in creating a more lifelike experience to be worthy of further investigation, especially in their hypothetical relationship with the architectural criteria of commodity. It is true that the use of an avatar or figure could be “pinned” to existing HCI or aesthetic criteria, as an aspect of the graphic user interface or as an effective communicator of information, yet the findings suggest that figures in the system played a role that was more than decorative or informative – rather, the findings suggest, they were a part of the in world experience and played a role in the sense of presence, precisely the quality that we conclude is effectively represented by 3D design in the principle of commodity.

Our findings indicate that principles associated with aesthetics such as ornamentation improve attractiveness and promotes user engagement with the system content. Whereas motifs conveyed specific information – for example the eye of Horus on a boat in Giza – ornamentation does not have an informational purpose as such but rather participates in the commodious and aesthetically pleasing design of the 3D digital library by creating an impression that is true-to-life and credible.

The role of ornamentation and other aesthetic principles from architecture in the virtual world is therefore an important one which may modify existing standards for aesthetics on the 2D visual plain in computing, where traditionally, minimalism is favoured (see Nielsen 1995). One reason for stating this is that several users described the “plainness” of VG in negative terms, contrasting with their appreciation and engagement with beautiful or even superfluously beautiful detail. In design schematics for 2D websites it is often the case that “simplicity” is proposed as an effective aspect of attractiveness (Mullet and Sano 1995; Minocha and Mount 2009). The idea of literal or figurative “white space” features especially in 2D website design because of its cognitive role in attention and in allowing to users to accomplish functional tasks (Boulton 2007). The findings of our focus groups suggest that the virtual environment differs since users respond positively to superfluous ornamentation and therefore suggests the applicability of architectural principles for their aesthetic value, as proposed in the model.

The model also connects the architectural principle of wayfinding to HCI principles that help the 3D virtual world to be navigable. Since HCI principles relevant especially to 3D spaces and gaming have already been proposed and are a part of the most recent student literature on the subject (e.g. Shneiderman and Plaisant 2010), is there any role for proposing an architectural principle of ancient provenance as having applicability apart from the techniques developed in human-computer interaction? The most important constituent of architectural wayfinding is the use of features in the environment to mediate and guide exploration. In some cases, these features have a status as mere motifs, corresponding to a visual form of terminology in the virtual world in order to communicate function or direction to the user. For example, a dress or image at the entrance to a room in VG could be said to be a 3D feature helping with navigation in world. Architectural wayfinding additionally focusses on the user´s progression through a space – wayfinding is not only static but relies on the optics revealed to those moving through a city (Lynch 1959). In this case, the relationship of dimensional shape, space and design to user navigation is illuminated. For example, our findings suggest that scale is an important part of the user experience, with navigation speeds combining with scale in design conveying the scale of a virtual environment. In addition, when navigation speeds were varied in the context of magnitude in design this conveyed the scale of a virtual environment to the user who was navigating through it. Thus, 3D digital design gives designers the ability and facility to decide the relationship between architecture and the user in terms of magnitude combining both navigation techniques from HCI and wayfinding design techniques from architecture. Although navigation and its related principles are traditionally a usability concern, in considering HCI in the 3D digital space the role of 3D features in wayfinding also play a part.

The findings fit with an architectural way of conceiving of the 3D digital library, but we can now also re-evaluate the model to consider which relationships emerge from the findings, and which, as yet, are weaker. Furthermore, although architectural principles are apparently apt, it is also ripe to consider at the close of research whether other design apart from the direct application of architectural principles could account for the findings above, and as a result conclude whether the model adds value to existing readings of 3D digital environments or readings taken from traditional HCI.

When it comes to the principles proposed as normative in the Model of associated criteria from architecture and HCI, the findings present stronger indications for the applicability of some principles which were asserted in the original model, over others.

Considering those principles thought to pertain to an aesthetically pleasing environment, denoting *venustas* the following principles emerged more strongly from the findings:

- Beauty – corresponding most clearly to the user's finding the 3D digital library visually "impressive" and so perhaps also having some relation to the novelty of the presentation
- Use of impressive scenery and detailed graphics as ways in which beauty was perceived
- Ornamentation, as an aspect through which beauty was perceived which increased the aesthetic appeal of the system and users' engagement with it
- Use of appropriate text – however comments on the text size and colour pertained to readability as well as aesthetic considerations

- Propriety (appropriate magnitude) – played a communicative role and added to the user's impression of the scale of the environment, especially when combined with movement, since taking a long time to traverse a section connoted magnitude
- Propriety (sensitivity to environment) – although not situated in a real world context, and therefore representing a self-contained environment, which is realistically rarely possible for built world architects, the appropriateness of all components as comprising a credible environment added to the users' appreciation of the system
- Arrangement strongly influenced how users explored the system and encountered information within it

However, the following aesthetic principles were not strongly evidenced in this study:

- Proportionality – no ratios could be seen to be applied systematically throughout the design of the resource and no strong theme related to the proportionality of the system could be ascertained in the findings
- Symmetry – the only user responses to symmetry were negative responses, when the use of symmetry in the system was thought to impede the differentiation between parts. We suggest that this result down to the failure of graphic design, which should differentiate effectively between parts using techniques such as contrast (Mullet and Sano 1995), rather than a failure of symmetry *per se*, since not enough evidence can be found to reach that conclusion

In the examples above for which stronger affirmative conclusions can be made, it is evident that some of them impinge not only on the aesthetically pleasing result of the system, but to its fitness for purpose (*utilitas*). We suggest that this is because the association of architecture with the 3D space is so intrinsic that it naturally effects the user experience in ways beyond the aesthetic and can also impinge on information seeking processes, as we see with the principle of the arrangement of the spaces within an environment, where arrangement affects the way in which users explore the environment and the information contained within it. Thus arrangement, especially, was associated more strongly with the "fitness" of the system as a communicator of information content in the findings, than it was with the aesthetic pleasingness of the system. Text, too, had an aesthetic role, but also a utilitarian one insofar as text style helped or hindered readability. Indeed, all of the principles associated with aesthetic pleasingness, above, can be said to impinge on the fitness of the system to some extent. For example, propriety and beauty, as seen in scenery, graphics and ornamentation all serve as communicators of the subject of the 3D digital library itself. As Giebelhausen (2008) said of the built world museum, "the museum *is* the architecture", and so it can be said of the 3D digital libraries where, like a classical or modernist museum, the architecture itself communicates to us the collections and the subject of the resource.

When we move on to consider the principles which were cited as constituting “fitness for purpose” in the original model, we can therefore move arrangement more closely into this association in a future model, and can present “text” as bridging both aesthetic and “fitness” principles. The following principles which were cited in the original model as elements of *utilitas*, emerged more strongly from the findings:

- Relevance – use of the systems was especially predicated on the users’ information needs prior to and after using the system
- Commodity appears to be the overarching term that describes the effectiveness of the system in achieving the practical ends of users and conveying a certain environment. Commodity can be said to be analogous to “effectiveness” in the 3D digital context, and is related to the overall credibility of the system, too.

The following principles connoting “fitness for purpose” were less evident in the findings:

- Reliablity – although the users did not explicitly identify whether they thought the resources were reliable or not, instead showing implicit trust in the contents as learning materials, the value of the resources is evident as informative resources on a specific subject area as opposed to, for example, search engines, where the content is of less certain provenance and reliability.
- Currency – users did not strongly reference the currency of the content, but it could be inferred that the currency of the computer generated graphics was also important in conveying that the system was “up to date”.
- Credibility – users did not strongly reference the credibility of the resource, *per se*, but we suggest that for the user group, the aesthetics and commodity of the system positively influenced their impression of the exploration task which may have extended to a more positive impression of the system’s credibility.

For the above three points, although reliability, currency and credibility might be thought to be important to teachers when they select which resources to use in the school environment, these did not emerge in the data of from the focus group with teachers either.

The following themes were all identified as principles of facilitating movement through the 3D space (the principle end of *firmitas* in the 3D space) in the original model and also emerged as themes in the experimental research findings.

- Navigation was a crucial component in a 3D walkthrough system and was closely related to Wayfinding and to Terminology.
- Orientation was another component of Navigation which referred to the ease or difficulty of moving around the 3D space using the tools and methods available.
- Learnability was a key theme to emerge referring to the user's being able to grasp how to move around the system – however, users were able to tolerate some cognitive efforts required in learning to orientate
- Efficiency – efficiency was important in relation to the component steps in orientation / navigation. However, efficiency in retrieving discreet pieces of information was of less salience to the scope of what a 3D digital library can offer since it the 3D digital library is not ordered primarily to information retrieval.

Before we present a reformulated Model of relationships between HCI and classical architectural criteria in the light of research findings, it is worth interrogating the integrity of the model in the first place. In 2.5 we suggested that future directions in interactive digital design could follow the trajectory of an architectural metaphor, and could also follow other interaction design principles from the real world, such as Norman's (2013) principles for the design of everyday things. As a result of the experimental component of the study, can we throw further light on the following questions which pertain to the future of HCI:

1) Can the findings be accounted for by other representative frameworks from 3D non-HCI design, such as, for example, the principles for the design of everyday objects proposed by Norman (2013)?
2) If architecture is an appropriate representational framework, is there value in isolating principles specifically from the classical canon?

The first question asks us to whether the findings can be adequately supported by an alternative representative framework such as theories already current in interaction design, such as Norman's (2013) principles for everyday object design, or indeed, by more perennial HCI frameworks such as Nielsen's (1995). Each of Norman's (2013) principles: discoverability, feedback, conceptual models, affordances, signifiers, mapping and constraints, resonate with the research findings. The user's being able to understand what action was possible with each interactive element was crucial to their learning to use the system. Feedback was expected to be instantaneous, with user interaction having an immediately perceivable effect within the system. Insofar as conceptual models were used in the 3D space, it can be argued that the entire 3D digital library *is* a conceptual model, since none of the bricks and mortar are real, and the whole effect is to convey an explorable learning environment. Mapping was found to be an important element of the user experience, with lack of effective mapping proving problematic for some users. Finally, constraints were an important interaction principle within the 3D environment since they determined the paths and steps that could be taken by system users. All of these elements refer to interaction design, which is an important element of movement in the 3D space, and is therefore inserted in the diagram under the *firmitas* section of the Vitruvian triad.

Perhaps the most interesting synergy with interaction design principles and architecture, which emerges consistently in the analysis, is that motifs, as an element of commodious design, can be said to correspond closely to the idea of "affordances" (Norman 2013; Minocha and Mount 2009). If the overall appropriateness and connotation of the environment encapsulates the notion of commodious design, and motifs serve that as component parts, affordances which suggest a particular function at the component level correspond closely to the use of motifs in the 3D reality. Hence, motifs as a component of commodity are said to be closely related with affordances in interaction design, and this association is made clear in the revised diagram. The analogy between affordances and motifs can said to me so strong, that it moves beyond the mere *firmitas* of the system, and forms a part of the system's *utilitas*, or fitness for purpose. Since none of the principles impinge as strongly on the aesthetic values of the 3D digital library, they can be said to only play a part in the overall design of the system, and do not displace architecture as a key interpretive lens. Indeed, the aesthetic principles advanced in HCI alone do not account for the non-minimalised and ornamented design that is considered effective in the 3D digital library, nor for the arrangement of elements which are a component of the environment's "fitness".

The Model is striking for its use of a temple-like portico in a classical landscape – a scene reminiscent of an archetypal classical environment. Latterly, portrayals such as these were dismissed by Giebelhausen (2008) as "Arcadian and ideal" or "theoretical" in tenor. However archaic this may seem, the findings indicate that the architectural, or dimensional aspect of the 3D digital library does give the environment its meaning. Classical museum architecture, Giebelhausen contends (2008), was intended "to change the visitor's register from the everyday to the contemplative", and this is also the effect achieved by architectural design in the 3D digital libraries investigated, we suggest. The fascination and feeling of novelty evoked by both Giza 3D and Valentino suggest that the experience took the participants away from the quotidian and was thus exciting. In this sense, there is something of the classical didactic approach in the construction of a 3D digital environment, especially when the user is immersed in a time or place of interest, and the environment presents itself unabashedly so without critical reference to the irony of creating another "world". Indeed, even though Valentino owed some of its aesthetics to the “white cube” style of gallery (see O’Doherty 1999), according to Giebelhausen (2008) this still has a didactic thrust, since this type of display, along with the classical, “aimed to construct a contextual, educational, or illustrative connection between the objects and the overall gallery space”. Furthermore, the reproduction of the “white cube” style in a virtual space makes Valentino somewhat conservative – ironic, given that it is taking place in the contemporary and futuristic environment of the 3D digital space. Both Giza and Valentino rely heavily on the “history of the building type” and the expectation that it will always “be available in the mind” (Smith 1995). Far from the architecture “disappearing” (Teniguctii) in the 3D digital library, the architecture, and moreover the use of traditional forms, does not meaning that in many cases, just as in the built museum, the “architecture *is* the museum”. This does not delimit future studies to considering only the classical canon in architecture, but, as we argued in 3.2, it is an appropriate reflection of the range of extant 3D digital libraries and forms a basis from which new theoretical directions in architecture can be taken in future research.

The key changes which are made to the model below are the removal of some principles, due to limited evidence in this research: symmetry and proportionality are removed from the “aesthetically pleasing” principles, and currency, credibility and reliability from the “fit for purpose” principles. This is not to say that the principles are no longer operative - indeed they are well established within their respective literatures – but merely that they are not advanced within this combined model because they were not key themes emerging from the research. Another change is that “graphics” is made more central within the stylised classical temple, and represented by a person since this figure represents the population of the system with engaging graphics such as figures or milestones. “Text” is moved to an area between the “aesthetically pleasing” and “fit for purpose” principles since the findings show that text has aesthetic qualities and utilitarian qualities such as being readable. In the central “fit for purpose” section, “motifs” are inserted (they were previously not mentioned separately since they were held to be a sub-principle of commodity) and listed as analogous to “affordances” (Norman 2013, Minocha and Reeves 2009), since both motifs and affordances were prominent in the findings. To the right of the diagram, “orientation” is added close to “navigation” due to the importance of orientation as a function of navigation in the 3D space emerging in the findings, and “interaction design principles” summarises the emerging principles relevant to 3D interaction in HCI which optimise the user experience of *firmitas*. These principles exist alongside the traditional HCI and architectural principles that were found to be applicable in the findings and analysis of results.

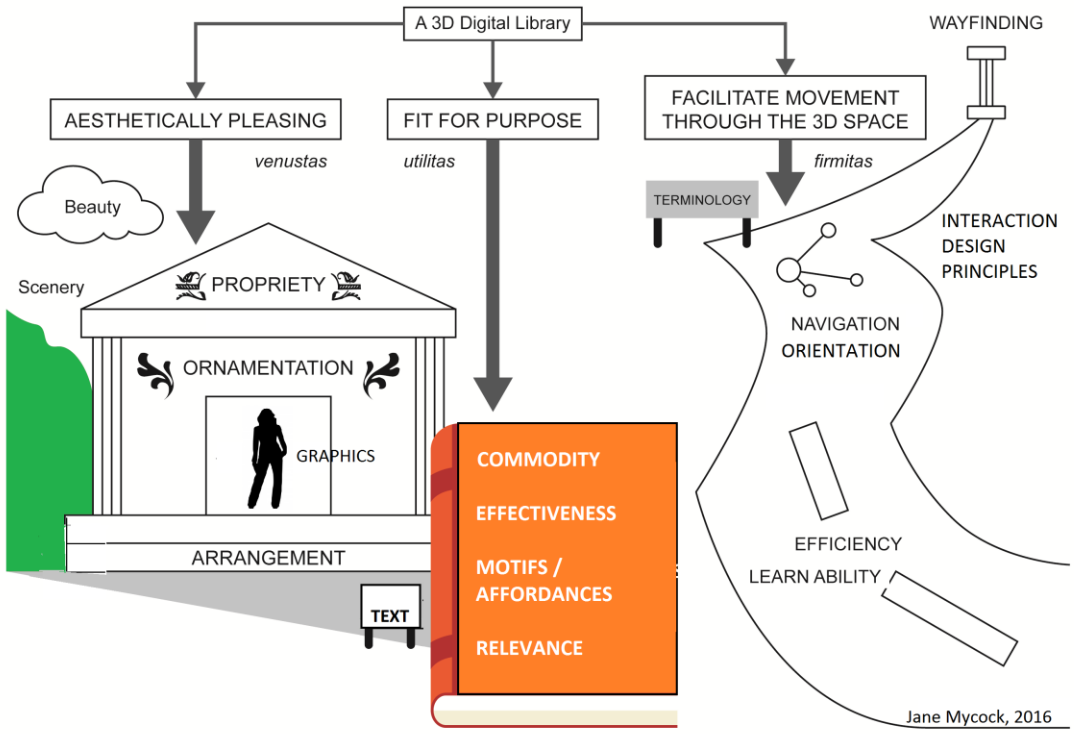

Fig. 48. Revised Model showing the association of HCI and architectural principles for the design of 3D digital libraries.

The discussion of findings relating to Research Questions 2 and 3 now follows, with findings considering the role of design in the user experience of exploration, curiosity and information seeking.

Research Question 2) How do 3D digital libraries encourage exploration and curiosity?

Our main conclusions as to the role of 3D digital libraries in encouraging exploration and curiosity are summarised as follow:

> 3D digital libraries facilitate a virtual "visit" to a place or time within the classroom and therefore contribute to students' experiential learning.
>
> Component features within a 3D digital library can be applied to encourage users to explore and to encounter information in the 3D world.
>
> Allowing the user to explore individually gave users a feeling of individual control as to what content to engage with during their use of the 3D digital library.

Our findings suggest that users conceive of visiting a 3D digital library which contributes to the sense of exploring an environment. Users regularly made statements to the effect that they "were there" within a real environment or used related vocabulary such as "lifelike" to compare it to antecedent real-world environments and analogue artefacts within them. Users used vocabulary of movement relating to a sense of presence (e.g. "coming in", "standing", "going"). The sense of exploring an environment was balanced by examples of awareness of participating in a virtual reality which merged facets of both real world and virtually enabled exploration of both place and information. Simply by offering a virtual experience that allows movement through a 3D space and the exploration of a place, the resources encouraged users to explore. We suggest that the success of systems in conveying a sense of presence is a measure of commodity in the virtual world. We argue that 3D digital libraries therefore provide a natural option for teachers seeking to encourage exploration of time or place within the classroom environment. The users of both resource made comparisons with school trips and outings, with museum visits and with tourism, and hence, we conclude that the specific role of the 3D digital library in the classroom is to provide a visit-like experience through remote access to a virtual world. Additionally, where 3D digital libraries are compared to the real world construct and mirror of the school trip, they may confer some benefits. Focus groups indicate that the perceived comfort of the resource in contrast to other modes of exploration – among them the "real world" as well as traditional lessons and reading - could positively influence users to explore. Users also indicated that their attention was improved at key aspects of the experience of using their chosen resource as a result of the lack of peripheral uncomfortable aspects which constitute a real world visit to a site such as Giza or a museum.

Therefore, 3D digital libraries arguably have an application in the learning environment where a variety of teaching and learning approaches are applied to help students fully grasp a subject. Among these, experiential learning, which involves the learner as creator of learning, and not just as a passive recipient (Kolb and Fry 1975) is the most operative. Harnessing such environments by educationalists to prioritise "encounter, discovery and sense-making" may well enhance the capacities of virtual worlds to deliver experiential learning experiences, say Hevner and Chatterjee (2010, p.150).   According to Rymarz (2013) the use of experiential learning experiences within a constructivist learning paradigm can prove complex, challenging and engaging, especially when used alongside direct instruction techniques such as coherence, signalling and recognition of prior learning. In the research, the virtual "visit" was not embedded within a curriculum learning context within the school, in that the students were not studying the subjects of the 3D digital libraries in their classes. Resources such as VG and Giza may be more effective, still, if the virtual "visit" is incorporated into a relevant part of the curriculum. For example, data from the Giza focus groups indicates that it precipitated curiosity and interest induction, with users raising specific questions about the life and culture of ancient Egyptians as a result of using the resource. In a structured learning activity, teachers could encourage participants to research these information needs and incorporate their findings into their knowledge.

Where a resource reflects a real-world scenario or environment (this is, of course, not necessary, because a resource could be developed for a fictional universe or abstract learning scenario), a compelling or credible virtual visit is dependent not only on the principles and techniques as combined on screen by designers, but the fact that digital libraries are expected to be successfully harnessed to visualise certain scenarios in 3D, and by implication are less suited to others. Focus groups revealed that participants thought that the resources would be credible as conveyors of historical and geographical information through recreations of heritage sites. Participants indicated that the visualisation of dresses, or of the pyramids, in 3D, respectively, influenced their choice of resource, thus indicating that for cultural policy makers the choice of which areas of knowledge best translate to 3D digital library visualisation is important to user uptake.

An effective “virtual visit” to whatever type of place or time also depends on commodity – the extent to which the environment conveys a certain use through the application of design principles. Consequently, we found that the virtual visit translated to a user experience of curiosity and of exploration of information when certain examples of 3D design, reflected also in the classical architect´s toolkit, were applied in the virtual world. For example, the focus groups offered preliminary indications that an experience of details (such as ornamentation of objects and surfaces) contributed to the sense of being in an environment, as does the presence of figures or avatars, and that these encounters corresponded to user curiosity, zooming and exploration of the details and to learning outcomes such as citing new knowledge encountered or formulating new research questions about the subject in question. The ability of architecture to orchestrate a sense of scale when moving through the system conveyed, using a combination of time and space, information about the scale of the site portrayed in Giza. Furthermore, architectural features such as optics and milestones encouraged user exploration. This is suggested by users explaining their exploration in relation to entrance to rooms where content was first obscured and then revealed, and by reference in particular to the milestone-like object, a dress, in the centre of the entrance hall where users advanced towards it after it made them curious. Users moved towards these architectural features in order to find further information and explore. 3D digital libraries that successfully employ component-specific architectural features such as these may thereby serve as instructional tools by encouraging new encounters with knowledge but within the experiential context that harnesses the appeal of a “visit”-type experience. Naturally, the role of both environment and components in encouraging exploration and curiosity can be linked to wider learning theories. Both experiential and instructional learning operating in concert are mentioned here but will also be taken up again when we discuss findings and conclusions in relation to RQ4): in what ways do 3D digital libraries deliver benefits to the learning experience?

The findings also lead us to offer as a preliminary conclusion the assertion that 3D digital libraries, which as a characteristic allow the user to explore individually and choosing their own personal trajectory through the environment, gave users a feeling of individual control as to what content to engage with during their use of the 3D digital library. Notably, encouraging a feeling of control is one of Nielsen’s (1995) HCI principles. In the research, participants stated that being able to explore individually without the mediation of companions or leaders, they could explore the topic in a way that felt less inhibited. Instead, participants reported a positive of freely exploring the system in a wandering fashion. It is not yet known whether the age group of participants was an intervening factor in their positive response to the 3D digital libraries’ capacity to encourage “free” exploration. We hypothesise that the 14-15 year-old age group may include members who do not have much experience of exploring a real-world historical site or museum completely independently since it is common for people of this age group to be accompanied on such visits. Further studies would need to investigate whether age is a key factor in this response since indications about the practical use of 3D digital libraries could ensue. They could be harnessed to encourage individual exploration and learning in contexts where the user group is more used to being “led” in educational scenarios, for example. The influence of potential variables in-world is also worthy of investigation: for example, whether the same feeling of inhibition and freedom would be replicable in a multi-avatar environment where users are encouraged to act with other users or with programmed characters.

Several design features either enhance or mitigate the feeling of freedom, we conclude. The combination of flyover navigation and menu navigation, which was remarked upon especially in focus groups related to Giza, may also have positively influenced users’ feeling of freedom, which was more pronounced in Giza than in VG. Users related using a combination of the two in order to explore and to enter and withdraw from areas at will. The structure enabled users to embark upon a structured exploration of the subject while having the freedom to determine the pace and order in which they learned. Restraints to the user intention encountered in-world are also suggested as influencing the users´ sense of freedom when exploring the 3D digital libraries. In the focus groups, when users were able to realise their intention to go somewhere they wanted, it resulted in satisfaction. On the other hand, problems experienced during orientation were a limiting factor to the free actuation of user intentions. They resulted in frustration and not being able to go to a wanted place would contribute to a reduced feeling of freedom, we suggest. Examples in the focus groups indicate that difficulty in maintaining a connection between user intention and input on the one hand and the on-screen navigation achieved was related to users' struggling to engage with parts of the system and to an affective experience of frustration. In 7-month follow-up focus groups, it was indicated that annoyance and confusion related to orientation in 3D may have reduced motivation to explore or return to the system. Another limiting factor on the users' sense of freedom to explore was the users' degree of success navigating in 3D. External factors such as users' previous experience with 3D navigation in video games could impinge on the user's familiarity with navigating in the system, in addition to in-world successful application of the principle of navigability. As a physiological factor, experiencing dizziness or malaise could have affected the users' desire to continue exploring, though just one instance whereby physical discomfort influenced the decision to explore further was reported in the data, in relation to the discomfort of looking at a screen.

Other theorists have suggested that the greater the learner's control and engagement in 3D virtual environments, the greater the learning gains that may be accrued (de Freitas *et al.* 2010) and hence we recommend that designers enable users to feel a sense of control and agency in their exploration of the system by ensuring that exploratory tasks are consistently executed throughout the resource and that visual elements purporting an affordance are able to be explored as expected. The use of a variety of navigation techniques, with menus and good terminology balancing purely walkthrough or flyover pathways enables users to enter and exit at will, and thus adds to the feeling of self-efficacy. The facility to exit an area or resource at will when the user has entered it and changed their mind is also an important factor in achieving this effect.

The 3D digital libraries studied did not include social features insofar as users did not interact with other users. This factors could also potentially increase users' sense of engagement if it were employed, although it would remain to be seen whether a feeling of "exclusivity" noted in VG would still be experienced was the presence of other users to be experienced. Gaming, for example, is often a social experience, and it would be interesting to investigate the effects of virtual social presence on user engagement in future 3D digital library iterations which incorporate this feature. The social element could also be used to increase a sense of agency in the 3D digital library by employing crowdsourcing features whereby users could leave their mark on areas they had engaged with or see evidence of the engagement of others. This ability to shape or tag the environment could, we hypothesise, be effectively employed to increase positive feelings of control and self-efficacy without impinging too greatly on the feeling of exclusiveness that was experienced as beneficial.

Research Question 3) what types of information behaviours take place with 3D digital libraries?

The research has elucidated the information behaviours which users display when they explore 3D digital libraries. In the literature review chapter 5, we found that the concept of information behaviour can in fact encompass behavioural, cognitive and affective aspects. We reach the following conclusions about information behaviours of users of 3D digital libraries uncovered by the research:

> The presentation format of information within a 3D digital library influences the information seeking strategies employed by users. In-world factors that impinge upon the information seeking strategies of users include arrangement, the presentation of information (e.g. text size) and the presence of clickable objects.
>
> Browsing in a 3D digital library related to an information seeking process where the presence of interactive objects revealing further information stimulated curiosity and interaction, culminating in satisfaction and continued exploration.
>
> Movement through an environment is related to an information seeking process whereby users, precipitated by initial curiosity, and their curiosity further stimulated by encounters during exploration, are motivated to explore items of interest to the point of satisfaction.
>
> Video media in 3D digital libraries is related to an information seeking process whereby users engaged with video media as long as they wanted as is related to an experience of curiosity. Being able to enter, exit or fast forward through video media was a key positive variable in facilitating curiosity in the information seeking process with video media.

When the exploration of information takes place within a 3D digital library, users must interact with a space, and as such their movements are directed in relation to pathways and objects within that space. The architectural features identified that acted as factors in the process of movement through the system were the use of division and ornamentation. For example, the division of the environments into rooms and chambers influenced exploration as users explored the system by progressing through the rooms. This study did not find many instances of users trying to subvert the system since exploration in-world was not found in usability testing to have errors that could be exploited in such a way.

Since the system suggests certain exploration paths and the user follows them, it follows that affordance (Norman 2013) is an important factor influencing the system design, and which effects user information seeking in world. Use of 3D design often carries user expectations of affordance – perceived affordances – and can lead to frustration when interaction is expected but not permitted. For example, the stairs in VG appeared to users to be a route they could use to explore further, but the user instead experienced a dead end. Another intervening factor in the information seeking strategies employed by users in the virtual environment is the presentation format of information. Small text related to users having to increase their effort to read and sometimes led to lack of engagement with the written information with the system. The presence of interactive objects stimulated user curiosity. These clickable objects, which permitted access to further relevant information, was said by users to spark their curiosity to explore and was effective in promoting the interaction of users with information in the system. The systems, with their facility to reveal new information in this way, also created user expectations of interaction with similar objects that they then encountered in the system.

The first information seeking process taking place in 3D digital libraries is in relation to interactive objects. Users' movement through the 3D space related to the interactive artefacts within as they advanced towards objects to find out more using a *point of interest* interaction technique (see Mackinlay *et al.*). The process we identified is detailed below:

(1) Walking in and perceiving the object,

(2) Wanting to know more,

(3) A clicking action,

(4) Finding information,

(5) Moving on.

At point 4), users either satisfied or did not satisfy their motivated intention[2] to explore further on exploring an object, and this resulted either in a cessation or information seeking or a return to browsing as a repeat of the process. When satisfaction occurred, analysis of the focus group

[2] In a 3D digital library, where users engage in browsing, we found it was more appropriate and in keeping with terminology in the literature to talk about the affective notion of a motivated intention in place of information needs, since users did not always speak of specific needs but of their curiosity to explore, which resulted in their taking actions while exploring that would allow them to discover more.

transcripts indicate that users reported increased curiosity, and so this process served to perpetuate the curiosity-driven browsing experience. The process is visualised in the Model below.

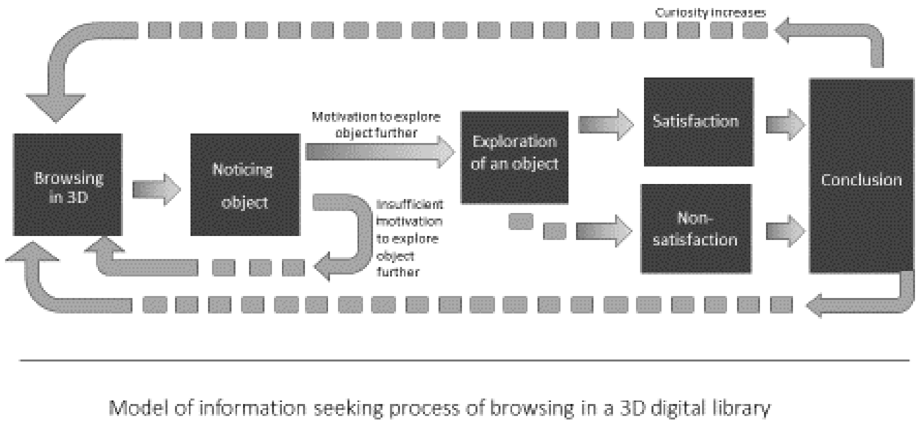

Fig 49. Model of information seeking process while browsing in a 3D digital library.

During the information seeking process detailed above and illustrated in the Model of the browsing process in a 3D digital library users made connections in their understanding, thus indicating that a learning process was taking place in relation to information seeking using clickable objects in the 3D space, and indicating the interdependence of the curiosity induction, information seeking processes and learning benefits variously discussed in relation to the 3D digital library in this conclusion. The process identified in relation to video media in the 3D digital libraries refers to a specific characteristic of both VG and Giza, which was not considered essential in our selection of 3D digital libraries as potential resources to investigate.

In the case of video media, focus groups suggested that the main factor which either facilitated or interrupted a smooth information seeking process was the presence of controls enabling users to pause, fast forward or exit videos. Another factor in users' engagement with video media was the content of media itself. Users engaged with content such as a well-structured story and engaging camera angles such as close-ups.

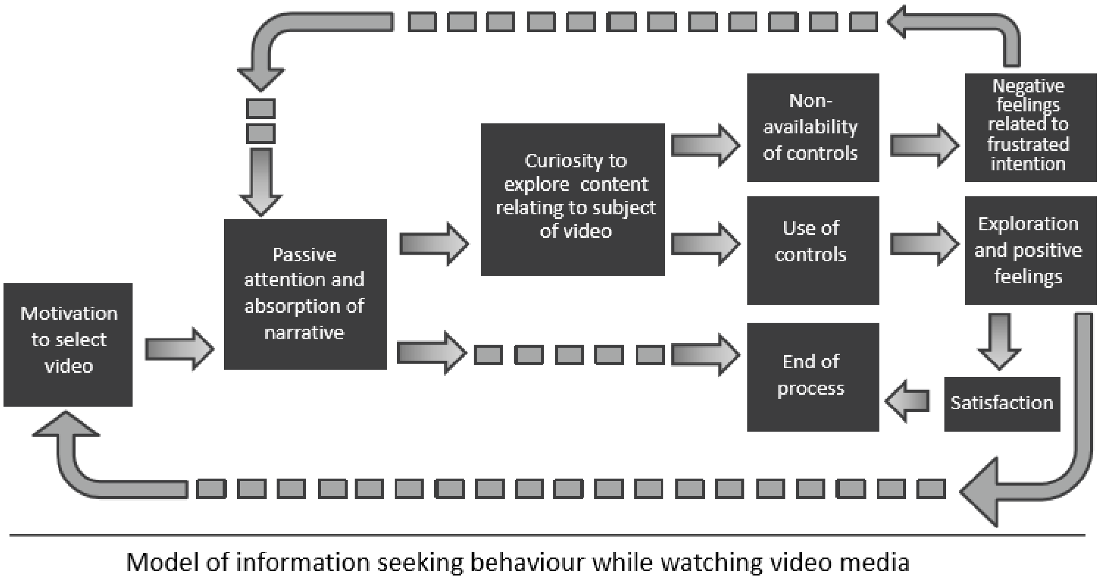

Fig. 50. Model of information seeking behaviour while watching video media.

Research Question 4) In what ways do 3D digital libraries deliver benefits to the learning experience?

The research suggests that 3D digital libraries do deliver benefits to the learning experience in the investigative context. The conclusions already reached suggest several learning benefits which can be summarised as follows:

> 3D digital libraries are appealing and enjoyable to most participants in the 14-15 year-old female user group and thus provide a useful tool for the creation of a learning experience combining both experiential and instructional content. As resources which users perceive they are "visiting", they are comparable to a school field trip in terms of other forms of learning familiar to school teachers, but they confer extra benefits such as convenience and comfort to both users and teachers.

The conclusion that 3D digital libraries are appealing and enjoyable, made of the basis of users' responses in the usability questionnaires and focus groups, is important in the learning context because it translated to a positive user experience which drives the potential of the resources as tools in education. Enjoyment, considered a key component of usability in interactive systems (Sharp *et al.* 2007), has an educational application because the supporting literature indicates that enjoyment influences motivation (Wilson 1997), a key feature of successful learning (Bekele 2010; Jones and Issroff 2007). Although the experiment did not involve a control group, users indicated that using the resources was more enjoyable than the ordinary school day and visiting a museum or historical site in person, due to increased interactivity and to the relative comfort of using a computer system. Teachers also indicated that they would be interested in using similar resources during the school day because their enjoyability was like a "hook" that would engage young people.

Some factors were found to influence the appeal and enjoyment of the resources. We previously discussed how orientation difficulties could intervene in the users' enjoyment of the resource. In addition, beauty of the resources was arresting and engaging and visual attractiveness is thus a major constituent of the appeal of such systems to the user group. However, it must be borne in mind that prior interest in the subject matter may have influenced users' appreciation of the system, since VG users already had the highest appreciation of fashion, and Giza users of ancient Egypt so were arguably liable to appreciate more fully being able to access the resources during the school day. However the fact that both focus groups generated spontaneous suggestions of other 3D digital libraries in geography or history indicates that the participants may also find the resources appealing in the context of their humanities curriculum.

As a consequence of their appeal, the resources could then be used encourage the kind of independent investigation, experiential learning and encounter with existing knowledge which occurs during the exploration of a 3D digital library, as is evident from the results of this study. Focus groups suggest that VG and Giza created a learning experience characterised by "learning by doing" which, according to the participants, was a contrast to a typical lesson during the school day, as well as with 2D media such as texts in books or on websites. "Learning by doing" is a synonym for experiential learning and also implies active learning. In direct comparisons made during the focus groups, users made comparisons between traditional learning and "learning by doing", where users were favourable of the latter, which they associated with the 3D digital library, rather than the former, which they associated with normal school lessons. As we previously mentioned, experiential learning combines with instructional elements in the 3D digital libraries because the resources were successfully populated by learning artefacts which encouraged users to interact with objects and increase their knowledge about the subject in question. The resources also encouraged independent exploration of information both in world and in the intervening time between their use and the focus group interviews. At the 7-month interval after using the 3D digital libraries, 2 of 17 volunteer participants in the focus groups had independently sought further information on the subject of the 3D digital libraries as a result of using the 3D digital libraries. It is not clear yet whether the degree to which the resource is perceived to contain “complete” information influences whether or not students seek to fill in the gaps they notice in their knowledge while exploring by independently seeking the information outside the system. The study yielded comments about the completeness of information in world (e.g. several users of VG stated that they did not look for further information on the subject subsequently because they considered that the information in world was satisfactory, while several Giza users stated that they were unable to find answers to all of their information needs generated while exploring while in world), but the role of completeness in influencing further independent information seeking would need to be established in further studies.

10.3 Recommendations

As a result of the theoretical contribution of this study and the findings which are indicative of a new emergent field of architectural design research as a facet of 3D digital library design for the user experience, it is recommended that digital designers take into account the combined model of architectural and HCI principles cited in 4.3 as they approach the challenge of developing the visual interface of new 3D digital libraries. It is recognised that designers and user experience experts, as well as cultural heritage professionals and educators, will require new knowledge to be demonstrated and validated through a series of future studies, but on the basis of the indicative findings of this study, we are able to recommend the following:

3D digital library design should use scenarios that are successfully visualised in 3D. We recommend that geographical and historical sites will be excellent candidates for future humanities-based 3D digital libraries. These sites enable exploration and also allow for the collocation of artefacts from different time periods to enable users to embark on a credible visit to an environment which differs from their everyday experience, and allows them to enter another world that nonetheless resembles artefacts from the real world, so facilitating comparison in humanities learning.

It is recommended that designers work in collaboration with experts in the field to populate the environment with visual artefacts and accurate detail, since this too add to the users’ sense of presence, according to our indicative findings as well as improve the knowledge base available to users exploring the system. Collaboration with architectural advisors may be advantageous since they can recommend ways in which the narrative experience can be structured and dimensional features can increase the visual and explorational appeal of the environment. We note that a recent successful example of a 3D digital library, St Andrews Cathedral 1318 (Open Virtual Worlds 2013), which was discussed in 6.3.2, did just this, with collaboration between historians of art, classicists and archaeologists, who could advise on dimensional design, rare books librarians who could advise on informational content, and computer scientists with expertise in computer games design involving such considerations as orientation and interaction techniques. The historical recreation was a successful choice of humanities subject because the Cathedral is now ruined and so exploring the resource in a virtual environment allows for immersion in a an engaging environment which simultaneously engages and departs from today´s reality. In the future we predict an increase in the quantity and range of systems that are designed to support active learning as described.

The presence of interactive objects in the environment is a successful component of 3D digital library design and it is recommended that design collaborators embed many of these in an environment to allow users to explore at their desired depth. A 3D digital library should enable both superficial and deep exploration to give users the sense of "going deeper" into a subject, and to allow the resource to cater to different levels of engagement with the subject matter so as to encourage further exploration in world as curiosity is experienced. It is recommended that users are able to navigate towards explorable objects of interest by clicking on objects of interest to advance towards them, as per a "point of interest" interaction technique, since the evidence indicates that this facilitates information seeking processes in the environment.

10.4 Limitations

The Methodology chapter outlined the specific characteristics of the investigation taking place in the school. This results in some limitations to the scope of the study. The experimental element was conducted in a secondary school for girls in the south of England, with a group of 13-15 year olds. As a result, the results may be specific to this user group. It would be interesting to investigate with male participants, since the thesis indicated research findings in the wider literature that suggest gender differences in the uptake of computer games, and also in interest in different subjects between the genders. However, the applicability of the results to one user group is not unusual in the wider research field, since it is a limitation of qualitative or user studies in general that a select group of participants is able to take part. In fact, the relative homogeneity of the user group in this study may accrue some benefits by reducing variables among participants.

The availability of 3D digital libraries to investigate also needs to be considered as a limitation in this study. Several resources located in an empirical study were no longer accessible, which may highlight problems of technology or preservation strategies to prolong the shelf life of still recently created resources. The preference of the majority of students for a high fashion resource resulted in more questionnaires being completed for VG than any other resource. The selection of three resources in fact yielded data for two resources, since only one participant opted to use the Virtual Museum of Iraq. As a result, the results pertain to two specific digital libraries, the Valentino

Garavani Museum and Giza 3D, and further study would be required to verify the applicability of suggested principles, findings and analysis over a wider range of similar resources. In addition, the school´s role in selecting pupils who used both resources to make up the 7-month focus groups, rather than separating them by resource – a mistake in communication – resulted in limited 7-month data from Giza users.

The experiment was well designed to see whether information seeking continued over the longer term regardless of the fact that the resources were not being used in the curriculum, thus reducing the possibility that further information seeking occurred as part of a Hawthorne effect, since users were not at any point deliberately given the impression that further information seeking was expected of them. However, the results are inconclusive given the sample size and composition of the 7-month focus groups. It would be necessary to conduct more longitudinal studies to further investigate the potential of 3D digital libraries to encourage longer term independent curiosity or information seeking.

10.5 Further Research

Since the research considered an emergent field, it is highly recommendable that further research take place to improve the corpus of literature and the evidence base relating to design and behaviour in the 3D digital library or virtual world context.

It is proposed that a future study could engage in a design research paradigm through building and developing a 3D digital library from scratch. Design research as a process combining both theory and the iterative programme of building is a valid approach in both digital design and the older architectural discipline from which it stems (Hevner and Chatterjee 2010). This approach of building a 3D digital library would potentially allow for better experimental conditions with the resource itself, because the design principles could be isolated or perhaps varied across versions to allow for control experiments to take place.

When it comes to future research methods, we consider that the methodology advanced in this research is original and salient in relation to the emergent subject area defined. The combination of usability trials and of more qualitative methods has proved effective in this research, since it provided both a disciplinary anchor as well as a deeper exploration of interdisciplinary factors such as the chosen architectural and ISB theoretical framing of this study. While any form of usability trial allows for the design of an experiment generating mostly quantitative usability data, the potential for narrative analysis or thematic coding arising from focus group transcripts better allows for an expanded, interdisciplinary and contextual analysis to take place.

The value of control groups would be to explore individual conclusions made in this study, and explore the contributory factors such as design principles using a comparison with a control group, thus creating the experimental conditions to isolate empirical data on the role of each proposed design feature in influencing the user experience. For example, comparisons could be conducted between the virtual "visit" and a school trip, or the virtual visit used as a complement to learning before or after a school trip. Comparisons between component features encouraging exploration such as orientation tools or dimensional figures could allow for a greater elucidation of their role on learning. Control groups could be used for different user groups, investigating whether results also apply to other groups of learners, such as older learners, specialist learners or those engaged in informal or lifelong learning.

If future research is to repeat the research conditions involving a group of young people learning in a school, it is recommended that the experiment could be configured to coincide with a curriculum topic and that young people could complete a learning task such as a longitudinal project as part of their study, as occurred in Kuhlthau´s (1994) research into the information seeking process. While the research summarized here quite validly differs in its tenor by mitigating against the other factors increasing engagement with information in this potential context, it is noted that in this research the main reasons that participants cited for not engaging in independent information seeking after the event included the competing demands on their time and the fact that they were not studying the subject in school – a reason also cited by their teachers. This suggests that a more true-to-life task in a school, involving the embedding of 3D digital library resources into a learning task or curriculum topic, could also be attempted. This could open up the possibility of more ethnographic and longer-term studies to investigate the influence of 3D digital libraries on learning.

10.6 Reflection

At the commencement of this research, limited previous work was in existence involving investigating 3D virtual world advances in technology and changing user behaviours. Many of these studies have used 3D digital libraries on an *ad experimentum* basis, testing or exploring them with reference to traditional usability testing but without explicitly discussing their visual appearance beyond usability heuristics (see Almeida *et al.* 2006). Several have also gone on to suggest further investigation into the potential normative benefits of 3D virtual design, and others emphasising its role in the exploration of information (see Roussou 2006; Das Neves and Fox 2000; Almeida *et al.* 2006; Kickmeier-Rust *et al.* 2007; Dalgarno and Lee 2009; Chow *et al.* 2010).

This research is the first known attempt to codify the architectural principles applicable to 3D virtual design and to proffer a methodology capable of exploration of their role on information seeking behaviour. As 3D online resources advance become more frequently used in the educational setting, it is crucial that their design and application is supported by sound evidence. The impact of this research is to provide a theoretical justification for the consideration of dimensional architectural criteria in the design of 3D digital libraries and to advance the evidence base demonstrating the effectiveness of such resources in an educational application with reference to the benefits of the in world, dimensional experience on the exploration of information.

A dissemination plan for paper publications is now in process, and aims to target the highest-rated information science journals. Clearly, an emergent topic such as this requires much further investigation where this research can only be indicative in its conclusions but the research nevertheless involves a highly topical and relevant subject, contributing original and new insights into the design and investigation of 3D digital libraries.

In conclusion, the study has provided evidence in support of the view that interdisciplinary principles combining HCI and architecture are now an important factor of understanding 3D digital libraries as they grow in quantity and range. It has shown that architectural principles are operative in 3D digital library design and that the unique attributes of 3D digital libraries can positively influence the information seeking and learner experience of young people. A “visit” to a 3D digital library in the context of the school day is appealing and enjoyable to most participants in the 14-15 year-old female user group and thus provide a useful tool for the creation of a learning experience combining both experiential and instructional content.

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12 Appendices

12.1 Task running sheet

The task running sheet comprises the list of steps required to achieve the successful running of tests and focus groups. The running sheet ensures that the test is run smoothly, without unnecessary distractions which could compromise the test delivery and even test results. The running sheet for each component of the test plan is given below.

TASK RUNNING SHEET

One day before the experiment, the moderator will ensure that the computer laboratory is set up for a class activity and will create links to the three 3D digital libraries using the bookmarking facility on the internet browser to be used.

On the day of the experiment, the moderator will be present in good time for the start of the class period of 40-50 minutes.

LABORATORY USABILITY AND USEFULNESS EXERCISE

The study is part of a PhD research project. Today, we are going to be exploring three 3D digital library options. You will have a short initial questionnaire, and then you can freely explore one of the 3D digital libraries of your choice. Once you are satisfied that you've explored enough, I will give you another questionnaire, which is about the usability of the library you have explored.

You also have the option to volunteer to participate in a follow-up focus group interview taking place the following week, to further discuss the user experience.

Verbal explanation of Initial Questionnaire:

Before we start the exercise today, please could you fill in an initial questionnaire? This is designed to gather some background information on you and your preferences.

Distribute Initial Questionnaire. Allow time to elapse while participants complete the questionnaire.

Verbal explanation of Task Sheet:

Today each of you is asked to pick one of three 3D digital libraries to explore before you complete a questionnaire on it. This worksheet gives the title of each resource, an indication of the subject and a brief explanation of the content. Please take a look at the information and choose just one resource that you would like to explore. When you have decided, follow the instructions to access the resource. Don't worry if the resource is not as you expected, or if it has strengths and weaknesses. Part of this test is that we discover the pros and cons of the resources together. You can go on exploring the 3D digital library you choose for as long as you like, until you feel satisfied, and you are just asked to explore. Please put up your hand when you're finished. There will be a cut-off point, as at some point you'll need to start the questionnaire, but if you finish before then, please put up your hand. Don't worry about putting up your hand early. You will still be able to use the resource after you have finished the questionnaire. I just want you to put up your hand when you are satisfied.

Distribute the Task Sheet to each student. Make a note in moderator's notes about start time of 3D digital library exploration. While the students are using the system, remain a visible presence to answer any questions. Make a note of any questions asked, or other notable activity apart from individually using the system.

As students raise their hand, pick a Second Questionnaire from the pile and write the time on it. Assign code to Second Questionnaire. Ask them to come and give you the questionnaire when they are finished.

20 minutes before the end of the class period, explain to the remaining students still using the system that they need to start the Second Questionnaire. Pick as many Second Questionnaires as there are students remaining and write (15) on these Second Questionnaires. Assign code to Second Questionnaire.

Distribute **Focus Group list** in which students who are interested in participating in focus groups are asked to give their name and the resource they used.

FOCUS GROUPS

In advance: arrange volunteers into three focus groups of 8-12 corresponding to the resource used. Following a screening process if volunteers are not required, due to the sought after focus group numbers, they will be informed before the event of the focus groups. Before the focus groups, a place and time and date for the focus groups is agreed with the school. The moderator is responsible for checking the allocated venue and confirming with the school that logistical timetable matters are considered before the date of the focus groups.

Focus groups take place one to two weeks after the laboratory experiment.

Moderator arrives in advance of the focus groups.

The room is arranged with chairs in a circle and recording equipment set up. Since the room is likely to be a familiar part of the school environment, decor and furniture not a part of the focus groups will remain in place, since this provides a familiar surroundings to put the participants at ease.

Moderator greets the focus group participants and informs them of the time allocated, assures them of the confidentiality of their answers, and invites them to speak openly about their thoughts and impressions. Moderator explains that participants may speak whenever they feel like it but if they feel that their point has not been heard and they wish to speak, they can also raise their hand to indicate that they want to speak. For good practice, information which they read in the Formal Consent form for the focus groups is repeated before the focus groups.

Recording device is switched on.

Focus group questions (duration 45 minutes). The moderator can also respond to questions and probe for greater detail.

The moderator takes notes throughout. After the session, the moderator makes further annotations to the notes taken during the interview which give greater detail and context. At end of session, moderator thanks the students and asks if it would be possible to contact some of them approximately six months later to answer a short series of questions via email. Asks for email names and email addresses of those who would like to receive the email. Participants write their names and emails on a sheet which is passed around.

The focus group questions are as follow:

<u>Agenda point 1: Students' information behaviour during the task</u>

Who would like to describe what you did when you used the 3D digital library. Can you talk me through it? Do you remember what you looked at in particular?

<u>Agenda point 2: What did they like?</u>

What features of the 3D digital library did you like? What features of the 3D digital library did you not like?

Optional visual aid: graph representing results from questions 12 and 13 of the questionnaire, showing the three "best" and "worst" features as listed by users of each 3D digital library. Researcher asks "do you agree?" and "why/why not?"

<u>Agenda point 3: Feeling of engagement and curiosity with the 3D digital library</u>

Would you like to use similar resources in school in the future? Why/why not?

No apposite optional visual aid could be located for this question but the researcher will attempt to encourage discussion by summarising points made and asking if they are representative statements.

<u>Agenda point 4: Extent of learning and increased interest in the subject matter</u>

Why did you decide to pick that particular 3D digital library, out of the three? How do you feel about the subject matter having used it? Would you access anything else on the subject matter now?

<u>Agenda point 5: The aesthetics of the system</u>

I see that in the usability questionnaire, the ratings for the visual scenery were as follows: [show participants graph showing distribution of responses and average rating]. Do you agree with those overall ratings on the visuals of the system?

What did you think of the style and design? Visual prompt: a "still" shot of the 3D digital library [Virtual Museum of Iraq: the Babylonian Hall; Giza3D: the Sphinx; Valentino Garavani Museum: the NNNN]. Researcher's question: "what do you like/dislike about the style and design?"

<u>Agenda point 6: Students' information behaviour after the task</u>

Have you looked at the resource again since you tried it in the laboratory? Would you go back to it again? Why/why not?

<u>7-month interval focus group questions</u>

1) [At this stage, the first question is announced so that participants are conscious of the process in which they are involved.] **"Have any of you looked for any more information on this subject since then?"** [A show of hands is sought]. [Addressed to all:] "Can any of you tell me a little bit more about that?" [In the course fo the discussion, the researcher seeks answer to "**What** did you look for?, "**Where** did you look for it?", and "**When** did this happen?", as well as asking "Was there any particular reason you wanted to know that? ("**Why?**")".] [Not all participants will volunteer information, but in order to widen the

discussion to those who have not yet contributed, participants will be asked “Was your experience similar to that, or different?”.

2) **“Now I would like to ask whether any of you returned to the site again after the classroom session. Can I take a show of hands?”** [A tally is taken.] “**Why** did you go back?”
3) [If the answer to either 1) or 2) is “no” for some particiapnts:] **“Is there any particular reason that you didn’t?”**
4) [If the answer to 2) is “no” for some participants]: **“Do any of you plan to go back to the site?”.**
5) [If more material is needed: Repeat of original focus group questions.]

TEACHER FOCUS GROUPS

Also at the 7-month interval, focus groups (or small, semi-structured interview groups) are recruited respectively of teachers in Art, History and the school Librarian. Teachers are asked to express their initial interest and provide contact details, which does not constitute formal consent. It is anticipated that these groups be for two to six teachers in the case of Art and History.

Two weeks before the focus groups distribute **Focus Group Consent Form** to staff who indicated that they would like to take part in focus groups, via email. Collect completed copies digitally.

Moderator arrives in advance of the focus groups.

Moderator greets the focus group participants and informs them of the time allocated, assures them of the confidentiality of their answers, and invites them to speak openly about their thoughts and impressions. Moderator explains that participants may speak whenever they feel like it but if they feel that their point has not been heard and they wish to speak, they can also raise their hand to indicate that they want to speak. For good practice, information which they read in the Formal Consent form for the focus groups is repeated before the focus groups. The Focus Group begins with a brief on the laboratory experiment and focus groups with the young people. The Focus Group then sets aside ten minutes for a demonstration of the relevant resources on a desktop or laptop computer. The recording device is switched on. The participants are then asked the focus group questions. During the session, the moderator takes notes. After the session, the moderator makes further annotations to the notes taken during the interview which give greater detail and context.

<u>Questions for teachers</u>

1) **“Did you notice any changes in the students’ behaviour or interests as a result of their using either Giza 3D or VG? Did they talk about it?”**

In addition, the teachers will be asked to discuss whether they would use the resource in the classroom, to add context to the research questions. The question will be worded as such:

2) **"I appreciate the practical considerations, but purely in the learning context would you consider using this resource in the classroom and why?"**

12.2 Participant information sheet

University of Strathclyde Research Study in collaboration with [NAME OF SCHOOL REDACTED]

Title of the study: *"The application of classical architectural criteria to 3D digital library design to enhance the user experience"*

Participant Information Sheet

Introduction

The researcher is Jane Mycock, a doctoral (PhD) student in Computer and Information Sciences at the University of Strathclyde.

What is the purpose of the research?

The study is part of a doctoral research project funded by the Engineering and Physical Sciences Research Council (EPSRC). The research investigates the role and usability of 3D digital libraries in the learning context and, in particular, explores design factors enhancing the user experience. The study has been granted ethical approval by the University of Strathclyde Department of Computer and Information Sciences Ethics Committee.

What is involved?

The investigation involves participation in a usability trial of 3D digital libraries, conducted in a school computer room during a single art or history class between 2nd and 6th June. Participants will freely explore a 3D digital library (from a choice of 3) and then complete a short usability questionnaire. Participants will then have the option to volunteer to participate in a follow-up focus group interview taking place the following week, to further discuss the user experience.

Participation in all parts of the investigation is voluntary. You are not obliged to answer all of the questions or complete the exploration of the 3D digital library during the usability trial, and you will be able to withdraw from participation at any point should you wish. If you decide not to take part you will remain in class.

What happens to the information in the project?

Anonymity will be respected. Data from the investigation (e.g. your questionnaires) will be kept in a secure and confidential place. If you chose to share any personal identifying information in your questionnaire or in a focus group, this information will be anonymised. [NAME OF SCHOOL – REDACTED] will also be anonymised. After the investigation is complete, the results will be published as a PhD thesis and published in one or more journal publications. Data from the investigation may be obtained by emailing the researcher (contact details below).

What happens next?

If you are happy to be involved in this project, please discuss this with your parents/guardians and then sign the enclosed consent form. If you do not want to be involved in the project, thank you for reading.

Researcher contact details

Jane Mycock, Department of Computer and Information Sciences, Livingstone Tower, University of Strathclyde, 26 Richmond Street, Glasgow, G1 1XH. Tel: 0141 3523583. Email: jane.mycock@strath.ac.uk.

If you have any questions or concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or from whom further information may be sought, the supervisor in charge of the investigation is Dr Steven Buchanan, Department of Computer and Information Sciences, Livingstone Tower, University of Strathclyde, 26 Richmond Street, Glasgow, G1 1XH. Email: steven.buchanan@strath.ac.uk.

12.3 Participant consent form

University of Strathclyde Research Study in collaboration with [NAME OF SCHOOL – REDACTED]

Title of the study: *"The application of classical architectural criteria to 3D digital library design to enhance the user experience"*

Consent Form for students in Y9 taking part in laboratory testing

I confirm that I have read and understood the information sheet for the above project and what participation involves.

- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, without having to give a reason and without any consequences.
- I understand that I can withdraw my data from the study at any time.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.

(PRINT NAME)	
Signature of Participant:	Date:

12.4 Usability questionnaire

[Page break]

Investigating the user experience with 3D digital libraries: Initial questionnaire

Please answer the following questions:

1 **Age (please circle)** 12 13 14 15

If other, please specify: ………………

2 How many hours do you estimate that you spend online per day? (Please circle)

Up to 1 hour	Up to 2 hours	Up to 3 hours	Up to 4 hours
Up to 5 hours	Up to 6 hours	Up to 7 hours	More than this

3 Of your time online, please estimate the percentage you spend on the following activities, so that the total adds up to 100:

Academic study	
Gaming	
Social networking	
Other personal use (e.g. entertainment, reading)	
	Total = 100%

10 I would like to know how interested you are in the three subjects covered by the 3D digital libraries. Please circle your answer to the following statements:

a) I am interested in the Pyramids of Egypt

Strongly disagree 1 2 3 4 5 6 7 **Strongly agree**

b) I am interested in the cultural artefacts of ancient Iraq

Strongly disagree 1 2 3 4 5 6 7 **Strongly agree**

c) I am interested in high fashion design

Strongly disagree 1 2 3 4 5 6 7 **Strongly agree**

[Page break]

Researcher's use

Researcher's use

Investigating the user experience with 3D digital libraries: Usability and usefulness questionnaire

This part of the questionnaire asks you to think about how easy the 3D digital library you chose was to use (its *usability*) and how useful you found it.

Which 3D digital library did you use?

Name of 3D digital library used:

Please select your answers to the following questions, circling your answer on the scale where appropriate. Please use the text box to make any further comments.

1. While you were browsing, did a particular question or information need come to mind?

Yes / No

If "yes", please go to question 6. If "no", please go to question 7.

2. When looking for information during exploration, I was able to find what I was looking for.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

3. The system responded quickly to what I wanted to do without delay or error.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

4 The text type and font size is engaging and readable.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

5 Colours, graphics and icons are used appropriately.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

6 The visual scenery is attractive.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

7. The terms used to label the menu functions are understandable.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

8. The menu functions listed on the menu are logical.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

9. Orientation is straightforward.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

10. Steps I undertook during exploration were understandable.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

11. I think that the information presented was from a credible source.

Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

11: Please list the three things you liked best.

1

2

3

12: Please list the three things you liked least.

1

2

3

13. I enjoyed using the 3D digital library.

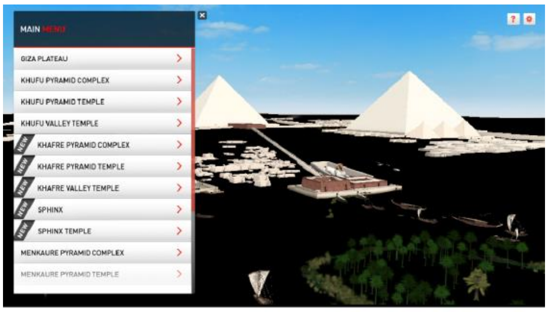
Strongly disagree	1	2	3	4	5	6	7	**Strongly agree**

Any further comments:

12.5 Participant task sheet

Information on the 3D digital libraries

Please use this information to choose just one 3D digital library to explore.



Name of library: Giza 3D

Subject: The Pyramids of Egypt

Creator's description: "Giza 3D is a new international project that uses the latest real-time 3D web technology to display the Egyptian Pyramids and other monuments of the Giza Plateau interactively, based on evidence from more than 100 years of archaeological excavations. This model is based, as much as possible, on attested archaeological data, but some theoretical restorations have been made".

Name of library: The Virtual Museum of Iraq

Subject: Cultural artefacts of ancient Iraq

Creator's description: "The *Virtual Museum of Iraq* is a scientific and cultural initiative […]. The purpose of the project is to provide the public with the opportunity, through a web site, of coming into contact with the archeological, historical and artistic heritage of one of the most important museum institutions in the world, the National Museum of Iraq, in Baghdad".

Name of library: Valentino Garavani Museum

Subject: High fashion design

Creator's description: "Valentino Garavani, legendary fashion designer, has defined a unique world of couture for almost half a century. Now his achievement takes radical new form, in keeping with the creative traditions of the house: THE VALENTINO GARAVANI VIRTUAL MUSEUM. Over 5000 documents have been installed in a spectacular 3D Palazzo. Visit the museum […] and create your unique route through the galleries, to discover and enjoy every aspect of Valentino's extraordinary world."

12.6 Departmental ethics application

Text of departmental ethics application

Title of research

The application of architectural criteria to digital library design to enhance the user experience.

Summary of research

The study is part of a doctoral research project funded by the Engineering and Physical Sciences Research Council (EPSRC). A new development, 3D digital libraries, involves the placement of objects and museum artefacts in a 2-3D visual context, often supported by learning resources and tools. This study seeks to investigate their usability among young people aged 13-15 and their impact on the learning experience, in particular whether or not they have the capacity to foster curiosity and further engagement with the subject matter. Primary methods will be usability tests and semi-structured group interviews, conducted in three stages: usability test; group interviews exploring usability issues (one week post-test) and follow-on interviews exploring further use (approximately six months later).

How will participants be recruited?

Contact has been established with [NAME OF SCHOOL AND LOCATION – REDACTED]. Four teachers with classes in the Year 9 (Scottish equivalent: S2) year group have volunteered to support the project by allowing a laboratory exercise with questionnaires to take place during their lessons over the course of one week. Following this, participants who took part in the first exercise will then be recruited for focus groups interviews. The participants will therefore be recruited from the pupils in these four classes (numbering approximately 88 in total if all were to volunteer [at least 60 volunteers are sought]). In addition, focus groups with teachers (ideally, two groups involving c. 8 teachers in total) will be recruited from the original contacts and from other teachers (or librarian) within the Art and History departments and school library.

How will consent be demonstrated?

Potential volunteers will be provided with Information Sheets and Consent Forms for all stages of the research (e.g. for the laboratory exercise, focus groups, and follow-on interviews). In practice, their initial consent will be confirmed at each stage with a call for volunteers to take part. Potential teacher focus group participants will also be provided with Information Sheets and Consent Forms. Informed consent forms will, in terms meaningful to participants, outline the purpose and scope of the research, how it will be conducted, and how data will be managed and used. It will be made clear that participation is voluntary with approximate participant time commitments provided. It will also be made clear that participants will not be obliged to answer all questions asked during interviews/interactions, and will be able to withdraw from participation at any point, for any or no reason. Consent will be demonstrated by signing a Consent Form, and by continued participation and non-withdrawal of consent once the project is underway. In order to incorporate best practice in the MRS Code of Conduct (2014), which recommends parental consultation in the process of obtaining consent, pupils will be asked to take home their Information Sheet and Consent Form and show it to their parents, returning it signed once this has occurred. This online form does not offer me the facility of attaching participant Information Sheets and Consent Forms, but they are available from me at [RESEARCHER'S EMAIL – REDACTED] if they are required.

<u>What will the participants be told about the conduct of the research?</u>

The sponsors, purpose, and potential beneficiaries of this research will be communicated to participants from the outset (via the informed consent form), including expectations of participants, and how participant data will be managed and used for research. In relation, it will be made clear to participants that while all steps and safeguards will be taken to ensure anonymity and confidentiality, this cannot be 100% guaranteed due to factors outwith researcher control (Bryman 2008). However, the students themselves will be anonymised, and only demographic information which allows the identity of the school to be kept anonymous will be included in the analysis and write-up.

<u>What will participants be expected to do?</u>

The first half of the investigation involves student participation in a usability trial conducted in a school computer room during a timetabled art or history class between 2nd and 6th June, subject to volunteer participation of class members (with those who do not consent continuing with normal timetabled activities). Participants will be asked to choose and explore one of three pre-selected 3D digital libraries, and then complete a usability questionnaire (including demographic information). The second part of the research involves participants volunteering to take part in follow on focus groups. The focus groups will take place during a period which is agreeable to all focus group members between 9th and 13th June. Participants will be in one of three focus groups of 8-12 participants (one group per 3D digital library used). During the focus group participants will be asked open semi-structured questions about their thoughts and feelings about the 3D digital library, and their use of and interest in the 3D digital library that they used in the computer room. Participatory methods may also be utilised (brainstorming, ranking etc.) to encourage discussion. In focus groups with teachers, teachers will be shown the 3D digital libraries that the students used and asked semi structured questions on their thoughts and feelings about the 3D digital library as teachers and librarians, and any observations they have made of the student participants in relation to their use of the 3D digital libraries. At this stage, the researcher will take notes and audio recordings will be made. Audio recording will be mentioned in the Information Sheets and Consent Forms and in the case that participants do not consent at the point of recording, only notes will be made. The third stage will involve follow-on interviews with focus group participants taking place 7 months later to investigate the potential further use of 3D digital libraries after the first encounter. Questions focus on whether or not the participants have used the 3D digital library or associated resources again and any contextual reasons. Consent forms cover all events, but out of consideration for the participants' right to withdraw at any time, they are asked about participation before taking part in each stage of the research.

How will data be stored?

Data will be kept securely, in a locked filing cabinet. Participant and location anonymity will be respected at all times with assigned identifier codes stored securely on a laptop (rather than a memory stick) and separately from transcripts (with no names or locations on transcripts). In the case that data from the questionnaires and interviews contains responses which reduce anonymity for participants, it will be anonymised before reporting (e.g. proper nouns and identifying details will be redacted).

How will data be processed? (e.g. analysed, reported, visualised, integrated with other data, etc.)

Two broad datasets will be collected: data of a quantitative nature from the usability questionnaires, and data of a qualitative nature from the focus groups. Analysis of the quantitative data will involve univariate and bivariate analysis (e.g. time spent using system compared to usability ratings). This will be visualised in table and graph format and analysis will seek to identify and explore associations between variables. Analysis of the qualitative data follows the structuring of a semi-structured interview to include some questions of a narrative nature and some of a participatory format. These interviews will be transcribed and qualitative and narrative analysis will take place. The quantitative and qualitative datasets then be triangulated and compared.

How and when will data be disposed of?

All digital data (text and audio) is to be stored on secure institutional data servers with automated remote backup. The data will be stored for a minimum of ten years, during which data will be stored and managed in accordance with the University of Strathclyde's Records Management policy

(University of Strathclyde 2009), and after which disposal of datasets including metadata can take place.