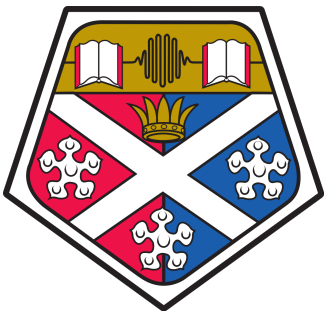
Exploring Exploratory Search when Conducting Literature Review Tasks



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Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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DATE: 10 Jan, 2024

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The completion of this thesis occurred amidst the devastating, unfair war in Gaza, Palestine, which brought me unimaginable sorrow and challenged my ability to work. Through my tears, however, arose a profound inspiration fueled by the extraordinary courage of Dr. Ghassan Abu Sitta, a British Palestinian Plastic and Reconstructive Surgeon, who bravely volunteered in Gaza hospitals under the harshest conditions. His tireless dedication to healing amidst unimaginable suffering inspired me to go back to work again. The medical professionals who tirelessly treated the wounded and the brave journalists who documented the harsh realities on the ground also played a crucial role in inspiring me to continue and complete this thesis. Additionally, the strength displayed by Gazan children like Kamal, Julia, and countless others in the face of unimaginable hardship served as a powerful source of determination for me to finish this work. My heartfelt wishes go out to all Palestinians for a better life and future.

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Dedication

In loving memory of my late father, the wind beneath my wings; to my dream-believing mother; and to my wise grandmother (sitty), rooted in the land and lover of olive trees. Your lessons shape this journey.

Abstract

The last two decades have seen a growing interest in exploratory and complex searches in the information-seeking and retrieval community. Despite the plethora of proposed definitions and support interfaces for Exploratory Search, the key dimensions and characteristics of exploratory search remain unclear, leading to uncertainty. In the realm of information-seeking and retrieval, exploring academic literature for relevant references, including theses, publications, and reports, is widely recognised as an exploratory search task. This task becomes even more challenging when searchers have limited prior knowledge of the subject matter. Therefore, this thesis aims to understand the main dimensions and characteristics of exploratory search tasks, mainly focusing on literature review tasks. The original contributions of this thesis are fourfold: Firstly, it offers a conceptual model of exploratory search, consolidating an array of characteristics about the core dimensions of exploratory search—namely, the problem context, users, and search process. Secondly, through a series of empirical studies, the thesis validates this model and introduces additional dimensions and characteristics, including 'Knowledge Gain.' Thirdly, it investigates the impact of the support exploratory interfaces on users' behaviours, perceptions, search outcomes, and overall experiences during exploratory searches within academic contexts. Lastly, serving as a specialised application of the exploratory search model, the thesis introduces a tailored version to cater to the requirements of literature review tasks. These insights aid in understanding the richness and multifaceted nature of exploratory searches and have the potential to shape design support user interfaces within the Information Seeking and Retrieval community.

Abbreviations

- `ISR` - Information Seeking and Retrieval
- `IR` - Information Retrieval
- `IIR` - Interactive Information Retrieval
- `LR` - Literature Reviews
- `AI` - Artificial Intelligence
- `ISP` - Information Search Process
- `PC` - Problem Context
- `SP` - Search Process
- `U` - Users
- `VE` - Very Exploratory
- `SE` - Somewhat Exploratory
- `NE` - Not Exploratory
- `NExper` - Not Experienced
- `SExper` - Somewhat Experienced
- `VExper` - Very Experienced
- `EFA` - Exploratory Factor Analysis

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Chapter 1

Introduction

> It's human nature to stretch, to go, to see, to understand. Exploration is not a choice, really; it's an imperative.
>
> *Michael Collins*
> *Gemini and Apollo astronaut*

The information space has become increasingly complex regarding its sizes, types, and ways to access it [146]. The enormous amounts of online information might cause searchers to feel lost in the information space [69], especially when searching for new topics or domains. This task becomes particularly challenging when searchers lack prior knowledge of the subject matter. Searchers employ exploratory search strategies when working on complex tasks involving scientific discovery, learning, and decision-making aspects, such as looking for literature or learning about a new topic in a domain they have no prior knowledge about [74, 192]. To help address the growing need for supporting exploratory search endeavours, researchers proposed numerous interfaces and solutions. However, the questions "What is exploratory search?" and "What characteristics make a search exploratory?" remain valid.

1.1 Motivation

Various researchers have offered different ways to characterise how exploratory a search task is, the main dimensions of exploratory search, and what factors make a search exploratory within each one of its dimensions. Marchionini [115] classifies search tasks

into a binary classification; searches are exploratory if they are not known-item searches. White and Roth [187] emphasise the problem context and the search process as the two primary aspects of exploratory search tasks to extend this characterisation, describing exploratory search in terms of open-ended, persistent, and multi-faceted problem contexts coupled with opportunistic, iterative, and multi-tactical search processes.

Many researchers in the field of exploratory search have predominantly drawn inspiration from Marchionini [115] and White and Roth [187] in their attempts to define and characterise exploratory search. As of the time of writing, Marchionini [115]'s seminal paper boasts 2,146 citations, and White and Roth [187]'s book has accumulated 1,046 citations on Google Scholar. Despite the widespread adoption of these frameworks, certain proposed aspects, particularly those related to the problem context and search process, introduce uncertainties. Some characteristics, such as the opportunistic search process, remain undefined or lack full explanations.

Despite the considerable interest in exploratory and complex search tasks, the definition of exploratory search remains vague and continues to evolve [132]. This evolution is in response to the ongoing complexity and evolution of information-seeking and retrieval tasks. Despite the availability of numerous user interfaces designed to aid exploratory searches, there remains a gap in understanding their impact on users' behaviours, perceptions, and outcomes. Moreover, while literature searches serve as a typical example of exploratory search, there is still much to explore regarding the strategies, decision-making processes, and knowledge acquisition involved in such searches.

Therefore, this thesis explores and examines the various aspects of exploratory searches, including their dimensions, characteristics, and influencing attributes. Rather than introducing a new user interface intended to aid exploratory searches, this thesis examines the impact of various user search interfaces on users' experiences, perceptions, and search outcomes. It also investigates how different tasks may influence users' behaviours. Additionally, the thesis investigates users' strategies, knowledge acquisition, and decision-making during exploratory search tasks, with a specific emphasis on literature reviews.

1.2 Context

This thesis concentrates explicitly on exploratory search within the academic domain, primarily focusing on the literature review task. Drawing on existing literature, I introduce a conceptual model of exploratory search that encompasses three main dimensions: the problem context, the search process, and the users. First, I present fourteen characteristics

corresponding to these main dimensions. Second, to validate the proposed model, I employ a questionnaire instrument, leading to the identification of a fourth dimension: knowledge gain (Chapter 4). Third, to gain more understanding of exploratory search and the attribute and factors that affect it, in Chapter 5, I utilise the proposed exploratory search model and conduct laboratory-based studies to examine how the interface influences users' perceptions, experiences, behaviours, and search outcomes. Additionally, I investigate how different task types affect users. Finally, shifting focus in Chapter 6, I analyse the strategies, approaches, and behaviours of exploratory users, particularly those involved in literature review tasks—a specific instance of exploratory search. This analysis leads me to introduce a tailored conceptual model of exploratory search for literature review tasks.

1.3 High-level Research Questions

This thesis focuses on exploring exploratory search in the academic context. More specifically, I seek to answer the following high-level research questions:

RQ1. What are the main dimensions and characteristics of exploratory search?

RQ2. How do people rate the different dimensions and characteristics of the exploratory search when performing a literature review?

RQ3. How do users' behaviours and overall experiences change when the user interface differs?

RQ4. What are the key exploratory characteristics that come into play when users search for literature in a new domain?

1.4 Thesis Contribution

In this thesis, I present several contributions that span both conceptual and theoretical perspectives derived from literature analysis, as well as empirical findings gathered through various user studies I conducted. The following are the main contributions of this thesis.

1. **Developing a Conceptual Model of Exploratory Search Tasks**: The primary contribution is to construct a conceptual model of exploratory search tasks grounded

in existing literature. This involves not only delineating the main dimensions of the task but also furnishing characteristics, explanations, and comprehensive definitions for these characteristics. The model serves as a foundational framework for research in information seeking and retrieval, particularly in the context of exploratory or complex tasks (Chapter 4).

2. **Empirically Validating the Proposed Model**: The second contribution is validating the conceptual model and gaining insights into individuals' experiences and behaviours during engagement in exploratory searches. Through a user study, I investigate the key characteristics of exploratory dimensions when conducting exploratory searches and reveal a fourth dimension of the model that has to do with knowledge gain (Chapter 4).

3. **Explore the Influence of Exploratory Interfaces**: Building upon the insights gained from the first and second contributions, I extend my understanding of the concept of exploratory search by examining how interfaces influence individuals' perceptions, behaviours, search outcomes, and overall experiences during exploratory searches. Using two laboratory user studies, I focus on studying how interfaces impact individuals' exploratory search perceptions, experiences, and outcomes. This is crucial given the substantial work done in proposing exploratory search interfaces to support users when engaging in exploratory tasks (Chapter 5).

4. **Developing a Conceptual Model of Exploratory Search Specific to Literature Review Tasks**: Building upon the insights gained from the previous points, the fourth contribution is studying a specific case of exploratory searches, namely literature reviews. I examine the behaviours, strategies, and search approaches associated with exploratory searches during literature reviews. I believe that this contribution supports a deeper understanding of exploratory searches in an academic context, enabling the research community to design more effective solutions and interfaces to assist individuals in conducting literature reviews (Chapter 6).

1.5 Thesis Statement

In light of the growing interest among researchers in the information-seeking and retrieval community toward exploratory and complex search, this thesis addresses the ambiguity surrounding its characteristics, dimensions, and definition. First, an extensive review of existing literature proposes a conceptual model of exploratory search, delineating

its main dimensions, characteristics, and comprehensive definitions (RQ1). Second, the thesis validates and extends this model through a user study and introduces another dimension to enrich the understanding of exploratory search (RQ2). Third, this thesis investigates users' experiences, perceptions, behaviours, and search outcomes during exploratory searches using various interfaces, and it examines the effect of task types (given or original) on users' behaviours (RQ3). Fourth, the thesis offers insights into the behaviours, approaches, decision-making processes, and knowledge acquisition during literature reviews, recognising literature review tasks as exemplary instances of exploratory search within information-seeking and retrieval research (RQ4). Overall, this thesis contributes to "*providing a solid understanding of exploratory search, including its fundamental characteristics, dimensions, and the factors influencing users' behaviours, experiences, strategies, and decision-making within the academic context*".

1.6 Thesis Summary and Outline

The work presented in this thesis is organised as follows:

Chapter 1 - Introduction: Presents the motivation, context, high-level research questions, and main contributions of the thesis.

Chapter 2 - Background: Reviews the existing literature on information behaviour, tasks in information seeking and retrieval, and exploratory search.

Chapter 3 - Methodology: Presents the formulation of research objectives, qualitative methods, quantitative methods, laboratory user studies, and ethics and research permission.

Chapter 4 - Conceptual Model of Exploratory Search: Presents the design of the conceptual model, the conceptual model of exploratory search, the conceptual model evaluation design, data analysis, and results of the first user study. This chapter answers my first and second research questions (RQ1 and RQ2).

Chapter 5 - Exploratory Search Interface Impact: Presents the user search interfaces used in the user studies, the two user studies, and their results and analysis. This chapter also investigates the influence of a more real-life task on users' behaviours, and answers my third research question (RQ3).

Chapter 6 - Understanding Exploratory Search Behaviours in Literature Reviews: Presents the data collection of the semi-structured interviews, methodology of inductive and deductive coding of the qualitative data, the analysis, results, and discussion. This chapter answers my fourth research question (RQ4).

Chapter 7 - Discussion and Implication: Presents a general discussion and implications of the findings.

Chapter 8 - Conclusion: Presents a thesis conclusions, a summary of thesis contribution, limitation, and future work and concludes the thesis.

Finally, the thesis contains appendices.

1.7 Publications

Most of the work presented in this thesis was previously published at the following peer-reviewed conferences:

1. Ayah Soufan, Ian Ruthven, and Leif Azzopardi. Untangling the concept of task in information seeking and retrieval. In Proceedings of the 2021 ACM SIGIR International Conference on Theory of Information Retrieval, pages 73–81, 2021 [165]. `https://doi.org/10.1145/3471158.3472259`. The content of this paper is discussed in Chapter 2.

2. Ayah Soufan, Ian Ruthven, and Leif Azzopardi. Searching the literature: an analysis of an exploratory search task. In ACM SIGIR Conference on Human Information Interaction and Retrieval, pages 146–157, 2022 [165]. `https://doi.org/10.1145/3498366.3505818`. The content of this paper is discussed in Chapter 2 and Chapter 4.

3. Ayah Soufan. Towards understanding and supporting exploratory searches. In Proceedings of the 2023 Conference on Human Information Interaction and Retrieval, pages 490–494, 2023 [164]. `https://doi.org/10.1145/3576840.3578304`. The content of this paper is discussed in Chapter 5.

4. Ayah Soufan, Ian Ruthven, and Leif Azzopardi. 2024. Uncharted Territory: Understanding Exploratory Search Behaviours in Literature Reviews. In Proceedings of the 2024 ACM SIGIR Conference on Human Information Interaction and Retrieval, 14 pages. `https://doi.org/10.1145/3627508.3638334`. The content of this paper is discussed in Chapter 6.

Chapter 2

Background

This chapter provides background information for this research. It reviews the literature in three main topics. It begins with a review of research in Information Behaviour (Section 2.1) and Tasks in Information Seeking and Retrieval (Section 2.2). Subsequently, the focus shifts to a specific task: Exploratory Searches (Section 2.3). In the domain of Information behaviour, I review the literature encompassing Information Retrieval, Interactive Information Retrieval, and Information Seeking behaviour Models and Theories. To further explore Tasks in Information Seeking and Retrieval, I perform a literature analysis, covering topics such as Stages of Task, Tasks and Sub-Tasks, Search Tasks, Information Processes and Tactics, Tasks Characteristics, and Task Hierarchies. Subsequently, I propose an Integrated Task Taxonomy based on the insights gained from the reviewed literature. To illustrate the practical application of the proposed taxonomy, I provide a Real-Life Example. Finally, I examine key papers and studies in the field of Exploratory Searches, the Literature Review as an Exploratory Search Task, and Exploratory Support Interfaces.

2.1 Information Behaviour

Information behaviour is a field within information and library science that explores human information-related activities [197]. It encompasses various aspects, primarily focusing on understanding how individuals seek and use information in specific contexts [196]. According to Wilson [197], information behaviour encompasses individuals' activities when identifying their information needs, searching for relevant information through various methods, and ultimately utilising or transferring the acquired information. Bates [15] describes information behaviour as the preferred term to encapsulate the diverse

ways humans interact with information, particularly in seeking and utilising it. According to Wilson [194], information behaviour encompasses the entirety of human actions concerning sources and channels of information, covering both active and passive information seeking and use.

Within the realm of information behaviour, a central component is an information-seeking behaviour. This involves how people actively seek, passively consume, and incidentally encounter information. Information-seeking behaviour is the outcome of an individual perceiving a need and interacting with information sources or services, ultimately resulting in either success or failure to find relevant information [194, 195]. Information searching behaviour is a subset of information seeking and a micro-level behaviour, which refers to purposeful actions when interacting with information searching systems, including information retrieval systems [12, 14]. It typically involves active and directed browsing, monitoring, and reading of information sources to fulfil specific information needs [12, 14]. The following sub-sections provide an overview of key aspects of information behaviour, including Information Retrieval, Interactive Information Retrieval, and Information Seeking Behaviour Models & Theories.

2.1.1 Information Retrieval

Information Retrieval (IR) is a crucial aspect of human information behaviour, serving as a fundamental activity online and an essential skill for various professional groups, offering a competitive advantage [146]. In the increasingly complex electronic information landscape, individuals navigating this environment are faced with more diverse sources, types, and access methods than ever before [146]. This complexity demands heightened decision-making and engagement with a growing array of search systems for anyone seeking information [146]. IR involves the process of locating unstructured material, typically textual documents, to satisfy an information need (topical similarity) from extensive computer-stored collections [114]. It also involves the organisation, storage, retrieval, and evaluation of information contained within document collections (usually text). It entails the process of accessing material, typically unstructured, such as text, that fulfills an information need from computer-stored collections. The research of IR aims to mitigate information overload and reduce search times [150]. IR research is rooted in the system-oriented Cranfield paradigm [40], which concentrates on the system itself. In IR research, the focus is primarily on the system itself or its algorithms rather than on the human aspect [33]. This perspective assumes that information seekers approach the system with clearly defined information needs [33].

2.1.2 Interactive Information Retrieval

According to Kelly et al. [94], the foundations of *Interactive Information Retrieval* (IIR) can be traced back to diverse fields, such as traditional information retrieval, library and information sciences, psychology, and human-computer interaction. IIR research primarily focuses on users' behaviours, tasks, and information needs rather than the system's requirements [40]. IIR research serves as a bridge between system-oriented and user-oriented approaches, ensuring that IR systems are not only accessible and usable but also effective for users [146]. IIR research considers viewpoints from both the user's and system's perspectives. For example, researchers might share findings from a user study focusing on a particular facet of a searcher's behaviour, concurrently offering insights from a system evaluation. This thesis contributes to the field of IIR by emphasising the human aspect within the exploratory search domain, as elaborated in the subsequent chapters.

2.1.3 Information Seeking Behaviour Models & Theories

Numerous models have been developed in information-seeking behaviour to describe various facets of information-seeking activities, the underlying causes, the consequences of such activities, and the intricate relationships underpinning these behaviours. In this subsection, I overview some influential models and theories, such as Dervin's Sense-Making theory, Information Foraging theory, Kuhlthau's Information Search Process (ISP) model, Ellis's Behavioural Model, and Bates' Berry-Picking Model. These frameworks have been instrumental in my overall understanding of human information behaviour and particularly in exploring the tasks and strategies involved in the exploratory search, as elaborated in the subsequent chapters.

First, Dervin's Sense-Making theory [47] introduces a triangular framework comprising situational factors, a gap or bridge, and outcomes. Within this construct, situational factors represent the contextual scenarios giving rise to information-related challenges. The gap serves as a conceptual marker delineating the disparity between the existing situational context and the desired state, while the bridge signifies a mechanism employed to traverse this gap. In their quest to bridge this gap, individuals engage in information-seeking activities to generate novel insights.

Second, Information Foraging [151] is a theory that describes information retrieval behaviour. The Information Foraging theory underscores two distinct foraging strategies: 1) specialists who concentrate their efforts on a single high-density "patch" of sources that

they encounter through informal communication channels and heavily rely on sources within their collections, and 2) generalists who, in contrast, adopt a broader approach by gathering sources from a diverse array of "patches."

Third, Kuhlthau's *Information Search Process* (ISP) model [102] provides valuable insights into the emotional and cognitive aspects involved in information searching. Although this model was studied in the context of students conducting literature reviews over a term, it lacks detailed information on students' actual approaches, resource assessment methods, and the key exploratory characteristics they employ during this task.

Fourth, Ellis's Behavioural Model of Information Searching Strategies [44] examined the various activities of social scientists. However, it still does not comprehensively understand the specific activities involved in literature review tasks. It is worth noting that Ellis's model was developed before the advent of digital libraries and online environments.

Fifth, Bates' berry-picking model [13] suggests that information seeking is not always systematic but often resembles "berry picking," where people gather information bit by bit from various sources. In her theory, most information is obtained through passive, aimless actions. At the same time, the rest comes from three types of behaviours: monitoring, browsing, and directed search. Bates explains that "berry picking," which involves sampling and selection, underlies most browsing and directed searches, drawing from traditional mating and foraging behaviours.

2.2 Tasks in Information Seeking and Retrieval

Tasks serve as fundamental drivers in the realm of *Information Seeking and Retrieval* (ISR) and constitute pivotal components influencing users' information-seeking and searching strategies. 'Task' is a generic word that can be applied to everyday and professional activities. Here, I focus on tasks that incorporate an information focus, often manifesting as a search activity. Tasks are also relevant in studying human behaviour [61]. However, some researchers tend to overlook the role of tasks within their studies, treating them as implicit aspects without comprehensive definitions or characterisations [181]. In contrast, other researchers have studied tasks with more granularity, examining various aspects such as task stages [102, 180, 199], task characteristics [29, 32, 199], or tasks performed by specific individuals in specific environments. Notable areas of focus include academic scientists [62, 68, 127, 198], students [59, 102, 138], and patent engineers [65]. Despite these efforts, ISR researchers have yet to reach a consensus on a singular definition of

the term 'task,' often employing task-related terminology interchangeably to describe diverse concepts associated with tasks.

This section aims to illuminate the crucial field of IR and establish a foundation based on a contemporary understanding of exploratory search tasks. These tasks inherently involve breaking down into multiple actionable sub-tasks and often necessitate several iterations of interaction (queries and clicks) to accomplish the intended objectives [8, 156]. In this section, I offer an introductory overview of the different approaches taken in the literature to investigate the concept of a task. Specifically, I examine the stages involved in task execution, diverse definitions of what defines a task, the distinguishing characteristics of tasks, and the concept of task hierarchies. Additionally, I present an integrated taxonomy of tasks within the context of IR.

2.2.1 Stages of Task

Several researchers have examined the stages that users go through in the context of information seeking and retrieving. Kuhlthau [102] presents one of the most influential task models based on students completing an essay-based assignment. Kuhlthau describes six stages of the information search process as initiation; exploration; selection; formulation; collection; and presentation. Each of these task stages is associated with distinct physical actions, cognitive thoughts, and affective feelings.

Building on Kuhlthau's ISP model [102], Vakkari [179] and Vakkari and Hakala [182] identify three stages in task performance: pre-focus; formulation; and post-focus. Based on Vakkari, at the pre-focus phase, thoughts are general and actions involve seeking background information. At the formulation phase, the search for information becomes more directed and a clearer understanding guides the individual to seek relevant information. At the post-focus phase, search becomes more specific and concentrated. Vakkari and Hakala's study showed the effect of task performance stage on search tactics and terms choice. Additionally, Xie's [199] research validates Vakkari and Hakala's research results.

Byström and Hansen [31] divide task performance into three main parts: construction; actual performance; and completion. The construction part consists of comprehending the preconditions and goals for performance and completion in relation to a given assignment. The actual performance part consists of the practical and conceptual actions taken to achieve the goals. The completion part includes evaluating task resolution to modify or accept it as a final task resolution.

For Järvelin et al. [86], information interactions are the behavioural and cognitive activities related to task planning; searching information items; selecting between information items; working with information items; and synthesising and reporting. Based on Järvelin et al. these five activities are essential in learning tasks and contribute to task performance and outcome. According to Järvelin et al., information interaction is broader than searching and subsumes information access; task-based searching; or task-based information retrieval.

The reviewed literature shows that different researchers characterised different stages that individuals go through while working on their tasks. Researchers used different terms but their concepts are the same. For example, Vakkari [179], Vakkari and Hakala [182], and Xie [199] identify three stages of tasks, unlike Kuhlthau [102] who identifies six. Vakkari's pre-focus stage corresponds to Kuhlthau's 'initiation' and 'selection' stages. Vakkari's post-focus stage associates with Kuhlthau's 'collection' and 'presentation' stages. In addition, among Byström and Hansen's [31] three main parts of task performance, the construction part can be divided into the 'initiation,' 'selection,' 'exploration' and 'formulation' of Kuhlthau's ISP model. Kuhlthau's ISP model was initially developed in connection to a school assignment task, but Byström and Hansen focus on tasks in work settings, so they did not emphasise the construction phase as Kuhlthau. Byström and Hansen believe that people are more confident in their judgments in performing their everyday work tasks and are less uncertain of the requirements of the tasks. The 'actual performance' and 'task completion' parts developed by Byström and Hansen can be mapped to the 'collection' and 'presentation' stages of Kuhlthau's ISP model. Figure 2.1 shows an illustration of tasks stages based on Byström and Hansen [31], Kuhlthau [102], and Vakkari and Hakala [182].

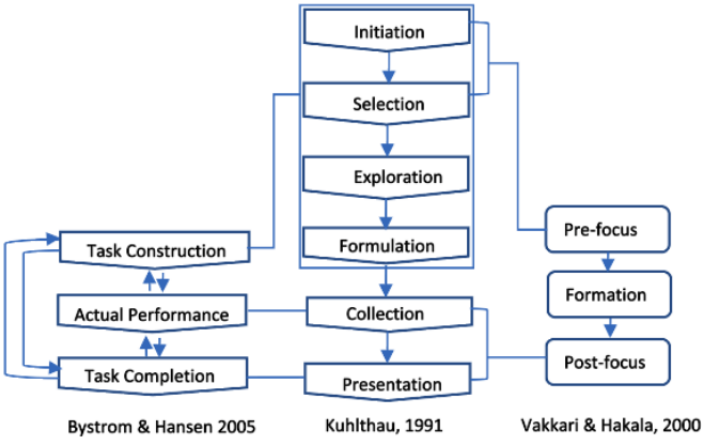

Figure 2.1: Task Stages.

2.2.2 Tasks and Sub-Tasks

In the ISR literature, tasks are sometimes called work tasks, information seeking tasks, search tasks, or information retrieval tasks. Some researchers restrict the term 'task' to work tasks that might trigger information search tasks [181]. Other researchers view work tasks as a motivation of information-seeking and information search tasks [64, 111]. Järvelin et al. [86] understand tasks as the larger tasks motivating information interaction. Byström and Hansen [31] define three levels of tasks including work tasks; information-seeking tasks; and information search tasks.

According to Byström and Hansen, work tasks are to some degree outlined by the work organisation which provides the environment or domain to which a task belongs. Vakkari [181] defines a task as an activity to be performed to accomplish a goal. Xie [199] classifies tasks into two levels: work and search tasks. While a work task leads to information searching, a search task determines what an individual is searching for [199]. For Xie [198], tasks and goals are inseparable in the ISP process. Xie [198] describes goal structure to represent four levels of goals including long-term goal; leading search goal; current search goal; and interactive intentions. For Toms [173], a work task is explicit and has a goal to be achieved through following a set of instructions. Toms [173], Järvelin et al. [86], Xie [199], Byström and Hansen [31] and Vakkari [181] believe that a task has a recognisable beginning and end. Additionally, a task may range from a simple one requiring little thought, to a very complex decision-making task. Complex tasks consist of smaller sub-tasks and both a large task or any of its sub-tasks may be considered as a task as well. Those sub-tasks must be accomplished and connected to reach a meaningful result.

2.2.3 Search Tasks, Information Processes and Tactics

Several researchers have examined information related tasks, particularly search tasks and search actions. Based on Byström and Hansen [31], information search tasks are sub-tasks to an information-seeking task, and information-seeking tasks are sub-tasks of a work task. For Byström and Hansen, information-seeking tasks focus on the satisfaction of an entire information need through consultations of several channels and sources. While information search tasks focus on the satisfaction of a fraction of an information need through searching for information from one or more sources.

Based on Toms [173], a task\sub-task may use one or more information processes and actions. Toms defines a process as a set of partially ordered steps intended to reach a goal.

Thus, information processes are those actions and operations that modify or augment information so that the original unit of data or information changes in some fashion. For Bates [11], a move is the basic unit of analysis and the identifiable thought or action of information searching behaviour. In addition, based on Bates, a tactic is a move made to further a search. Tactics are primarily designed to help in more complex searches that involve many stages. Bates defines twenty-nine tactics used in information searching which are grouped into four categories: monitoring; file structure; search formulation; and term tactics. While a tactic deals with short-term goals, a strategy deals with overall planning in the context of information searching.

Järvelin et al. [86] identify generic activity types that are performed across the task process stages related to information interaction. Järvelin et al. understand information interaction as behavioural and cognitive activities related to task planning, searching and selecting information items, working with information items, and synthesising and reporting. Figure 2.2 shows an illustration of information processes, tactics and activities based on Toms [173], Bates [11], and Järvelin et al. [86].

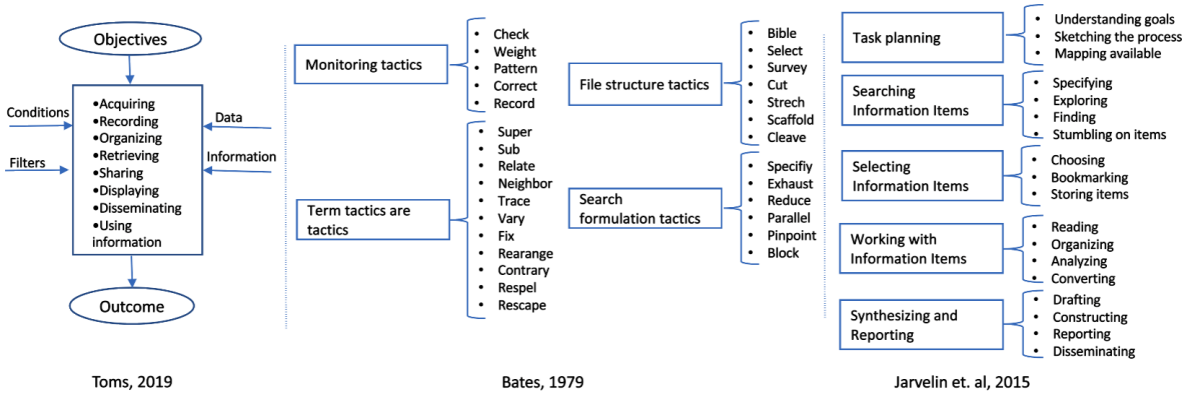

Figure 2.2: Information Processes, Tactics and Information Activities.

The reviewed literature shows that different researchers used different terms to describe or categorise information-related tasks, which are related to actions such as searching, acquiring, organising, synthesising, disseminating, and using information.

2.2.4 Tasks Characteristics

In addition to describing the nature of a task, task characteristics or what makes tasks different have been discussed in different ways in the ISR field [31, 34, 64, 199]. Li and Belkin [110] identify some of the essential task facets and attributes. They categorise those facets of work tasks and information search tasks into generic attributes including source

of task; task doer; time; action; product; and goal, and common attributes including task characteristics and user's perception of task. The following subsections describe some of the main task characteristics that have been studied in the ISR literature:

2.2.4.1 Origin of Tasks

Xie [199] classifies tasks based on the origination of the task into two types: self-generated and assigned tasks. Self-generated tasks refer to the tasks that participants came up with themselves. Assigned tasks refer to tasks that are delegated or suggested by people other than the participants themselves. Byström and Hansen [31] classify tasks based on their origin into subjective and objective tasks. Subjective tasks are seen as internal to the performer and defined by themselves. Objective tasks are external to the performer and imposed on them. These types of origination of tasks aligned with Hackman's [61] task classification.

2.2.4.2 Structured\Unstructured Tasks

Based on Hansen [64], structured tasks have a designed course, whereas unstructured tasks may involve creative planning and flexibility. For Toms [173], structured tasks are mostly instructional, and they leave little discretion to the worker. Meanwhile, unstructured tasks are constraints-based, epitomise cognitive work, and require significant mental effort in combination with knowledge and skills.

2.2.4.3 Nature of Tasks

Xie [199] identifies three types of tasks: routine; typical; and unusual: Routine tasks are repetitive tasks, typical tasks are new tasks to the performer but they are similar to tasks which they used to perform, and unusual tasks are new tasks to the performer, and they are not similar to tasks that they used to perform.

2.2.4.4 TimeFrame

According to the time needed to fulfil tasks, Xie [199] classifies the timeframe into extremely urgent; urgent; and non-urgent: extremely urgent means that the task has to be accomplished within half an hour, urgent means that the task has to be accomplished within twenty-four hours, and non-urgent means that the task can be accomplished in more than twenty-four hours.

2.2.4.5 Task Complexity

Task complexity is one of the most important and most studied attributes of tasks in ISR. Task complexity affects the performance and the information needed to complete a task [177]. For Campbell [34], task complexity is related to characteristics of repetitivity; analysability; the number of alternative paths of task performance; and outcomes novelty. Campbell characterises tasks based on their complexity into five categories: simple tasks; decision tasks; judgement tasks; problem tasks; and fuzzy tasks.

Task complexity can be classified as objective and subjective. Based on Adewale et al. [2], subjective task complexity is studied from the task performer's point of view, and objective task complexity has to do with the feature of the task itself, not the performer. Campbell [34] concludes that any objective task characteristic that implies an increase in information load, information diversity, or rate of information change can be considered a contributor to complexity.

Byström and Järvelin [32] divide tasks based on the predeterminability of information requirements, process, and output of the task into five categories: automatic information processing tasks; normal information-processing tasks; normal decision tasks; in-known tasks; and genuine decision tasks. Likewise, Byström [30] classifies tasks according to their complexity into three classes: automatic information processing tasks; normal information processing tasks; and decision tasks. Byström & Järvelin conclude that when the task complexity increases, the complexity of information needed and the number of sources increase as well. According to Kuhlthau [102] and Vakkari [177], task complexity is associated with the degree of uncertainty of task performance.

Notably, the term 'exploratory search tasks' was adopted instead of 'complex search tasks' following the seminal work of Marchionini [115] on exploratory search. For many years, there was a prevalent emphasis on comprehending and facilitating exploratory searches. However, a recent shift in terminology has occurred, with researchers now referring to exploratory searches as complex searches, as evidenced in studies such as [156], [186], and [157].

2.2.5 Task Hierarchies

Several researchers proposed various task hierarchies and structures. Some of these hierarchies were explicitly mentioned in the previous papers such as Toms' task hierarchy [173]. In most cases, these were implicit such as in the works of Byström [31], Xie [199], and Järvelin et al. [86]. I have constructed the different task hierarchies and structures

based on my readings in the mentioned works.

I believe that these hierarchies and structures are helpful and have several strengths as well as weaknesses. Thus, I used the most significant hierarchies and unified them to retain the strengths and expand them with more concepts from the work environment to propose an integrated task taxonomy that I believe can be used within various work environments and real-life contexts.

Toms [173] built a task hierarchy that describes work tasks and shows the relationships between activities, tasks, and information processes. For Toms, work is made of a set of activities and tasks. Activities are defined within the scope of a worker's job description, and they provide the goals for individual work roles. Toms put activities at the highest level of the task hierarchy. Activities may consist of one or more tasks. For Toms, a task is explicit and has a goal to be achieved through following a set of instructions. In addition, a work task consists of one or more sub-tasks, and the task itself may be considered as a sub-task to a larger project. Those sub-tasks must be accomplished and connected in order to reach a meaningful result. Information processes are in the lower level of Toms' task hierarchy. Based on Toms, information processes are those actions and operations that modify or augment information so that the original unit of data or information changes in some fashion.

According to Xie [199], task and goal are inseparable in the information seeking and retrieving process. Based on Xie, there are four levels of goal structures (hierarchy): long-term goal, leading search goal, current search goal, and interactive intentions. For Järvelin et al. [86], a task is a sequence of activities a person performs to accomplish a goal. Based on Byström & Hansen [31], work task is at the top level, information seeking tasks are sub-tasks to a work task, and information search tasks are sub-tasks to an information seeking task. Figure 2.3 shows an illustration of the different task hierarchies based on Toms [173], Xie [199], Byström & Hansen [31] and Järvelin et al. [86].

According to Taylor [170], *"Tasks do not exist independently but in interaction with the context of which they are a part"*. Various researchers talked about or corporated the socio-organisational context in their ISR models or hierarchies [16, 112], but their contributions had issues with simulating the real-life experience in work environments. Their models fell short of describing work roles or their effect on information seeking and retrieval tasks. For Toms [173], there is no clear difference between a job description or a job role; both can define the core activities. Other hierarchies and task models ignored activities and work roles completely. I believe that the previous hierarchies and structures are important but they are not complete and do not take into consideration the real-life

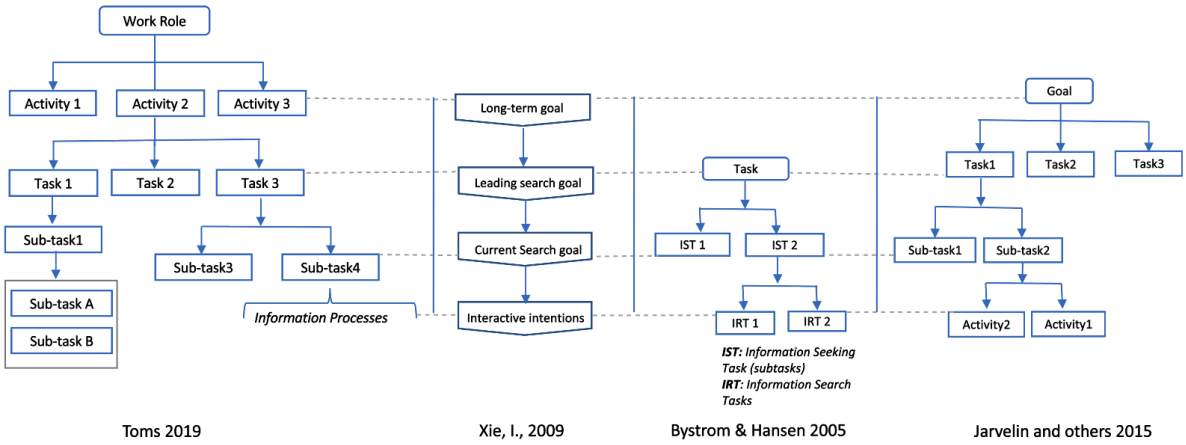

Figure 2.3: Task Hierarchies.

scenarios at workplaces.

To summarise, previous research has studied the concepts of tasks from different perspectives. Ultimately, previous research did not agree on the same definitions for tasks and the related key terms. Additionally, the proposed various task hierarchies (explicit or implicit) do not agree on the components of task hierarchies and the involvement of work roles and their effect on tasks. Therefore, I propose an integrated task taxonomy, which I believe draws a full picture of tasks and their relationships with work roles, activities, sub-tasks and information related tasks in work environments. My task taxonomy can also be used in real-life contexts as well as work environments. I also provide a series of working definitions that will help in solving the inconsistency in the literature related to tasks and their related key terms.

2.2.6 Integrated Task Taxonomy

ISR researchers who studied work tasks ignored the fact that individuals may take a limitless number of potential roles at work [58]. The literature in work structure, management, and human resources shows that information need is highly related to the performance of a particular role and its associated activities and tasks. Thus, I propose a task taxonomy that builds on the previous task hierarchies and completes them. Also, I provide a series of working definitions of work role, activity, and task\sub-task.

2.2.6.1 Work Roles

Most researchers in the field of information seeking and retrieval ignored the different roles taken by individuals while working on their tasks even though work roles have an

effect on information-related tasks. The reviewed literature suggests that the same task might be approached in different ways depending on the performer's role at the time of completing the task. Some researchers implicitly mention work roles and their effect on the work and information-related tasks. For example, Järvelin & Wilson [85] raise a crucial point about work roles and the importance of thinking of tasks from a context or discipline point of view.

Järvelin & Wilson make it clear that there may be significant differences in the nature of the tasks from one department to another in the same administration. Based on Järvelin & Wilson, different departments may have different concerns which can lead to approach the same tasks in different ways. Thus, it is important to study the context of tasks and work roles taken by individuals to complete their tasks. Leckie et al. [107] show that it is common that professionals play many distinct roles throughout any given day. Besides, Leckie's et al. review concludes that different tasks are associated with different roles taken by the same employee, which generate different information needs that must be met to move forward with work.

Sonnenwald's study [163] shows that individuals may assume one or more roles and may change roles during the design process. The literature in the field of management and human resources assures that individuals can take multiple work roles while working on their tasks and duties inside their organisations [56, 58, 185]. Based on Huvila [79], an individual in a work environment may be required to work on a set of activities and tasks to accomplish a goal. Besides, most work environments are dynamic. Thus, individuals may perform multiple roles at the same time [79]. Even though job description specifies details about the job responsibilities, requirements, skills, knowledge, and expertise which are needed to fill a certain work role, employees may have multiple roles that may be extended to other different sub-roles [58].

Work roles can not be divorced from the organisational context within which they exist [81]. Even though some organisations are more hierarchical than others, employees in flat organisations also have roles and tasks. Parker et al. [135] show that employees do not react passively to the jobs, tasks, roles, and goals assigned by their managers. Rather, they actively change, shape or expand their work roles. Griffin et al. [58] suggest that work roles must emerge dynamically in response to changing conditions and demands in work environment. They believe that role behaviours can contribute to effectiveness at three levels including individual, team, and organisation.

Roles refer to the social position people have and the behaviour associated with that position (e.g., mother, teacher, and lawyer) [1]. Work roles are *"behaviours and activities*

that are directly associated with achieving specific objectives" [81]. Employees may have a work role that matches their domain of knowledge and expertise, which can be called the main role, but they have to perform other roles within the organisation environment to fulfil all their duties and responsibilities [107]. Besides, some roles can be extended to other different sub-roles [81, 107]. An employee can perform multiple work roles at the same time or share the same work roles with others [79]. Here is a summary of the main characteristics of a **work role**:

- Work roles exist within an organisational context [81].
- A work role can be extended to other sub-roles [81, 107].
- There are two types of roles: main and secondary roles [107].
- Individuals can perform multiple work roles at the same time [79].
- More than one individual can perform the same role [79].
- A work role can define a series of core activities [173].

2.2.6.2 Activity

In the literature of ISR, some researchers defined and used the term 'activity' in their research, others did not. While Toms [173] believes that an activity may consist of a set of tasks, some researchers believe that the opposite is true. For example, Järvelin et al. [86] define the task as a sequence of activities a person performs to accomplish a goal. Also, Li & Belkin [111] view work task as an activity people perform to fulfil their responsibility for their work.

According to Toms, work is made of a set of activities and tasks. Activities provide the goals for individual work roles. According to Norman [128], activities are not the same as tasks. An activity is a coordinated and integrated set of tasks. Based on Toms, activities are defined within the scope of a worker's job description, and they are implicit in discussions of work. Toms puts activities at the highest level of the task hierarchy. She believes that activities may consist of one or more tasks. Meanwhile, Xie [199] believes that tasks and goals are inseparable in the information seeking and retrieving process.

Xie's 'Long-term goal', which resides at the top of her goal\task structure, refers to a user's personal goal that they pursue for a long time such as professional achievement. Such a goal is similar to Toms' activity concept. Activities can be implicit or explicit depending on the activities themselves and the individuals who work on them. For

example, Software Engineers who work in tech companies need to keep learning about better ways to build their products. 'Learning' activities can be implicit in this case. However, other activities such as supervising other engineers and attending conferences can be explicit activities.

In summary, an **activity** is an abstract concept that contains one or more tasks that might expand and generate more tasks depending on the task and the one who performs them. An activity has a goal and objective within the organisational environment. Activity is long-running and open-ended, which does not have a recognisable beginning and end. An activity is flexible and may be semi-structured. Here are some of the main characteristics of **activities**:

- Activities exist within an organisational context [173].
- Activities are generic and may not have specific guidelines to follow [173].
- An activity may consist of one or more tasks [173].
- An activity may be associated with one or more work roles.
- An activity may consist of a set of sub-activities.
- Activities can be implicit [173] or explicit.
- Activities have goals and objectives.
- Activities are open-ended.
- Activities are long-running.

2.2.6.3 Tasks

Work tasks are often seen as the motivation for information-seeking and information search tasks [109]. Järvelin et al. [86] understand tasks as the larger tasks motivating information interaction. Byström & Hansen [31] define three levels of tasks including work tasks; information-seeking tasks; and information search tasks. Xie [199] classifies tasks into two levels: work and search tasks, and her goal\task structure describes four levels of work tasks. For Toms [173], an activity consists of one or more tasks, and a work task is explicit and has a goal to be achieved through following a set of instructions.

Additionally, tasks have recognisable beginnings and ends despite not being recognisable the moment they are happening [31]. Tasks can be accomplished by following some

guidelines, and can also be measured. A task may range from almost automatic processing requiring little thought, to very complex decision-making [31, 86, 173]. Complex tasks consist of smaller sub-tasks. Either a large task or any of its sub-tasks may be considered as a task [85].

In summary, **tasks** are what someone does to achieve an activity's goal under a specific work role. They can be given to or identified by the individuals themselves. Tasks have recognisable beginnings and ends. Besides, tasks have goals and objectives within the organisational environment, and they can be measured. Tasks have constraints and requirements to fulfil, and they may range from simple to complex decision-making. They can be divided into smaller sub-tasks. Here are some of the main characteristics of **tasks**:

- Tasks are either assigned or self-generated [31, 32, 61, 199].
- Tasks have recognisable beginnings and ends [32, 86, 173, 181].
- A task has a practical goal (some form of output) [31, 32, 86, 173].
- A task has a meaningful purpose (a reason) [31].
- A task has requirements to fulfil [31, 173].
- A consequence of the last point is that a task's progress can be measured to some degree.
- A task may range from simple to very complex decision-making [31, 32, 86, 173].
- A task can be structured or unstructured [64, 173].
- A task may have some constraints [173].
- A task can be divided into smaller sub-tasks [31, 32, 86, 173, 199].
  - Each sub-task has a goal.
  - Sub-tasks may need to be undertaken together to build a meaningful whole.
  - Sub-tasks may be further decomposed into more sub-tasks.
  - Sub-tasks may consist of or contain information seeking and retrieval tasks.

Figure 2.4 shows the integrated taxonomy and the relationships between work roles, activities, tasks and information related tasks.

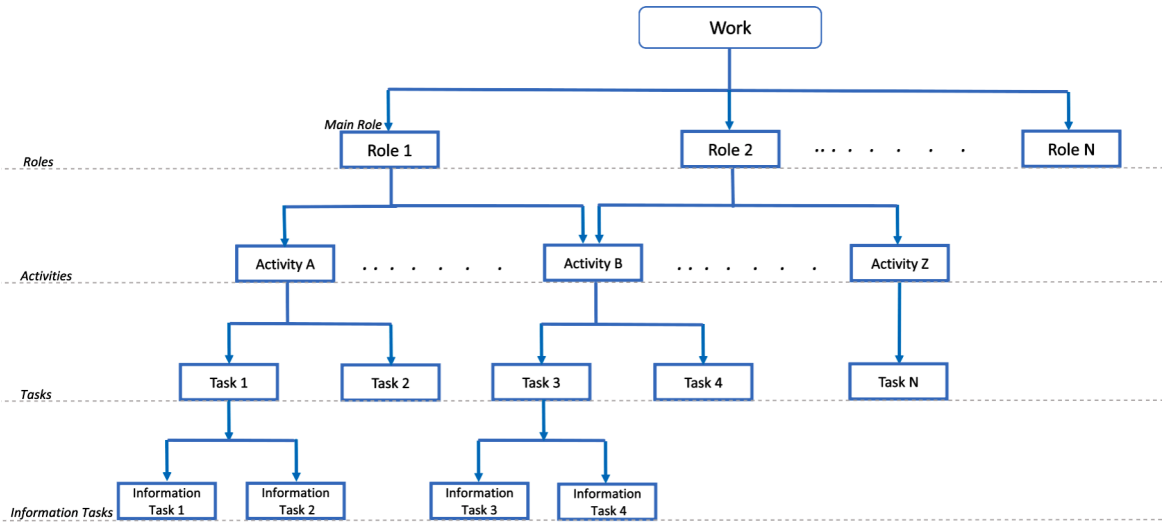

Figure 2.4: Integrated Task Taxonomy.

2.2.7 Real Life Example

In this section, I illustrate the integrated task taxonomy by applying it to a real-life example in a working environment: the scenario of an academic working in a university. An academic working in a university may take several roles such as being a researcher, head of a school, lecturer, manager, or supervisor. Each role of these may consist of a series of activities. For example, a researcher may work on disseminating or researching activities. Disseminating activity may consist of several tasks such as writing a book or a conference paper. On the other hand, a lecturer may work on researching and teaching activities.

Researching activity may be associated with two roles: researcher and lecturer. An academic may work with their students on a research project as part of a taught module or as a researcher who conducts research as part of their responsibilities and requirements at the institute. The research activity may consist of several sub-activities and tasks such as working on a specific case study and completing a literature review on a specific topic, etc. Being a lecturer includes teaching specific modules or planning a specific curriculum.

A task of teaching a module may consist of a series of tasks including preparing slides, preparing a reading list, marking, etc. Each one of these tasks may consist of one or more information-related tasks. Figure 2.5 shows the work hierarchy and the relationships between work roles, activities, tasks and information-related tasks for an academic.

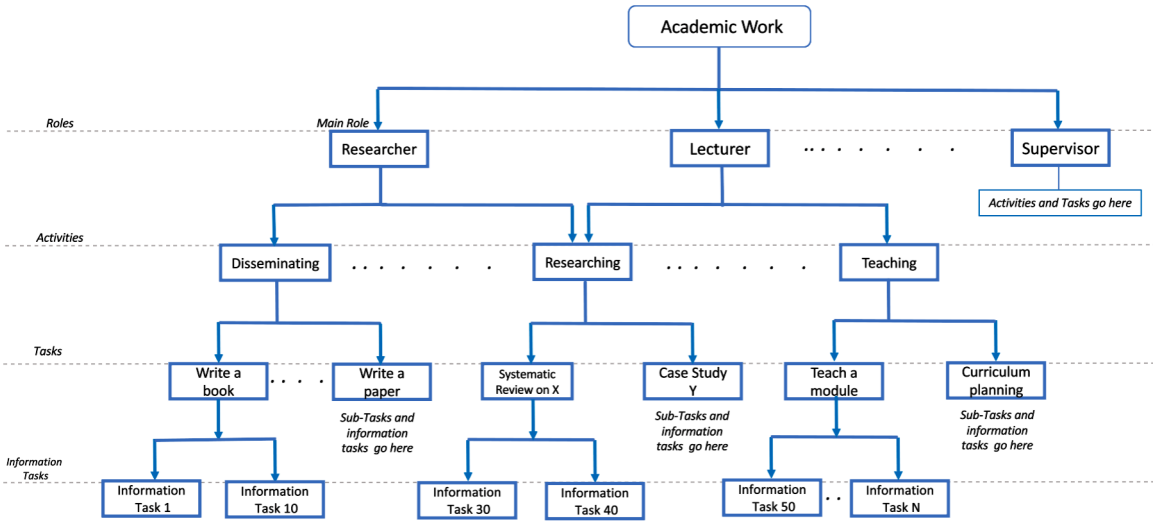

Figure 2.5: Task Hierarchy for an Academic.

2.3 Exploratory Search

In the previous section, I provided an overview of tasks related to information-seeking and retrieval in a general context. In this section, my focus shifts to a specific and distinctive type of task known as the Exploratory Search task. Search activities can be devided into three main types: lookup, learning, and investigation, where the learning and investigation activities are core to exploratory searches [115], as shown in Figure 2.6.

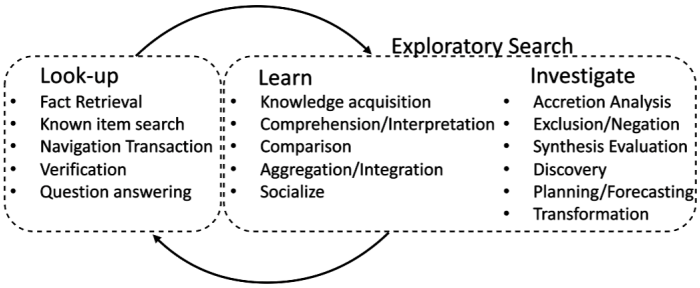

Figure 2.6: Search Activities based on [115]

Lookup or known-item search is the most basic search task with a clear and well-defined definition [6, 115]. Lookup searches are assumed to have precise search goals and return discrete and well-structured objects [6, 187]. The most distinctive types of lookup tasks are finding facts and answering specific questions [7]. Overall, having precise search goals with simple search paths are the main characteristics of lookup tasks [6]. Marchionini [115] defines the exploratory search by exclusion; he considers exploratory search as every search that is not lookup.

While lookup search has a well-defined definition, exploratory search definition is still vague and considered to be complex, multifaceted, and keeps evolving [132, 187]. Exploratory search is a specialisation of information exploration where a broader class of activities is done to look for new information in a defined conceptual area [192]. Users can employ exploratory search when they want to learn, discover, and gather information about a domain that interests them but might not have prior or specific knowledge about that domain [115, 189].

It is noticeable that most of the previous researchers follow White and Roth's [187] attempt to define the exploratory search. They use exploratory search to describe two aspects: problem context and search process. White et al. [192] describe the exploratory problem context as open-ended, persistent, and multi-faceted. They also describe the exploratory information-seeking process as opportunistic; iterative; and multi-tactical. It is apparent that the literature attempts to provide characteristics of the problem context and the search process, but they do not define or fully explain these characteristics.

Exploratory problem contexts are commonly found in scientific discovery, learning, and decision-making contexts [192]. Meanwhile, the exploratory information-seeking processes can be used in all information-seeking manners [115, 192]. Based on Hassan et al. [66], exploring sessions are where users are engaged in an open-ended and multi-faceted information-seeking task to foster learning and discovery by submitting multiple queries intended to address different aspects of a topic.

After reviewing the core papers and many previous studies about the exploratory search, I found that problem context and search process are commonly used in the literature as the main dimensions to define the exploratory search. However, there is not adequate focus on other dimensions, such as users who engage in the exploratory search, users' information needs, and the exploratory goals. Some papers describe users who engage in the exploratory search, but they do not consider exploratory users as one of the main dimensions of the exploratory search. The literature mentioned some characteristics of the problem context and the search process but did not define or fully explain them such as opportunistic search process.

Based on my literature analysis, I believe that the three main dimensions that describe the exploratory search and have a significant effect on the exploratory levels are the following: users who engage in the exploratory search; the exploratory problem context; and the exploratory search process. Chapter 4 extensively studies these three exploratory search aspects. Additionally, it models the key characteristics that control the exploratory levels.

2.3.1 The Literature Review: An Exploratory Search Task

In the realm of Information Seeking and Retrieval, searching the literature for relevant references in the context of academic work, such as theses or publications, is widely recognised as an exploratory search task [74, 96, 123, 159]. Literature reviews provide an overview of previously published works on a topic, encompassing various scholarly materials like books, theses, dissertations, and journal articles [9]. Literature reviews summarise and evaluate literature collections related to a specific theme, theory, or method to enhance the existing knowledge base [100, 136]. It is worth mentioning that while there have been numerous studies examining researchers engaged in academic tasks such as conducting literature reviews or writing proposals that require reviewing the literature such as Vakkari et al. [183], Vakkari [178], Pennanen and Vakkari [138], and Kuhlthau [102], these studies did not approach the literature review task from the perspective of exploratory search, as I do in this research.

Reviewing the literature involves collecting research literature, comprehending its content, establishing connections among gathered data, and synthesising insights [168, 203]. The process of reviewing literature involves the examination of numerous papers to extract meaning and identify connections across a substantial volume of publications. This task is becoming increasingly challenging due to the exponential growth of scientific publications [20, 89]. This task's complexity further intensifies as science's interdisciplinary nature continues to expand [130, 184].

A literature review requires various skills, including finding and evaluating relevant materials, synthesising information from diverse sources, employing critical thinking, and effectively summarising content [26]. An effective literature review should have a logical flow, connecting different sections and topics within the review [144]. Exploratory search strategies are crucial in conducting literature reviews, where individuals aim to gain insights into specific topics. It is important to note that literature reviews are regarded as processes of knowledge construction [168, 203]. The term "mental model" is frequently used in sense-making literature [141, 168, 203] to describe this evolving comprehension as searchers encounter new information during exploratory searches [17].

Although many researchers in the information seeking and retrieval community used conducting a literature review as a tool to study exploratory search, interestingly, in other literature, it is often considered a much formal, well-defined, and structured process with a clear goal [41, 134]. Some researchers tried to formalise this intuitive and high-level understanding of the exploratory search more precisely. For example, Nedumova and Kuznetsov [123] examined which scientific search tasks can be classified as exploratory

search ones.

Athukorala et al. [4] tried to formalise a model to estimate the subjective specificity in exploratory search by observing the behaviour of computer science researchers exploring the literature. Shukla and Hoeber [159] assumed that academics employ exploratory search strategies when searching for literature on a new topic. However, there is a lack of empirical studies on exploratory search behaviours, and the literature lacks empirical evidence supporting the claim that reviewing the literature is an exploratory search task.

Many researchers have developed interfaces to aid searchers in literature reviews and paper discovery through exploratory searches. I review some of these interfaces in the following sub-section.

2.3.2 Exploratory Support Interfaces

Standard\traditional search interfaces require searchers to assess results sequentially for relevance to their information needs, a method well-suited for simple tasks like lookup searches, but not for exploratory ones [72, 188]. Exploratory search, as highlighted by Bozzon et al. [21], presents unique challenges for state-of-the-art search engine interfaces. These challenges arise due to the demand for comprehensive support throughout all phases of information acquisition.

In exploratory search scenarios, where searchers tackle unfamiliar domains and deal with complex evolving problems, traditional list presentations often fall short [60], as these lists may not effectively convey crucial concepts or their relationships [60]. To address these issues, information visualisation techniques come into play, assisting searchers in querying, comprehending, interpreting, and making sense of the extensive information space within their area of interest [71].

Prior researchers have attempted to overcome the limitations of traditional interfaces by designing support tools that incorporate visualisation, categorisation, or clustering methods to facilitate learning and exploration. There has been an increase in commercial tools that use state-of-the-art technologies and claim they support exploratory searches, such as Research Rabbit[1], Zeta-Alpha[2], and Semantic Scholar [52]. Previously, some researchers explored different methods to enhance exploratory search, such as navigation interfaces with faceted search [175], sequential facet pipelines [54], and expanded facets for deeper browsing [84].

[1]https://researchrabbitapp.com
[2]https://www.zeta-alpha.com

Interactive timeline visualisations have been employed to identify significant time periods [161]. Some researchers have focused on creating systems tailored for touch devices [99], mobiles [137] and enabling cross-session and cross-device searches [55]. Additionally, certain search interfaces offer features like information grouping and reorganisation [108], while others support exploratory strategies such as query expansion techniques to help users refine their initial queries [143].

Some researchers worked on supporting the exploration behaviour by designing advanced user interfaces with interactive keywords, key-phrases or word-clouds visualisations [49, 72, 92, 142, 145, 155, 159, 200]. Other researchers proposed ontology-based support systems to help searchers. For example, Maksimov et al. [113] worked on using ontology graphs as a navigation map, and Hoeber et al. [73] used a concept knowledge base to help searchers who struggle with crafting queries. Additionally, Sarrafzadeh et al. [153] proposed a system that combines knowledge graphs with document retrieval to support exploratory users with their complex search tasks. Certain systems have been specifically designed to provide scaffolding for literature review tasks [133].

Despite the growing interest in exploratory search and the development of interfaces to support users employing exploratory strategies, there is still room for improvement. Firstly, many of the interfaces proposed to facilitate exploratory strategies have not been widely adopted by major search engines and have seen limited usage. Secondly, several of these proposed interfaces have limitations, yet many were not evaluated initially. Thirdly, there is a lack of a comprehensive understanding of how searchers utilise the support user interfaces and how their behaviours, experiences, and perceptions are influenced when using them for exploratory search tasks. It remains uncertain whether these interfaces affect their strategies and search outcomes and how. Therefore, Chapter 2.3.2 is dedicated to investigating the impact of exploratory search on users' experiences, behaviours, and search outcomes.

Chapter 3

Research Methods

In this research, a mixed-method approach combining both quantitative and qualitative research methodologies was employed to develop thorough study designs. Three distinct user studies were designed for this thesis. This chapter outlines the formulation of my research objectives and elucidates the various quantitative and qualitative methods employed in general, providing justifications for their utilisation. However, specific details on how these methods were utilised within the context of each user study are provided in the following chapters. Chapters 4, 5, and 6 offer precise information on the application of these methods within each particular study's context. This chapter outlines my research objectives (Section 3.1) and elaborates on the quantitative and qualitative methods (Sections 3.3 and 3.2) used to collect data during laboratory user studies (Section 3.4). Additionally, it provides details on the ethics and research permissions obtained for this research (Section 3.5).

3.1 Formulation of Research Objectives

My initial literature review on tasks in *Information Seeking and Retrieval* (ISR) revealed various classifications based on different criteria. Some researchers categorised tasks according to the stages of information seeking and retrieval, as seen in the works of Kuhlthau [102], Vakkari [177, 182], and others. Task performance was a focus for some researchers [31], while others studies information interactions [86]. Certain scholars examined the anatomy of tasks, exploring activities, tasks, sub-tasks, moves, tactics, etc. [11, 31, 86, 173, 181, 199]. Tasks were also analysed based on various attributes, including the task source, task doer, time, action, product, and goal. Common attributes included task characteristics and the user's perception of the task. Task complexity emerged as a

pivotal and extensively scrutinised attribute in ISR. The literature landscape transformed around 2006 when complex tasks were redefined as exploratory search tasks, influenced by the seminal work of [115] and others.

Campbell [34] identified task complexity by considering repetitiveness, analysability, the number of alternative paths for task performance, and the novelty of outcomes. He categorised tasks into five types: simple tasks, decision tasks, judgement tasks, problem tasks, and fuzzy tasks. Campbell concluded that any objective task characteristic leading to an increase in information load, diversity, or the rate of information change contributes to complexity. Byström & Järvelin [32] categorised tasks based on the predeterminability of information requirements, process, and output into five groups: automatic information processing tasks, normal information-processing tasks, normal decision tasks, in-known tasks, and genuine decision tasks. They found that as task complexity increases, the complexity of required information and the number of sources also increases. Kuhlthau [102] and Vakkari [177] associated task complexity with the degree of uncertainty in task performance.

After conducting an in-depth examination of tasks in ISR, I introduced an integrated task taxonomy as discussed in Chapter 2 (Section 2.2.6). Subsequently, I shifted my focus from tasks in ISR in a general context to an exploratory search task type. I started by conducting a literature analysis to scrutinise the concept of exploratory search, aiming to identify its constituents, main characteristics, and attributes. The multitude of definitions regarding the exploratory nature of searches lacked empirical validation and data-driven foundations. As a result of this identified gap, the main objectives of my research emerged.

These objectives include developing a conceptual model of exploratory search tasks rooted in existing literature. This model aims to outline the primary dimensions of the task and provide comprehensive characteristics, explanations, and definitions for these attributes. Additionally, the research seeks to empirically validate the proposed model, gaining insights into individuals' experiences and behaviours during engagement in exploratory searches. The investigation also extends to exploring the key characteristics of exploratory dimensions when conducting exploratory searches. These objectives are closely aligned with my first and second general research questions (RQ1 and RQ2): What are the main dimensions and characteristics of exploratory search? And how do people rate the different dimensions and characteristics of the exploratory search when performing a literature review?

While studying the concept of exploratory search, its definitions, dimensions, and characteristics, it was notable that there were numerous studies that propose interfaces

to support exploratory searches, some without thorough evaluation, as observed in [49, 55, 84, 92, 113, 142, 161, 175, 200]. In contrast, others undergo evaluation and comparison with standard interfaces, as exemplified in [54, 72, 99, 108, 143, 145, 153, 155, 159]. Many of these studies reveal participants' preferences for exploratory interfaces, emphasising their effectiveness in aiding document discovery, information navigation, query formulation, and information organisation. Despite these findings, a gap exists in the literature regarding the comprehensive examination of how diverse user interfaces impact users' behaviours, perceptions, experiences, and search outcomes. To enhance my comprehension of the exploratory search concept, I aimed to explore the interface's role in defining the exploratory nature of the search process. This inquiry led to the formulation of my third general research question (RQ3): How do people rate the different dimensions and characteristics of the exploratory search?

Building upon the insights gained from the previous research questions, this thesis extends the understanding of the concept of exploratory search when conducting exploratory or complex tasks in the academic context such as literature reviews. Certain literature segments depict literature review tasks as more formal, well-defined, and structured processes, usually characterised by a clear and specific goal [41, 134, 174]. On the other hand, searching the literature for relevant references in the context of report, thesis, or publication preparation is commonly acknowledged as an exploratory search task within the ISR [74, 96, 123, 159]. Researchers have proposed various models in information-seeking behaviour to elucidate different aspects of information-seeking activities, the underlying causes, consequences, and intricate relationships involved in these behaviours. Examples include Dervin's Sense-Making theory [47], Information Foraging Theory [151], Kuhlthau's *Information Search Process* (ISP) model [102], and Ellis's Behavioural Model of Information Searching Strategies [44]. Motivated by this, I aim to study exploratory behaviours and the diverse approaches employed in literature reviews to propose a conceptual model of exploratory search specifically tailored to literature review tasks. Consequently, this led to the formulation of my fourth general research question (RQ4: What are the key exploratory characteristics that come into play when users search for literature in a new domain?

In addressing my research objectives and questions, I conducted various user studies, employing a mix of quantitative and qualitative methods. These diverse research endeavours collectively contributed to the evolution of exploratory search models. Initially, the thesis introduced the first model of exploratory search, which was subsequently refined by incorporating additional dimensions or influencing attributes. Additionally, a customised

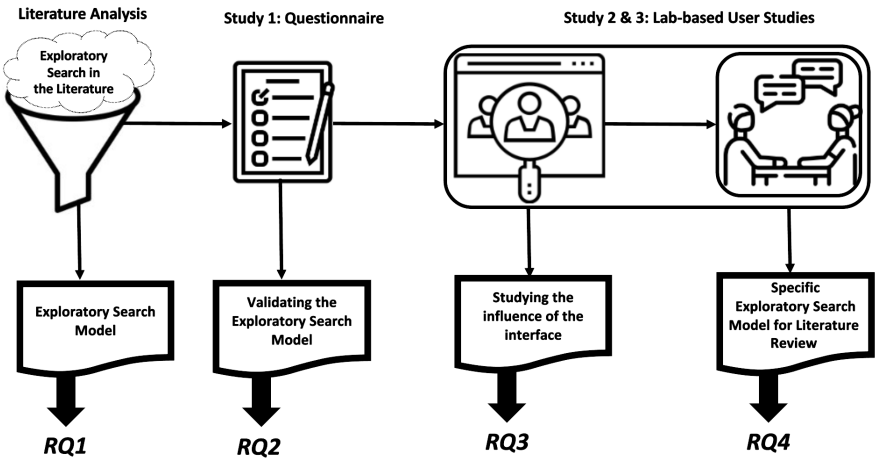

Figure 3.1: Flow of the thesis studies

version of the model was developed, explicitly tailored to literature review tasks. Figure 3.1 provides a comprehensive overview of the studies conducted, intricately linked to the main objectives and underlying research questions.

The following sections provide detailed insights into the methodology and methods employed to address my research objectives and questions. Each method is linked to the specific study (chapter) that employed it, and those chapters detail insights into their application within the respective contexts.

3.2 Qualitative Methods

Qualitative studies focus on interpreting data to comprehend individuals' experiences, biographies, opinions, values, aspirations, attitudes, and feelings [25]. Qualitative research seeks to understand the meaning individuals attribute to their world and how they interpret and experience various events [70]. Data in qualitative research are often generated through methods such as interviews, observation, analysis of visual materials ethnography, and focus groups, among others [172]. This section centres on two qualitative methods employed in this PhD research: conceptual models and interviews.

3.2.1 Conceptual Models

A conceptual model is a high-level depiction of how a system is organised and operates [90]. A conceptual model is a learning object representing one or more related concepts or ideas [38]. It describes various elements, including the concepts, attributes, operations

that can be performed, and relationships between these concepts [57, 90]. Concepts are not arbitrarily chosen but are formed by abstracting knowledge about instances [171]. The usefulness of an identified concept depends on meaningful differences from existing concepts, with meaningfulness defined by the context [171].

Conceptual models might be similar to print-based diagrams, images, drawings, or charts [38]. They also might be interactive visual representations designed to depict a concept or several connected concepts to support conceptual learning [39]. Conceptual models can be used when designing a software product, electronic appliance, or web service [90]. These visual educational materials improve the ability of learners to transfer their learning to solve new problems because learners have constructed applicable mind models that they can mentally manipulate when needed [119].

To formulate a conceptual model, one must actively engage in acquiring and applying knowledge [38]. In the realm of research, a conceptual model assumes the role of a guiding framework, providing a visual representation of theoretical constructs and variables of interest [42]. According to Crewell [42], a comprehensive literature review is essential in the design of a conceptual model. Aligned with Kerlinger's perspective [95], theories serve as the cornerstone by offering a systematic understanding of phenomena, establishing relationships among variables through interconnected constructs, definitions, and propositions.

Consequently, this research undertook a literature review and analysis within the exploratory search domain, contributing to developing a conceptual model for exploratory search. Chapter 4 provides details of this proposed conceptual model.

3.2.2 Interviews

Interviews are widely recognised in qualitative research [24], suitable for reconstructing events, describing feelings about current events, and predicting future developments [139]. Semi-structured interviews were chosen as the preferred method as they balance the structure needed to explore specific key aspects across all participants and the flexibility required to ask follow-up and tailored questions based on individual experiences. This approach ensures that essential information is gathered while allowing room for personalised insights. It is crucial to note that the researcher's observations of participants during tasks, such as search sessions, offer valuable context for shaping interview questions. While Section 3.4 provides an overview of the user studies conducted, it is worth highlighting here that observing participant behaviour during task execution provided me with insights that informed the development of focused and relevant interview questions.

The flexibility of semi-structured interviews proved invaluable, especially when participants had diverse experiences. This approach enabled a deeper exploration of specific responses, facilitating a more comprehensive understanding of individual perspectives. Overall, combining structured data collected via the quantitative methods with the qualitative insights from semi-structured interviews contributes to a more comprehensive analysis and offers a more holistic and nuanced understanding of participants' behaviours, experiences, and perceptions. Chapters 5 and 6 offer details regarding the conducted interviews and gathered observations, along with their respective outcomes and findings.

3.3 Quantitative Methods

The quantitative research approach prioritises using numerical data in data collection and analysis, focusing on statistical methods to draw conclusions [23]. This approach offers several advantages, including the efficiency of using statistical tools to save time and resources [51]. Another key benefit of quantitative research is that the scientific rigour applied to data collection and analysis enables generalisation [51]. Additionally, this approach facilitates the implementation of control and study groups in research design [51]. This thesis employed various quantitative methods, including questionnaires, system logs, and the rating of literature review outlines. The subsequent sections provide more detailed insights into applying these quantitative methods in my research.

3.3.1 Questionnaire

Questionnaires represent structured research instruments for collecting social research data through various modes such as face-to-face interviews, self-completion surveys, telephone interviews, or web surveys [28]. In the context of *Interactive Information Retrieval* (IIR) experiments, questionnaires serve as essential tools for gathering data from participants [93]. Typically, questionnaires consist of a series of questions presented in a schedule, whether on paper, in an interview format, or on a web page [93]. In IIR studies, questionnaires are commonly self-administered via electronic or pen-and-paper interviews [93].

Questionnaires play a crucial role in eliciting various types of information, including factual details, behavioural patterns, attitudinal responses, and affective and cognitive perceptions of information tasks and systems [93, 129]. Questionnaires can encompass closed questions, open questions, or a combination of both [93]. Closed questions offer a

predetermined set of responses from which participants must choose. Typically, responses are measured on 5–7-point Likert-type scales, with one endpoint indicating strong agreement and the other reflecting strong disagreement [93].

In contrast, open questions do not provide predefined responses, allowing participants to offer any response they find fitting [93]. In my studies, I employed online questionnaires primarily featuring closed questions. This approach facilitated data collection about users' behaviours, experiences, and perceptions in exploratory search tasks such as literature review. While questionnaires are valuable for capturing subjective self-report measures, they are considered less robust than objective, quantifiable measures such as the number of mouse clicks or page visits [129].

To address this limitation, I diversified my data collection methods in the studies where possible, incorporating system logs, ratings of literature reviews, and conducting interviews. However, in the first study, which relied solely on questionnaires, I collected over 400 responses to enhance the rigour of the analysis and findings, more details on this study are in Chapter 4. The Qualtrics [1] platform was employed to construct the questionnaires used in my studies. This platform proved suitable for my online studies, providing a versatile and user-friendly interface for questionnaire design and administration. Further details on the specific questionnaires used in this research are outlined in Chapters 4, 5, and 6.

3.3.2 System Logs

System logs pertain to log files generated within an experimental IIR system. This logging mechanism, integrated as a component of the IIR system, systematically captures and documents all interactions defined by researchers. [94]. Log files can be compared to the black box on an airplane, recording events within an organisation's system and networks [162]. These logs consist of crucial entries in evidence gathering, each containing information related to specific events within a system or network [162].

Studying searching behaviour through log data has been a common practice in the IR field. System logs have been used to define specific searcher stereotypes and evaluate systems [202]. Log files are comprised of log entries containing information about specific actions within the system, such as clicks and queries. These entries are recorded along with additional data, including timestamps, task topics, interface types, and participant

[1] https://www.qualtrics.com

IDs. System logs provide an objective and quantitative perspective on users' behaviours and interactions with the system.

While logs solely capture interactions and lack insights into users' motivations or thoughts, logging is a valuable method for capturing users' natural search behaviours, particularly in studies conducted outside laboratory settings, as emphasised by Kelly [94]. As Kelly asserts, "query logs alone are not enough." Therefore, in this research, I employed a combination of methods, including questionnaires, interviews, and literature review outlines, to complement the limitations of relying solely on query logs. Additional information regarding the utilisation of system logs in my user studies can be found in Chapter 5.

3.3.3 Rating of the Literature Review outlines

Literature reviews, in the context of this research, are conceptualised as processes of knowledge construction [168, 203]. This process involves collecting research literature, comprehending its content, establishing connections among gathered data, and synthesising insights [168, 203]. In essence, conducting literature reviews can be viewed within the framework of search-as-learning.

In many prior works, learning assessments have been used to measure learning as an outcome of the search process. As stated by Urgo and Arguello [176], the literature discusses various learning assessment methods such as self-report, implicit measure, multiple-choice, short-answer, free recall, sentence generation, mind map, argumentative essay, and summary & open-ended. Each of these methods has its own advantages and limitations. This research adopted the summary & open-ended method as the research aimed to simulate a real-life exploratory search scenario, specifically in the context of conducting literature reviews.

Evaluating summaries and open-ended answers poses challenges due to the unstructured nature of the data, where human bias can be a factor. To mitigate this, involving different independent researchers for assessment proves valuable. Ensuring consistency in assessment criteria is crucial, as it promotes a standardised evaluation process. The involvement of independent researchers, distinct from those who designed the experiment, is essential to eliminate potential researcher bias. Employing tests to measure the agreement among assessors enhances the reliability of the data analysis findings. This approach not only addresses potential biases but also strengthens the overall validity of the results, which is the approach I followed in this research. Further details on how I employed ratings of literature reviews in my user studies are outlined in Chapter 5.

3.4 Laboratory User Studies

A laboratory experiment is a purposefully designed and artificial setting where the experimenter manipulates certain factors (independent variables) while minimising the influence of other factors not currently under consideration (controlled variables) [37]. The objective is to measure changes in behaviour (dependent variables) resulting from or induced by the independent variables [37]. Laboratory studies hold significant value in developing and evaluating information retrieval systems due to the control they offer [94].

Laboratory studies also can be used to understand human behaviours. Laboratory studies can be easier to replicate, cost-effective, and less time-consuming compared to alternative methods [94]. However, it is essential to note that in contrast to naturalistic approaches, laboratory studies may be criticised for their artificiality. They might not faithfully represent real-life scenarios and can have limitations in terms of generalisability [94]. Studies can be categorised as either between-subjects or within-subjects designs.

In a between-subjects design, participants are exposed to only one level of the variable, meaning each participant interacts with just one system, for example [94]. Conversely, within-subjects design involves participants experiencing all levels of the variable, such as each subject using all system types or interface variations. The choice between these designs depends on the specific experiment and variable being studied [94]. Each type of experimental design comes with its advantages and disadvantages.

Within-subjects design requires fewer participants and enhances the likelihood of identifying genuine differences among conditions [27]. On the other hand, between-subjects designs minimise learning effects across conditions, result in shorter sessions, and may be more straightforward to set up and analyse [27]. The decision between these designs hinges on the goals and considerations unique to the experiment. Further details on the conducted between-subject and within-subject studies are in Chapter 5.

3.4.1 Piloting

A crucial phase in user studies is the pilot study, which serves as a preliminary examination of research protocols, data collection instruments, sample recruitment strategies, and other research techniques in anticipation of a more extensive study [167]. The primary objective of a pilot study is to uncover potential problem areas and flaws in the research instruments and protocol before the actual implementation [101, 106]. Additionally, the pilot study facilitates familiarising the researcher with the protocol procedures. It is pivotal in aiding decisions between alternative study methods or designs [160].

The pilot study encompassed various components, including assessing the feasibility of the study protocol, participant recruitment, testing the measurement instrument, and conducting data entry and analysis [67]. Despite careful planning, unforeseen difficulties may arise during the actual execution of user studies [67]. However, the investment in time and resources dedicated to pilot studies is typically deemed worthwhile. These preliminary investigations not only help anticipate and address potential challenges but also contribute to the overall success and validity of the main study.

3.4.2 Search Tasks

Tasks serve as significant driving forces for Information Seeking and Retrieval (ISR), profoundly influencing users' information-seeking and searching strategies[31]. Additionally, tasks play pivotal roles in the study of human behaviour [61]. Given the research focus on exploratory search tasks, careful consideration was given to designing tasks in user studies that simulate exploratory search within the specified time limitations. The guidelines followed for designing exploratory search tasks in this research were primarily derived from works such as Borlund [19], Kules and Capra [105], and Wildemuth and Freund [193].

In the context of Borlund [19], a simulated work task situation involves the creation of a brief 'cover story' that outlines a scenario where an individual needs to use an Information Retrieval (IR) system. This 'cover story' serves as a relatively open description of the context or scenario associated with a particular work task situation. The concept of a simulated work-task situation originates from Ingwersen's cognitive-communication models, as found in works like Ingwersen [82] and Ingwersen [83]. Additionally, the application of the work task concept by Byström and Järvelin [32] to information problem-solving and information-seeking processes contributes to the development of this concept [19]. A simulated work task situation is considered a stable concept in terms of the source of the information need, the environment of the situation, and the problem to be solved, helping participants understand the objective of the search [19]. This stability enables experimental control, facilitating the collection of comparable cognitive and performance data related to simulated information needs [19].

According to Kules and Capra [105], tasks designed for exploratory search systems should possess the following characteristics 1) Indicate Uncertainty: Tasks should convey a sense of uncertainty, prompting users to discover new information, 2) Unfamiliar Domain: The domain in the tasks should be unfamiliar to the searchers, but it should

also pique their interest. 3) Provide Sufficient Context: Task descriptions should offer enough context to enable searchers to relate to and apply the situation effectively.

As per Wildemuth and Freund [193], exploratory search tasks are associated with the goals of learning and/or investigation. These tasks are generally broad and open-ended, focusing on general exploration rather than specific outcomes. They typically involve multiple items or documents as the target of the search, introducing an element of uncertainty. Information problems that prompt exploratory search behaviours are described as ill-structured and challenging.

Tasks can be categorised based on their origin into two types: self-generated (subjective) tasks and assigned tasks (objective tasks) [31, 199]. In the context of this research, which primarily focuses on exploratory search tasks in the academic field, the emphasis is on conducting literature reviews. For one user study, participants were assigned specific search tasks and topics. In contrast, they were encouraged to work on their own topics for another one. This variation aimed to make the tasks more naturalistic and explore whether the nature of the task (self-generated or assigned) would impact participants' behaviours and the results. Further details on the search tasks employed in this research are in Chapter 5.

3.5 Ethics and Research Permission

I prioritised ethical considerations throughout this thesis. I obtained approval from the Ethics Committee at the Computer and Information Sciences Department at Strathclyde University to involve human participants. Additionally, I crafted a Data Management Plan for my studies. To ensure the protection of participants' rights during data collection, I developed an informed consent form, which was presented to participants before their engagement in any of the studies. The information gathered for this thises, including personal or identifiable data such as participants' names and email addresses (for communication purposes) and video, audio, and transcripts of the user studies, were handled with confidentiality.

It is important to note that the questions and data analysis undertaken did not solicit personal or potentially harmful information. Also, before conducting any data analysis, I took steps to remove identifiable information. Each participant was assigned a random identifier, which was utilised for analysing their associated data. Additionally, no identifiable data was included in any of my publications or research outputs.

Chapter 4

Conceptual Model of Exploratory Search

This chapter presents a conceptual model of exploratory search, drawing insights from existing literature in the field. The model is also empirically validated through a user study that utilises a questionnaire instrument. This chapter represents one of the initial inquiries into understanding how the suggested exploratory dimensions and characteristics capture the essence of exploratory search.

4.1 Introduction

Various researchers have offered different ways to characterise how exploratory a search task is, the main dimensions of exploratory search, and what factors make a search exploratory within each one of its dimensions. Marchionini [115] classifies search tasks into two categories: known-item search and exploratory search. In known-item search, users are already acquainted with the topic, possess knowledge of the specific item they seek, and know how to retrieve it. On the opposite side of the spectrum, in stark contrast to known-item search, lies exploratory search. According to White et al. [192], the exploratory search can be used to describe information-seeking problem context that is open-ended, persistent, multi-faceted and information-seeking processes that are opportunistic, iterative, and multi-tactical.

The extent to which a task is "exploratory" has been considered dependent on the user and their expertise and experience [46, 76]. The search task could be exploratory in one dimension or many. A highly exploratory search task is when the user is very unfamiliar with the topic or the problem context, very uncertain about the process, and

highly uncertain about the goal [4, 187, 188, 192, 193]. The literature is unclear about the driving factor(s) pertaining to this uncertainty for a given dimension.

Suppose a researcher has performed several literature reviews before and understands how to search the literature, knows the topic domain, but is uncertain of the different aspects and many facets of their information need. In this case, the task is exploratory in terms of the problem context, but less so with respect to the search process and their knowledge of the domain. However, a student about to write their very first dissertation may be uncertain across all dimensions. In this chapter, I provide a conceptual model features three main dimensions and 14 characteristics, encapsulating my understanding of exploratory search based on the reviewed literature.

Moreover, I provide one of the first detailed investigations into the nature of how exploratory literature review searches are –and more precisely, identify which dimensions and characteristics indicate the exploratory nature of such searches. Conducting literature reviews is intuitively considered an exploratory search task by the information-seeking and retrieval community [74, 96, 123, 159]. Chapter 2 (Section 2.3.1) provides a background of literature review as an exploratory search task. The literature review task was employed to capture the exploratory dimensions and characteristics integral to the model. In this chapter, my primary focus is on addressing three research questions. The first two questions are derived from the high-level research questions of this thesis, while the third question specifically explores aspects related to users' experiences.

RQ1. What are the main dimensions and characteristics of exploratory search?

RQ2. How do people rate the different dimensions and characteristics of the exploratory search when performing a literature review?

RQ3. How does the experience of the searcher influence how exploratory the literature review search is?

The following section outlines the methodology employed in crafting the conceptual model of exploratory search.

4.2 The Conceptual Model Design

In examining exploratory search tasks, I extensively reviewed key papers, including the seminal work by Marchionini [115] and White and Roth [187], along with numerous previous studies on the subject. I reviewed core papers on exploratory search and utilised

forward and backward chaining to explore related studies and papers in fields such as the design of supportive interfaces for exploratory search and the evaluation of exploratory search interfaces. The literature analysis I conducted was not a systematic review with defined keywords or inclusion/exclusion criteria. Instead, I searched for papers on the ACM Digital Library and through the university library's online portal, focusing on papers that addressed exploratory search. These papers often featured the term in the title, keywords, or abstract. I employed a "rabbit hole" strategy, discovering additional papers through those I was already reading. Most papers I reviewed were about proposing exploratory support interfaces. Some were related to the information behaviour models and the exploratory search.

Throughout this literature review, a consistent pattern emerged, with researchers frequently highlighting two key aspects of exploratory search: the problem context and the search processes [116, 187, 190, 191].

However, insufficient attention is given to other dimensions. Some researchers emphasised user interactions with results and query reformulation [66, 187], while other researchers focused on information needs [5, 35], along with various other attributes. I also reviewed the papers and studies that attempted to define, characterise, and design exploratory support systems [5, 6, 66, 104, 132, 152, 159, 193]. I systematically collected all exploratory dimensions, attributes, and characteristics mentioned in the literature. To structure these diverse characteristics, I compiled and organised them into different dimensions of exploratory search.

Based on the reviewed literature, initially, I identified four dimensions in the conceptual exploratory search model. However, after thorough discussions and reviews with my supervisors, I consolidated them into three main dimensions. Within these dimensions, I compiled over 20 characteristics. Through multiple reviews, some attributes were combined as they represented similar concepts described using different terms or were closely related in meaning and function. Following numerous revisions and discussions with my supervisors, the proposed exploratory model eventually included 14 characteristics, describing the three main dimensions.

This model incorporates definitions and comprehensive explanations sourced from existing literature. In cases where characteristics lacked accompanying definitions, explanations, or examples in the literature, I provided my own definitions aligned with my understanding of exploratory search, its dimensions, and the involved characteristics. In constructing the conceptual model, I explored various visualisation options. I ultimately chose axes to represent the exploratory dimensions, associated characteristics, and their

levels.

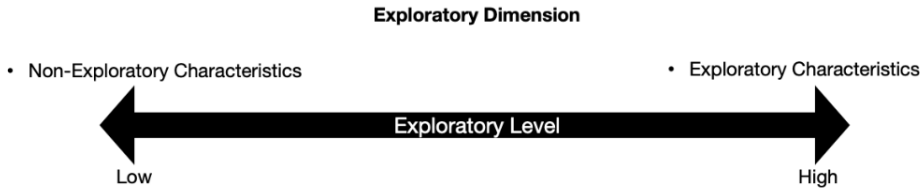

Figure 4.1: The Structure of the Dimension Visualisation in the Conceptual Model

Given that the model comprises three dimensions and 14 characteristics, I opted for three axes, aligning with each dimension. This choice enables the model to capture the spectrum of exploratory search, ranging from minimal exploration on the far left to the highest exploration on the far right. Each dimension includes exploratory characteristics, with the right side signifying the highest exploratory level and an opposing characteristic on the left indicating the lowest exploratory level. The axis emphasises that exploratory levels may differ across dimensions and characteristics, with some dimensions exhibiting high exploration while others involve less exploration. Figure 4.1 offers a visual representation of the axes employed in the conceptual model. Chapter 2 (Section 2.3) offers background information on Exploratory Search. The subsequent section elaborates on the conceptual model of exploratory search, delineating its three main dimensions and 14 characteristics derived from an extensive literature analysis in the field.

4.3 The Conceptual Model of Exploratory Search

The conceptual model of the exploratory search consists of three core dimensions and 14 characteristics, and it provides a framework for understanding and studying exploratory search. Figure 4.2 visually represents the main dimensions and characteristics, while detailed explanations of the Exploratory Search characteristics are provided below.

4.3.1 The User Dimension

Some of the previous researchers described users who engage in the exploratory search, but they did not consider users as one of the main dimensions of the exploratory search. Some literature suggested that the degree to which the search task is exploratory is influenced by how users are unfamiliar with the topic or domain, how uncertain they are

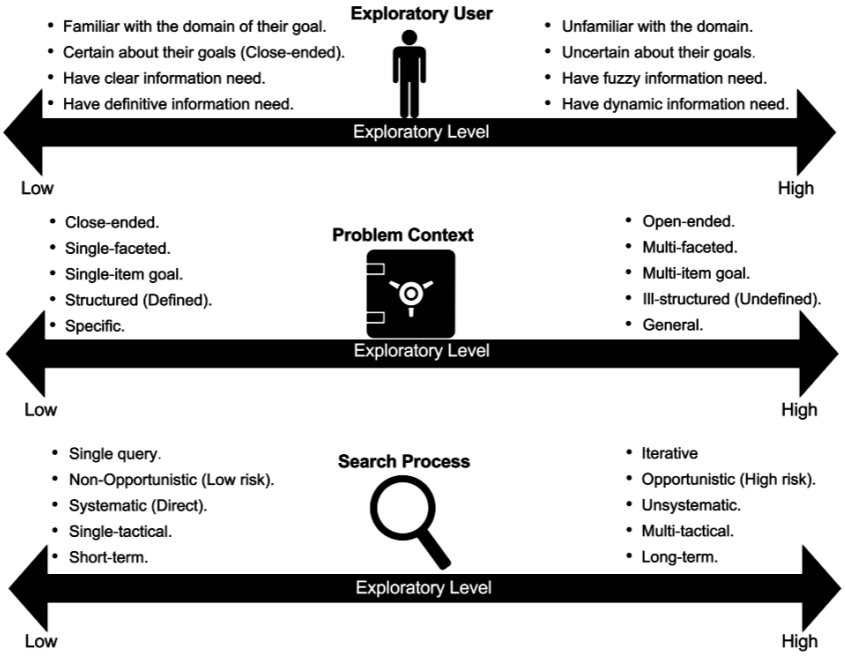

Figure 4.2: The Exploratory Search Conceptual Model

about the goal, and how clear they are about their information need [187]. Intuitively, the more uncertain the user is regarding the topic, goal, and information need, the more exploratory the search is likely to be. The following are the key characteristics of users who engage in the exploratory search.

4.3.1.1 Unfamiliarity with the domain

Users are likely to employ exploratory search to learn about a new topic. Previous researchers [80, 115, 132, 148, 187] claim that exploratory users are unfamiliar or new to the domain they are searching in, have little knowledge about it or insufficient expertise, or poorly understand the problem context's domain, resulting in more exploratory behaviours. Additionally, previous researchers [192] [123] suggest that exploratory users might not know the right keywords beforehand, and they might gather information and study the topic of interest immediately in the process of searching.

4.3.1.2 Uncertain about the goal

White and Roth [187] propose that users who engage in exploratory search might not have an imprecise goal in mind when they start, and the answer to the exploratory search may not be immediately apparent. Therefore, exploratory searches are typified by

uncertainty about the space they search in and the nature of the problem that motivates the search [188], and exploratory users might seek different opinions on a topic and explore various aspects to ascertain an overview of a topic [66].

4.3.1.3 Have fuzzy information need

For Kules and Capra [104], users' information needs might be unclear, ambiguous, or imprecise as exploratory users might not know the domain that they search in well or have a general interest but not specific knowledge of that domain [189]. Therefore, users' keywords are a-priori unknown, vague, and keep evolving [117]. Moreover, the exploratory problem context may be ill-structured and users' search goal may not be apparent [187]. Therefore, exploratory users might require additional information to clarify their goals [187].

4.3.1.4 Have dynamic information need

Based on Athukorala et al. [5], exploratory information-seeking has a dynamic nature. For some researchers [5, 187, 192], the exploratory search process starts with inadequately explained search goals; therefore, exploratory users might submit tentative queries, selectively exploring and passively gathering cues about the next steps. As a result, users' knowledge and information need constantly change throughout the iterative search process. During the exploratory searches, users are likely to understand the problem context better [187]; as a result, they tend to make more informed decisions about interaction or information use.

In sum, if users are more knowledgeable about the topic, and if they have a structured task with a defined goal, then presumably they would find the search task to be less exploratory in nature because they have the sufficient expertise, prior knowledge, and the terminology to formulate the search queries. Since their goal is clear, the information need might not be dynamic, or fuzzy. On the other hand, it has been hypothesised by some researchers [115, 132, 187] that users employ exploratory search to discover a new domain, increase their knowledge in an area, or learn about a new topic. As a result, they might not have sufficient expertise, prior knowledge, or the terminology to formulate search queries [80, 148, 187]. Moreover, users' information needs might be fuzzy\unclear while conducting the exploratory search process [117, 188].

Additionally, exploratory searchers might not have a specific search result in mind, and they might be unsure how to achieve goals [124, 187]. They might require additional

information from external sources to clarify their goals [187]. Consequently, their information needs might be dynamic and keep developing through the search process [4]. As exploratory searchers discover new information, they might experience uncertainty and confusion [187]. For these reasons, exploratory search is considered to be challenging [6].

4.3.2 The Problem Context Dimension

In terms of the problem context, five key characteristics are often mentioned when describing how exploratory the search is. For instance, if the problem context is open-ended and loosely structured, containing many sub-goals and facets; then, these are associated mainly with a more exploratory search problem context.

4.3.2.1 Open-ended (persistent)

Open-endedness relates to uncertainty over the information available or incomplete information on the nature of the search task [187]. The information need, the search goal, the problem context, the search process, and the search result of exploratory search are open-ended [124, 187]. The exploratory problem context, goal, and information need do not stay the same from the start to the end of the exploratory search. Additionally, having an open-ended problem context might lead to have fuzzy and dynamic information needs. Based on Athukorala et al. [6], because the search goal is open-ended, no single answer accomplishes users' information needs or ends the search. Since the open-ended problem is not finite, i.e., the literature keeps developing, so the search will never be complete as searchers cannot cover everything related to the task.

4.3.2.2 Multi-faceted

White and Roth [187] introduced this characteristic, but they did not define it. Based on Kintsch and Walter Kintsch [98] as in Wildemuth and Freund [193], the exploratory problem context and the end result might include various aspects and different concepts. Besides, the exploratory problem context might incorporate multiple sub-tasks. Therefore, exploratory users might end up searching for information related to various aspects of the domain they are looking in.

4.3.2.3 Multiple-item goal

Because the exploratory problem context might be open-ended and multifaceted, a single target answer may not exist and the target of the search is multiple items/documents

[115, 187]. The final result may be an integration of different aspects of the domain. Moreover, based on Hassan et al. [66], the information goal is likely to be satisfied with a combination of information encountered during the search using multiple queries dedicated to addressing different aspects of a topic.

4.3.2.4 Ill-structured (Ill-defined)

The problem context has imprecise task requirements [97]. It also may remain undefined or in a significant flux for much of the search session [187]. Therefore, users require additional information from external sources to clarify their goals and actions [187].

4.3.2.5 General rather than specific

The problem context is general, with a vague and under-specified description [193]. Exploratory search tasks provide a low specificity about the information necessary for their search, finding the required information, and recognising the needed information [104]. The exploratory problem context might be widespread among different areas of the domain and consist of various aspects of the domain.

In sum, open-ended is one of the fundamental characteristics of the problem context of the exploratory search [115, 188]. Users might never finish their exploratory search, but they might stop when they feel they have enough information to perform another task or do not have time to carry on the investigation [115, 132, 192]. Unlike the lookup tasks, the problem context of the exploratory search can be multi-faceted, complex [115, 192], ill-structured, and has imprecise task requirements [97, 118, 187].

In addition, the goal of an exploratory search contains multiple items [115, 193]. Exploratory search starts with imprecise and poorly defined search goals [5, 187] and a general search topic task with a vague and under-specified description [193]. As a result, users require additional information from external sources to clarify their goals and actions [97, 187].

4.3.3 The Search Process Dimension

In terms of the search process, five key characteristics are often mentioned when describing how exploratory the search is. For instance, the search process is iterative, multi-tactical, and opportunistic, yet unsystematic while searching over sessions.

4.3.3.1 Iterative

The exploratory search process starts with submitting tentative queries, selectively seeking and passively obtaining leads about the following steps, and iteratively searching with evolving information needs [5, 115, 187, 192]. The search process begins with an imprecise query, and then through several successive iterations of exploring the retrieved information and reformulating queries, the scope of the information need narrows down [5].

4.3.3.2 Opportunistic

White and Roth [187] introduced this characteristic, but they did not provide a definition. I define it as taking a greater risk on the premise of a bigger payoff. Since users do not have complete control over what to expect and do not precisely know what they are looking for, users' search process might be less direct. Users tend to select results that might have a higher opportunity to be beneficial for them. Moreover, users do not plan their next steps in advance but rather decide their next steps at each search stage.

4.3.3.3 Unsystematic

Users who engage in the exploratory search process are unsure how to achieve their goals (either the technology or the process) [187]. While searching and browsing, users encounter new information and concepts of interest, generating additional needs and guiding the search to new directions [88]. Users' exploratory search process might follow an unpredictable non-linear path during the search [88].

4.3.3.4 Multi-tactical

White and Roth [187] introduced this characteristic, but they did not define it. Users might employ multiple search approaches and consult different sources throughout the exploratory search process. The exploratory search process is characteristic of the alternation and iteration of querying and browsing activities [88, 115]. Users might use other ways and systems to reach the wanted information. They also might use these systems in different ways to find more relevant information.

4.3.3.5 Long-term

Exploratory searches can take place over multiple sessions and they can be long as hours, days, or even months [187].

Overall, if users are not knowledgeable about the topic, they would presumably find the search task to be exploratory. Thus, they might employ exploratory search processes to learn more about the domain. As hypothesised by White et al. [189] and Ianina et al. [80], exploratory users might submit some tentative queries, select and scan few documents, passively learn the terminology, and get cues to use in the following search iteration that helps them refine their knowledge and intentions. This iterative process is called the "query–browse–refine" process [80, 187].

Moreover, users' information-seeking processes can be described as opportunistic [187]; taking a more significant risk on the premise of a bigger payoff. Besides, exploratory users tend to select results that might have a higher opportunity to be beneficial for them. Since users do not have complete control over what to expect and do not know what they are looking for exactly, their search process might be less direct, nonstrategic, and unsystematic [187]. The exploratory search process is multi-tactical [115, 192], and the search process is cognitively complex and might take multiple days, weeks or months [187].

In conclusion, the literature claimed some characteristics of the exploratory search. Some of these characteristics were mentioned without explanations; others were vaguely or partially defined. In the above work, I tried to conclude and define the characteristics of the three main dimensions and highlight how they might affect each other. I used these characteristics and dimensions to propose an exploratory model that indicates how exploratory a search is. Following the formulation of the conceptual model of exploratory search based on an extensive literature review, the subsequent step involved testing the model.

4.4 Conceptual Model Evaluation Design

This section outlines the design of my first user study, aimed at evaluating the proposed model of exploratory search. In this study, I employ the conceptual model of exploratory search to devise a web-based online questionnaire to gather data on participants' experiences when undertaking a literature review task. My primary objective is to explore how academics and researchers assess the various dimensions and characteristics of exploratory

search. Additionally, I aim to identify which characteristics best describe the exploratory search task and understand how the searcher's experience influenced the literature review search.

Acknowledging that literature review tasks are considered exploratory search tasks within the ISR community [72, 74, 159], the questionnaire encompassed questions and statements related to participants' most memorable or latest written reports, including literature reviews in papers, journals, theses, proposals, or academic and industrial reports. The questionnaire contained a consent form and three main parts. The complete questionnaire and the full consent form used in this study are presented in Appendix A.1 and A.2. Further details on the various parts of the questionnaire are provided below.

4.4.1 Exploratory Search Questionnaire

Leveraging the main dimensions and characteristics of the conceptual model, I crafted a questionnaire instrument. The central component of the questionnaire comprises statements/ questions. Each of the fourteen characteristics was represented by statements reflecting scenarios or experiences in literature review tasks, resulting in around 50 statements. After multiple reviews, consultations with my supervisors, and a pilot study that involved removing redundant statements, I refined the questionnaire to 30 statements. These statements covered all fourteen exploratory characteristics across the three dimensions outlined in proposed conceptual model of the exploratory search.

Some statements and scenarios were interconnected with more than one characteristic or dimension. Table 4.1 illustrates the 30 statements and their corresponding dimenssions: Users, *Problem Context* (PC), and *Search Process* (SP). In order to provide a coherent and natural flow to the questionnaire, I grouped the statements into three logical stages: 1) before starting the search, 2) during the search, and 3) after completing the search. I chose this ordering so that participants could focus their attention on recalling their experiences at each respective stage. While these 30 statements constituted the primary part of the questionnaire instrument for testing the conceptual model, the questionnaire also included additional sections and questions, more details are in Section 4.4.2.

I requested participants to express their agreement level with these statements by selecting an option from a 5-point Likert scale: 1) Strongly Disagree; 2) Somewhat Disagree; 3) Neither Agree nor Disagree; 4) Somewhat Agree; 5) Strongly Agree. The utilisation of a 5-point Likert scale, which ranges from strongly disagree to strongly agree, was chosen based on recommendations from researchers, as it is expected to reduce respondent frustration and enhance both response rate and quality [147]. Additionally,

the use of a 5-point Likert scale allows for easy conversion to a 3-point Likert scale during the analysis stage, achieved by combining 'Strongly Disagree' and 'Somewhat Disagree,' as well as combining 'Somewhat Agree' and 'Strongly Agree,' while leaving 'Neither Agree nor Disagree' unchanged.

Table 4.1: Full version of the main questions of the questionnaire

#	**Question**	**User**	**PC**	**SP**
Q1	Before starting the search, I was already an expert on the topic	X		
Q2	Before starting the search, I already knew the right keywords and concepts to use when querying\searching	X		
Q3	From the start, I had a clear plan for finding relevant documents		X	X
Q4	I knew from the start what literature would go into the report	X	X	
Q5	At the start, I knew how to divide the review task into various sub-tasks/activities		X	X
Q6	During the search, I learned new keywords and concepts related to the review's topic	X		
Q7	During the search, I found information that was surprising or unexpected.	X		
Q8	During my search, I encountered new concepts which I chose to investigate further	X		X
Q9	During the search, I only examined result items/documents that I was sure were relevant.			X
Q10	I was able to easily decide which result items/documents were relevant	X	X	
Q11	I changed (reworded) the search query many times while searching for relevant results.	X		X
Q12	As I searched, what I thought was relevant changed over time.	X	X	
Q13	I was very thorough in checking through results/documents to find relevant items.			X

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Table 4.1 – continued from previous page

#	Question	User	PC	SP
Q14	The review's topic changed in response to reading some of the retrieved documents.	X		X
Q15	When searching, I wanted very specific and detailed information relating to the topic.		X	
Q16	The result items/documents I read helped me decide what to search for next.			X
Q17	I knew which sources/databases exactly contained the information/documents I needed		X	X
Q18	When reading a document, I looked up/examined items that were cited in it.			X
Q19	When reading a document, I checked to see who had cited it.			X
Q20	My supervisors and colleagues were able to suggest me relevant documents.			X
Q21	I used different tools to search for relevant results/documents (e.g., Google Scholar, Digital Libraries, the University Library, Mendeley etc.).			X
Q22	I searched for result items/documents using different query fields.			X
Q23	New materials on the topic are constantly being published.		X	
Q24	I had to run multiple searches to retrieve all the information that I wanted.			X
Q25	I was satisfied with the search results that I obtained.	X	X	
Q26	I was able to judge that I had retrieved most of the relevant results/documents for the review.		X	
Q27	The review report included literature from multiple topics related to the main topic.		X	
Q28	It took a long time to work out (put together) what I was looking for.		X	

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Table 4.1 – continued from previous page

#	Question	User	PC	SP
Q29	I stopped searching for documents because I found all that I was looking for.	X	X	
Q30	I stopped working on the review because of a deadline or other tasks to work on.		X	

Participants were also asked to rate the following statement by choosing an option from a 5-points Likert scale: "Given the review you just described, please indicate your level of agreement with this statement: I would describe this review task as being an exploratory task". This question was strategically positioned at the end of the questionnaire to prevent potential influences on prior responses. The goal was to categorise participants based on their perception of the exploratory nature of their search task. This categorisation was crucial for the subsequent data analysis stage, where the focus was on understanding how participants in different groups rated various statements and questions.

4.4.2 Demographics and Search Task Questions

The questionnaire included questions related to the participants' demographics, such as discipline, primary role/position, gender, and age. Also, the questionnaire had questions related to the users' latest or most memorable conducted literature review. Participants were asked how many times they reviewed the literature to produce a written report. I used this question as an initial screening, as I wanted academics who conducted at least one literature review to answer the questionnaire which is all about the experiences in conducting literature reviews. I also used it to indicate participants' experiences.

Additionally, when did they perform their latest review, for what (e.g., study, academic publication, funding proposal), in which topic, what type, if known, (e.g., systematic, narrative), number of references in the review, review length (i.e., number of words), and duration between the starting and completing the review task. These questions were vital in comprehending the participants' backgrounds and familiarity with literature review tasks. This information facilitated the grouping of responses based on their experience levels, enabling a nuanced exploration of how these experiences influenced how participants rated the exploratory characteristics. Analysing the participants' expertise and its impact on the main dimensions of the exploratory search was crucial for addressing the research questions effectively.

4.4.3 Piloting, and Recruitment

I put the questionnaire online using Qualtrics (a cloud-based platform for creating and distributing web-based surveys). Additionally, I piloted the questionnaire using a convenience sample to ensure all the questions were clear and fully understood by the participants. The pilot study's feedback helped me refine the questions. I asked the participants to focus on one particular literature review that they had conducted (either their most memorable or latest) and then respond to the questions with respect to that review because the questionnaire contained specific questions related to it, such as the number of references/papers that review contains, the size of the review, the time they took to complete it, etc.

Since I wanted to have academics and researchers from different disciplines and different work experiences, I distributed the finalised questionnaire via several different channels: 1) mailing lists of staff and Ph.D. students across my university, 2) research communities and research forums on Reddit (e.g., academia, Ph.D., SampleSize), ResearchGate forums, and national academic mailing list services (e.g., JiscMail), and 3) social media platforms (e.g., Twitter, Facebook, Linkedin).

The questionnaire was attempted by 598 participants, of which 368 responses were fully completed. The incomplete questionnaire responses were removed from the sample. Out of the completed responses: 222 were females, 137 were males, 6 were Non-binary/third gender, and 3 preferred not to disclose their gender. 59 participants were between 18 and 25 years old, 175 participants were between 26 and 35 years old, 83 participants were between 36 and 45 years old, 45 participants were above 46 years old, and 6 participants did not disclose their age.

The participants came from a range of disciplines: 134 were from Engineering, Technology and Physical Science, 67 were from Social Sciences, 45 were from Biology, Medicine and Health, 42 were from Law, Management, Economic, and Business, 38 were from Art and Humanities, and 42 were from other disciplines. Most participants were Ph.D. Students (196), followed by Masters Students (64), then Assistant to Full Professors (35), Postdoctoral Researchers (17), Non-Academic Researchers (24), and Others (32). I also asked them about the purpose of their most memorable or latest review; 214 participants conducted it for study (e.g., thesis/ dissertation/ proposal for Ph.D./ masters/ undergrad), followed by academic publication (e.g., journal/ conference/ workshop) (120), then project report/ funding proposal (26), and others (8). The approximate time for participants to complete the survey was about ten minutes.

No direct compensation was provided to participants; however, participants were

invited to leave their email address where they would be added to a prize draw to win one of five shopping vouchers (valued around £50). Participants' responses related to the prize draw were stored independently in a separate questionnaire to ensure that they remained anonymous. The questionnaire contained an initial screening question asking whether they had previously conducted reviews of the literature before.

4.5 Data Analysis and Results

I gathered 368 complete responses to the questionnaire. Subsequently, I categorised participants based on 1) their self-rated exploratory nature of the search task and 2) their level of experience. This grouping aimed to investigate how these factors influenced their ratings of exploratory search characteristics. Additionally, to gain deeper insights and identify potential hidden patterns, I conducted Factor Analysis. Further details on these aspects of data analysis are provided in the following sections.

4.5.1 Self Rated Exploratory Nature of Task

Participants rated how exploratory their review was at the end of the questionnaire. Table 4.2 shows the breakdown of the participant responses.

Table 4.2: Count of the responses on the exploratory nature of the review task.

Response	**Count**
Strongly agree	145
Somewhat agree	165
Neither agree nor disagree	32
Somewhat disagree	20
Strongly disagree	6
Total	**368**

I observe that over 84% of the participants described their review of the literature that they reported on as being somewhat exploratory or very exploratory in nature. This percentage confirms previous assertions in the literature that reviewing the literature is considered an exploratory task. To probe this more deeply, I consider across what dimensions/ characteristics is exploratory. To explore how the participants' answers of "how exploratory the task was" influenced their ratings of the exploratory search characteristics; I grouped the participants into three groups.

The three groups based on how exploratory they rated the tasks are the following:

- *Very Exploratory (VE)*: 145 participants strongly agree that conducting a literature review is an exploratory task.
- *Somewhat Exploratory (SE)*: 165 participants somewhat agree that conducting a literature review is an exploratory task.
- *Not Exploratory (NE)*: 58 participants neither agree nor disagree, somewhat disagree or strongly disagree that conducting a literature review is an exploratory task.

Next, I report the average rating by each group for each dimension and characteristic – where strongly agree was considered scoring the characteristic as a 5 and strongly disagree as a 1. To determine if there were any significant differences between the groups, I used an ANOVA and then performed follow-up t-tests with Bonferroni correction ($\alpha = 0.05$) [45]. Tables' rows that are in bold indicate that there was a significant difference between the groups ($p < 0.05$).

4.5.2 User Dimension vs. Exploratory Ratings

Table 4.3 shows the mean for each statement related to users' characteristics given the participants ratings of how exploratory their task was: Very Exploratory (VE), Somewhat Exploratory (SE), and Not Exploratory (NE).

Table 4.3: Mean for each question related to ***Users'*** (U) characteristics given the Exploratory groups: VE, SE and NE.

#	Question	**VE** (1)	**SE** (2)	**NE** (3)
Q1_U	**I was expert on the topic.**	**2.64**$^{(3)}$	**2.94**	**3.1**
Q2_U	I knew the right keywords to use.	3.39	3.59	3.79
Q4_U	I knew what literature I wanted.	2.7	2.9	2.78
Q6_U	**I learned new keywords and concepts.**	**4.49**$^{(2,3)}$	**4.19**	**4.02**
Q7_U	**I found surprising or unexpected information.**	**4.2**$^{(2,3)}$	**3.87**$^{(3)}$	**3.34**
Q8_U	**I encountered new concepts that I investigated.**	**4.41**$^{(2,3)}$	**4.1**$^{(3)}$	**3.64**
Q10_U	I easily decided which result items were relevant.	3.43	3.55	3.34
Q14_U	The review's topic changed after reading some items.	3.28	3.2	2.81
Q25_U	I was satisfied with the search results that I obtained.	4.01	3.89	3.91

First, I can see that those who felt their literature search was more exploratory (VE) are less likely to indicate that they were already experts on the topic before starting the search. In contrast to those who felt their literature search was not exploratory (NE), see (Q1_U) in Table 4.3. Also, the results show that the three groups are likely to indicate that they learned new keywords and concepts during the search. However, the VE group is significantly more likely to say they learned more keywords and concepts than those in the SE and NE groups (Q6_U). Thus, I might conclude that exploratory searches are associated with learning new concepts and keywords. Regarding finding surprising or unexpected information during the search, the three groups differed significantly. The VE group is significantly more likely to indicate that they found surprising or unexpected information, followed by the SE and the NE groups (Q7_U).

I found the same pattern regarding encountering new concepts; the VE group is more likely to express that they encountered new concepts, which they chose to investigate further, followed by the SE and NE groups (Q8_U). Therefore, I conclude that the exploratory searchers are associated with finding surprising or unexpected information, encountering new concepts, and choosing to investigate them further.

4.5.3 Problem Context Dimension vs. Exploratory Ratings

Table 4.4: Mean for each question related to the ***Problem Context's*** (PC) characteristics given the Exploratory Groups: VE, SE and NE.

#	**Question**	**VE** (1)	**SE** (2)	**NE** (3)
Q3_PC	I had a clear plan for finding relevant items.	3.29	3.45	3.36
Q5_PC	I knew how to divide the review task into sub-tasks.	3.08	3.19	3.07
Q12_PC	**What I thought was relevant changed over time.**	**3.83**$^{(2,3)}$	**3.48**	**3.33**
Q15_PC	I wanted very specific and detailed information.	4.13	3.96	3.83
Q23_PC	New materials on the topic are constantly being published.	4.13	4.12	3.97
Q26_PC	I retrieved most of the relevant documents.	3.82	3.58	3.47
Q27_PC	The review included literature from multiple topics.	4.21	4.02	4.07
Q29_PC	I stopped searching because I found all that I was looking for.	3.03	3.1	3.16
Q30_PC	I stopped working on the review because of a deadline or other tasks.	3.62	3.35	3.33

Table 4.4 shows the mean for each statement related to the problem context's characteristics given the participants ratings of how exploratory their task was: VE, SE and NE. Based on the results, it seems that the three groups (VE, SE, and NE) have more or less the same impression about the problem context characteristics. Among the nine statements related to the problem context, only one passed the ANOVA and the follow-up t-tests. The VE group is more likely to indicate that as they searched, what they thought was relevant changed over time more than the SE group, followed by the NE group. The results show significant differences between the VE group and the SE group on the one hand and between the VE group and the NE group on the other hand (Q12_PC).

4.5.4 Search Process Dimension vs. Exploratory Ratings

Table 4.5: Mean for each question related to the ***Search Process's*** (SP) characteristics given the Exploratory Groups: VE, SE and NE.

#	**Question**	**VE** (1)	**SE** (2)	**NE** (3)
Q9_SP	I only examined items that I was sure were relevant.	3.06	3.16	2.72
Q11_SP	I reworded the search query many times.	4.07	3.91	3.93
Q13_SP	I was very thorough in checking through items.	4.06	3.85	3.71
Q16_SP	**The items I read helped me decide what to do next.**	**4.3**$^{(3)}$	**4.12**	**3.84**
Q17_SP	I knew which sources contained the needed items.	3.51	3.53	3.45
Q18_SP	**I looked up items that were cited in it.**	**4.5**$^{(2)}$	**4.28**	**4.17**
Q19_SP	**I checked to see who had cited the item I was reading.**	**3.48**$^{(3)}$	**3.55**$^{(3)}$	**2.95**
Q20_SP	Colleagues were able to suggest relevant items.	3.74	3.59	3.36
Q21_SP	I used different tools to search for items.	4.52	4.32	4.12
Q22_SP	I searched for items using different query fields.	3.99	3.88	3.79
Q24_SP	**I ran multiple searches to retrieve the wanted information.**	4.64$^{(2,3)}$	4.39	4.31
Q28_SP	**It took a long time to work out what I was looking for.**	4.23$^{(2)}$	3.9	3.9

Table 4.5 shows the mean for each statement related to the search process' characteristics given the participants ratings of how exploratory their task was: VE, SE and NE. Based

on the results, the VE group is significantly more likely to indicate that the result items/documents they read helped them decide what to search for next than the NE group (Q16_SP). Also, the VE group is more likely to say that when reading a document, they looked up/examined items that were cited in it than the SE group (Q18_SP). Additionally, there are significant differences between the VE and the NE groups and the SE and the NE groups regarding checking who had cited a document while reading it. The VE group is more likely to check who had cited a document while reading it, followed by the SE and NE groups (Q19_SP).

Moreover, there are significant differences between the VE and the SE groups and the VE and the NE groups regarding running multiple searches to retrieve all the information they wanted than the SE and NE groups (Q24_SP). Regarding the time that took them to complete the task, the VE group is significantly more likely to indicate that it took them a long time to complete the entire review than the SE group (Q28_SP). In sum, those doing a more exploratory task are more likely to work harder, examine more documents, feel their search is more dynamic, and spend more time on the task. Unlike those who are already experts in the domain, know the right keywords and concepts and can easily decide which documents are relevant.

Overall, the user's and the search process's characteristics were more influenced than the problem context when grouping the participants based on how they rated the exploratory nature of the task. In general, the results suggest that the characteristics that best describe the exploratory users are unfamiliarity with the domain and having dynamic information needs. Also, the main characteristic that best describes the exploratory problem context is ill-structured. Additionally, the characteristics that best describe the search process are opportunistic, multi-tactical, and long-term.

4.5.5 Exploratory Dimensions vs. Experience

The questionnaire included a question about how many times the participant reviewed the literature (produced written reports). I used this question as an initial screening; I also used it to indicate the participant's experience. The aim here is to study how users' experience in conducting previous literature reviews influences the exploratory characteristics when searching the literature. Therefore, I grouped the participants into three groups as follows:

- *Not Experienced* (NExper): 167 participants have conducted between 1 and 5 literature reviews.

- *Somewhat Experienced* (SExper): 126 participants have conducted between 6 and 20 literature reviews.
- *Very Experienced* (VExper): 75 participants have conducted more than 20 literature reviews.

4.5.6 User Dimension vs. Experience

Table 4.6 shows the mean values of the different questions related to users' characteristics given the experience groups (VExper, SExper, and NExper).

Table 4.6: Mean for each question related to ***Users'*** (U) characteristics given the Experience Groups: VExper, SExper and NExper.

#	Question	VExper(1)	SExper(2)	NExper(3)
Q1_U	**I was an expert on the topic.**	**3.25**$^{(3)}$	**2.95**$^{(3)}$	**2.59**
Q2_U	**I knew the right keywords to use.**	**3.81**$^{(3)}$	**3.67**$^{(3)}$	**3.32**
Q4_U	I knew what literature I wanted.	2.84	2.9	2.72
Q6_U	I learned new keywords and concepts.	4.4	4.31	4.2
Q7_U	**I found surprising or unexpected information.**	**3.87**	**3.76**$^{(3)}$	**4.06**
Q8_U	I encountered new concepts that I investigated.	4.13	4.1	4.19
Q10_U	I easily decided which result items were relevant.	3.4	3.6	3.4
Q14_U	The review's topic changed after reading some items.	3.03	3.21	3.2
Q25_U	I was satisfied with the search results that I obtained.	3.95	4.0	3.89

The results show no significant differences between the three groups across most characteristics. However, there are some notable exceptions: First, the results show that the NExper group is significantly less likely to indicate that they were experts on the topic before starting the search than the SExper and VExper groups (Q1_U). Second, the NExper group is significantly less likely to reveal that they already knew the right keywords and concepts before starting the search than the SExper and the VExper groups (Q2_U). Third, the NExper group is more likely to indicate that they found surprising or unexpected information than the SExper group (Q7_U). Notably, despite their experiences, the three groups, low rated (Q4_U) *"I knew from the start what literature would go into the report"*. On the other hand, the three groups high rated (Q6_U)

"During the search, I learned new keywords and concepts related to the review's topic", which accords with the earlier observations, which showed that exploratory searchers are associated with learning new keywords and concepts.

4.5.7 Problem Context Dimension vs. Experience

Results in Table 4.7 show no significant differences between the experience groups. However, there are two notable exceptions. First, the SExper group is significantly more likely to express that they had a clear plan for finding relevant items than the NExper (Q3_PC). Second, the SExper group is substantially more likely to indicate that they knew how to divide the review task into sub-tasks more than the NExper group (Q5_PC). It could be argued that the previous experiences in conducting literature reviews improve skills of planning and organising such tasks.

Table 4.7: Mean for each question related to the ***Problem Context's*** (PC) characteristics given the Experience Groups: VExper, SExper and NExper.

#	Question	VExper(1)	SExper(2)	NExper(3)
Q3_PC	**I had a clear plan for finding relevant items.**	**3.51**	**3.57**$^{(3)}$	**3.16**
Q5_PC	**I knew how to divide the review task into sub-tasks.**	**3.27**	**3.32**$^{(3)}$	**2.92**
Q12_PC	What I thought was relevant changed over time.	3.6	3.62	3.57
Q15_PC	I wanted very specific and detailed information.	4.01	4.02	3.99
Q23_PC	New materials on the topic are constantly being published.	4.11	4.13	4.07
Q26_PC	I retrieved most of the relevant documents.	3.64	3.7	3.64
Q27_PC	The review included literature from multiple topics.	4.08	4.15	4.08
Q29_PC	I stopped searching because I found all that I was looking for.	3.23	3.06	3.04
Q30_PC	I stopped working on the review because of a deadline or other tasks.	3.33	3.35	3.58

4.5.8 Search Process Dimension vs. Experience

Based on the results in Table 4.8, the NExper group is less likely to indicate that the items they read helped them decide what to do next than the VExper and the SExper groups (Q16_SP). Also, the NExper group is significantly more likely to say that it took them a long time to work out what they were looking for than the VExper group (Q28_SP). It seems like the previous experience in searching for literature and the knowledge of the right keywords and concepts beforehand help save time while searching the literature.

Table 4.8: Mean for each question related to the ***Search Process's*** (SP) characteristics given the Experience Groups: VExper, SExper and NExper.

#	Question	VExper(1)	SExper(2)	NExper(3)
Q9_SP	I only examined items that I was sure were relevant.	3.01	3.01	3.1
Q11_SP	I reworded the search query many times.	3.96	3.97	3.99
Q13_SP	I was very thorough in checking through items.	3.79	3.94	3.94
Q16_SP	**The items I read helped me decide what to do next.**	**4.35**$^{(3)}$	**4.09**$^{(3)}$	**4.1**
Q17_SP	I knew which sources contained the needed items.	3.55	3.57	3.44
Q18_SP	I looked up items that were cited in it.	4.48	4.43	4.24
Q19_SP	I checked to see who had cited the item I was reading.	3.45	3.52	3.35
Q20_SP	Colleagues were able to suggest relevant items.	3.57	3.5	3.72
Q21_SP	I used different tools to search for items.	4.35	4.33	4.41
Q22_SP	I searched for items using different query fields.	3.85	3.88	3.96
Q24_SP	I ran multiple searches to retrieve the wanted information.	4.55	4.48	4.45
Q28_SP	**It took a long time to work out what I was looking for.**	**3.72**$^{(3)}$	**4.0**	**4.19**

The analysis indicates that participants with high experience and low experience have more or less the same impressions about the problem context. However, participants who have more experience seem to be more organised while tackling the task; hence, they expressed that they had a clear plan for finding relevant items and knew how

to divide the review task into sub-tasks. Additionally, it seems like participants with previous experience and knowledge of the right keywords and concepts spend less time searching the literature to complete the review task. In summary, not experienced users are unfamiliar with the domain, have fuzzy information needs, see the problem context as ill-structured, and their search processes are opportunistic and take a long time.

4.5.9 Factor Analysis

I performed an *Exploratory Factor Analysis* (EFA) to discover the latent relationships between the questionnaire's statements/questions. Firstly, I ran Bartlett's test, which confirmed a correlation in the given data with ($p < 0.05$) [10]. Secondly, I ran the *Kaiser–Meyer–Olkin* (KMO) test, which showed that dimensionality reduction techniques such as factor analysis could be applied to the data with an overall proportion of variance of 0.80 [91]. Thirdly, I used the Scree test to plot the factors and their eigenvalues [36]. To confirm the choice of the number of factors, I used Horn's parallel analysis [75]. I also checked the reliability/internal consistency of the factors by calculating the Cronbach α for each [43].

Table 4.9: EFA's results showing the statements group of each factor with the reliability consistency (α).

#	**Factor**	**Statements/Questions**	$\boldsymbol{\alpha}$
1	User Expertise	Q1_U Q2_U Q4_U Q3_PC	0.75
2	Search/Work Task	Q2_U Q4_U Q10_U Q25_U Q3_PC Q5_PC Q26_PC Q29_PC Q9_SP Q17_SP	0.78
3	Search Process	Q23_PC Q27_PC Q13_SP Q16_SP Q18_SP Q21_SP Q22_SP Q24_SP	0.61
4	Knowledge Change	Q6_U Q7_U Q8_U Q14_U Q12_PC Q11_SP Q16_SP Q28_SP	0.78

Table 4.9 shows the four factors' statements groups and their reliability/internal consistency. Based on Cronbach's α level of reliability, I conclude that the reliability/internal consistency of the four factors is reliable [63]. The analysis suggested that there are at least four factors within the data as follows:

1) The user expertise factor shares four statements, including being already experts before starting the search (Q1_U), knowing the right keywords and concepts to use when querying (Q2_U), knowing what literature would go into the report (Q4_U), and having a clear plan for finding relevant documents (Q3_PC). These statements relate to the

presence of familiarity with the domain, certainty about the goal, and seeing the problem context as well-structured.

2) The search/work task factor shares ten statements, including knowing the right keywords and concepts to use when querying (Q2_U), knowing what literature would go into the review report (Q4_U), being able to easily decide which result items/documents were relevant (Q10_U), being satisfied with the obtained search results (Q25_U), having a clear plan for finding relevant documents (Q3_PC), knowing how to divide the review task into various sub-tasks (Q5_PC), believing that they retrieved most of the relevant results/documents (Q26_PC), stopping the search because they found all the needed information (Q29_PC), examining only relevant items/documents (Q9_SP), and knowing which sources/databases contained the needed information/documents (Q17_SP). These statements relate to the presence of clear information need, certainty about the goal, well-structured and close-ended problem context, and a systematic search process.

3) The search process factor shares eight statements, including agreeing that new materials on their topic were constantly being published (Q23_PC), including literature from multiple sub-topics in the review (Q27_PC), being thorough in checking through results/documents to find relevant items (Q13_SP), the read documents helped them decide what to search for next (Q16_SP), when reading documents they employed backward chaining technique (checked to see items that were cited in it) (Q18_SP), using different tools to search for relevant results/documents (Q21_SP), searching for documents using different query fields (Q22_SP), and running multiple searches to retrieve all the information that they wanted (Q24_SP). These statements relate to the presence of multi-faceted and multiple-item goal problem context, and opportunistic, multi-tactical, and a long-time search process.

4) The knowledge gain/change factor shares eight statements, including learning new keywords and concepts related to the review's topic (Q6_U), finding surprising or unexpected information during the search (Q7_U), encountering new concepts and investigating them further (Q8_U), changing the review's topic in response to reading some of the retrieved documents (Q14_U), changing their thoughts about relevant documents (Q12_PC), rewording the search query many times while searching (Q11_SP), reading some of the retrieved documents helped them decide what to do next (Q16_SP), and taking a long time to complete the entire review (Q28_SP). These statements relate to the presence of unfamiliarity with the domain, ill-structured problem context, and iterative, dynamic, and opportunistic search process that takes a long time.

The Exploratory Factor Analysis helped characterising four factors when searching the literature, extending the typically considered three. The first describes the experts who already know the topic and how to complete the task. The second highlights the experts' experiences and how they plan to search the literature. The third highlights the exploratory tactics used when searching the literature. The fourth highlights the very exploratory experiences and the knowledge change when searching the literature. The analysis highlights the characteristics of the main dimensions of the exploratory search that were covered before. It also points to another dimension: Knowledge gain/change.

4.6 Discussion and Conclusion

In this Chapter, I formulated a conceptual model of the exploratory search based on the literature. The model includes fourteen characteristics of three main exploratory search dimensions: Users who engage in the search task, the problem context (of the search task), and the search process that users undertake to complete the search task. I also constructed a questionnaire to collect participants' search experiences when conducting literature reviews using the conceptual model. The majority of the 368 participants who completed the questionnaire described their task of reviewing the literature as being somewhat exploratory or very exploratory in nature (84%). The finding confirms previous assumptions in the literature that reviewing the literature is indeed an exploratory search task ±[74, 96, 123]. Moreover, participants see the task as exploratory regardless of their experience, discipline, education, or the type of the conducted review.

Regarding the task's self-rated exploratory nature grouping, I found that the two main characteristics that best describe the first dimension (user) are unfamiliarity with the domain and having dynamic information needs. Also, the main characteristic of the second dimension (problem context) is being ill-structured/ill-defined. Additionally, the three main characteristics of the third dimension (search process) are opportunistic, multi-tactical, and long-term. Regarding the experience grouping, several characteristics stood as most indicative of characterising exploratory search. The main characteristics of the user dimension are unfamiliarity with the domain and having fuzzy information needs.

Moreover, I found that participants with high experience and low experience have more or less the same impressions about the problem context. However, the main characteristic of the problem context dimension is ill-structured. Additionally, the main characteristics of the search process are opportunistic and long-term. Exploratory searchers are associ-

ated with finding surprising or unexpected information and encountering new concepts (unfamiliar with the domain). Furthermore, exploratory search appears highly amorphous because the notion of relevance changes as the searcher goes through the process and requires probing the literature in many ways and over time (multi-tactical and long-term) without any explicit or predefined path (ill-structured).

The results suggest that the main characteristics indicating a high level of exploratory knowledge gain/change include the following: 1) Learning new keywords, concepts, and information that might be surprising or unexpected, 2) Choosing to investigate the new information further, 3) Changing the review's topic and thoughts in response to reading some retrieved documents, 4) Rewording the search query many times while searching, 5) Reading some of the retrieved documents helps in deciding what to do next. On the other hand, the main characteristics indicating a low level of exploratory knowledge gain/change include the following: 1) Sticking to familiar keywords and concepts, 2) Ignoring or dismissing new information without further investigation, 3) Maintaining a consistent topic and thoughts throughout the review, 4) Keeping the search query unchanged, and 5) Making decisions without relying on insights gained from reading documents.

While my past work has mainly focused on defining exploratory search with respect to its three main dimensions, the EFA confirms these three main dimensions; moreover, it reveals a fourth dimension to the exploratory search, which appears to capture the notion of Knowledge Gain/Change. This work motivates the community to focus on knowledge gain/change and consider it when designing information retrieval interfaces and systems. These systems should support the exploratory users who engage in exploratory search processes. One option could be tracking their knowledge gain/change and recommending relevant documents based on their knowledge and the goal they want to achieve.

This work advances the understanding of Exploratory Search. The proposed exploratory model can help researchers control the level of complexity/exploratory when designing exploratory tasks for their studies. Also, this work suggests that more attention needs to be paid to facilitate how the search interfaces and tools can help map and curate exploratory users' knowledge gain and change during the search process. This departs from previous works on exploratory search, which have focused more on the task, and the search process. While I have considered users as third and uncovered a fourth dimension of exploratory search.

In conclusion, this chapter enhances the understanding of the concept of exploratory search, serving as a foundational cornerstone for my subsequent research. It highlights the

necessity to explore additional factors that may influence searchers during exploratory searches. Investigating the impact of supportive user interfaces on exploratory searches is a primary focus of this thesis research (Chapter 5). Additionally, I further investigate the dimension of knowledge gain, mainly focusing on how academics, especially novices, conduct exploratory searches such as literature reviews. Further details on this aspect and other aspects are provided in Chapter 6.

Chapter 5

Exploratory Search Interfaces Impact

In the previous chapter, I introduced a conceptual model of exploratory search based on the existing literature, and I designed a questionnaire to validate and extend that model. Building on that foundation, this chapter advances the understanding of exploratory searches by exploring additional factors that influence exploratory behaviours and strategies. I investigate how different interfaces impact users' perceptions, behaviours, search outcomes, and overall experiences during exploratory searches. Additionally, I examine the influence of incorporating a more real-life search task on users' experiences and behaviours. This chapter details information from two user studies elaborated upon in Section 5.3 and Section 5.5. Both studies are conducted within the framework of the proposed conceptual model of exploratory search introduced in Chapter 4.

5.1 Introduction

In the previous chapter, I introduced a conceptual model of exploratory search, that consists of three core dimensions and 14 characteristics. Additionally, my research findings suggest the existence of a fourth dimension. The main dimensions and characteristics of the proposed conceptual model are the following:

1. **The User**: unfamiliar with the domain, uncertain about their goal, has fuzzy information needs, and has dynamic information needs.

2. **The problem context**: open-ended, multi-faceted, and ill-structured topic/goals with multiple/many items to be retrieved.

3. **The search process**: iterative, opportunistic, unsystematic, multi-tactical, in nature, and performed over many sessions and usually over a long period of time.

4. **Knowledge gain/change**: This dimension relates to finding surprising or unexpected information during the search, learning and encountering new concepts/keywords, and choosing to investigate them further.

Exploratory search can be likened to information foraging theory [140], which compares information seekers to animals searching for scattered food patches in a vast landscape. In this analogy, the online information pieces represent these patches. Users navigate through these patches, considering factors like patch size and the effort required to move between patches. The goal is to gather as much useful information as possible while staying within an optimal time limit for each patch to maximise overall information acquisition. Another model, proposed by Bates and known as the berrypicking model [11], describes how users explore information. It suggests that users hop from one information source to another and switch between different search techniques, much like picking berries from different bushes. This approach helps users gradually build a satisfactory answer to their query.

User search interfaces play a critical role in aiding users in formulating queries and locating relevant information, likened to the act of identifying and picking ripe berries of information. Consequently, numerous researchers have proposed exploratory support interfaces to assist information seekers in navigating this complex task. These interfaces were developed to address shortcomings associated with standard or traditional search interfaces. Unlike traditional search interfaces, which necessitate users to sequentially evaluate search results for relevance to their information needs, exploratory support interfaces are tailored to accommodate the complexities inherent in exploratory searches [72, 188]. In exploratory search scenarios, where searchers tackle unfamiliar domains and deal with complex evolving problems, traditional list presentations often fall short [60], as these lists may not effectively convey crucial concepts or their relationships [60].

In Chapter 2 (Section 2.3.2), I reviewed the support interfaces for exploratory search. In sum, prior researchers have attempted to overcome the limitations of traditional interfaces by designing support tools that incorporate visualisation, categorisation, or clustering methods to facilitate learning and exploration. Various exploratory search support interfaces have been introduced to assist users in conducting exploratory search tasks to discover relevant information. The typical design of these user interfaces aims to support exploratory behaviour through features such as interactive keywords, key

phrases, word-cloud visualisations, and ontology-based systems [49, 72, 92, 113, 142, 145, 153, 155, 159, 200].

In many cases, studies proposed support interfaces for exploratory searchers but did not evaluate these interfaces. On other cases, where the proposed interfaces were compared to standard interfaces, these studies have shown that participants prefer the exploratory interfaces, which have helped them discover more relevant documents, navigate the information space, formulate queries, or organise information more effectively. However, what has not been extensively studied is how different user interfaces impact users' behaviours, perceptions, experiences, and search outcomes. The literature lacks empirical evidence on how these interfaces affect searchers and their behaviour when working on exploratory searches.

In this chapter, rather than proposing another user search interface to aid exploratory users, I investigate the impact of support interfaces on participants' behaviours, perceptions, experiences, and search outcomes. To achieve this, I design an interface akin to typical exploratory support interfaces. Additionally, I develop and integrate the questionnaire presented in the previous chapter and conduct two laboratory-based studies—one within subjects and one between subjects—each involving 30 participants. The first study involves assigned tasks, while in the second study, participants are instructed to work on their own real tasks. The primary objective of the second user study is to evaluate how changing the task may influence the results obtained from the first user study.

This chapter answers my third general research question (RQ3): How the interface employed during literature review tasks influences users' perceptions, behaviours, search outcomes, and overall experiences? Additionally, I explore two specific research questions. The following outlines the research questions addressed in this chapter:

RQ1. How do users'

(a) perceptions,

(b) behaviours,

(c) search outcomes, and

(d) overall experiences

change when the user interface differs?

RQ2. How does the interface affect the conceptualisation of Exploratory Search?

RQ3. How does a more real task influence users' experiences and behaviours?

5.2 User Search Interfaces

To address my research questions, I conduct two user studies using the Standard Search Interface and the Exploratory Search Interface. This approach allows me to investigate how users' behaviours, experiences, perceptions, and search outcomes vary when the interface changes. The following provides more details on the interfaces used in the studies:

- *Standard Search Interface* (SSI): This interface closely resembles the traditional interfaces and includes only standard list-based results. I use it as a baseline interface.

- *Exploratory Search Interface* (ESI): This interface incorporates both standard list-based results (A) and an interactive concept map (B), as illustrated in Figure (5.1). This interface is similar to the typical design of the proposed support user interfaces that aim to support exploratory searches.

The ESI mirrors the SSI in terms of core functionality. However, it has a concept map as a primary feature, which presents concepts related to the searcher's query from a large-scale ontology, as shown in Figure 5.1. Instead of the concept map, the SSI displays a blank space. The two interfaces used in this study include a searchbox (1) and a search button (2) that enable searchers to input and search for queries relevant to their information needs. The system retrieves related documents (standard list-based results) from a collection. For each document in the list-based results, the interface displays the title (3), authors, year of publication (4), a snippet of the abstract (5), and a "Show more" link button (6). If this link is clicked, the full abstract of the document (7) is shown. Additionally, searchers can click on the document title to access the entire document in a new tab if available.

For the ESI, when a searcher enters a query, the system identifies the nearest concept/root concept (8) from the large-scale ontology. Then, it presents both general (9) and in-depth (10) concepts. Hovering the cursor over a node in the concept map triggers a tool-tip containing a definition snippet from Wikipedia (11), if available. For concepts without Wikipedia articles/definitions, a tool-tip stating,"no definition available" is displayed.

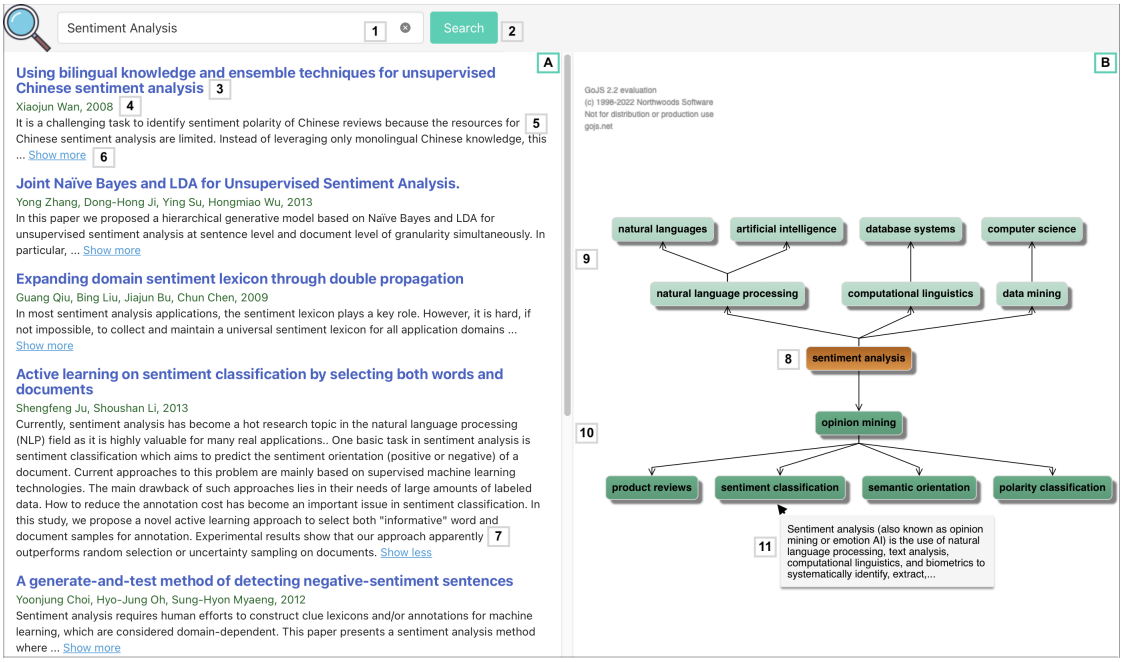

Figure 5.1: The exploratory support interface showing results for "Sentiment Analysis" query.

5.2.1 Interactive Concept Mapping and Search System Architecture

Clicking any concept node on the concept map in the ESI updates the whole system, including the searchbox, the standard list-based results, and the concept map. The root concept becomes the newly clicked concept, and new general and in-depth concepts appear.

Root, general, and in-depth concepts have different colours to distinguish between them. When a searcher searches for a query using the searchbox or clicking one of the concept nodes on the concept map, they send a request to the information retrieval system with the query or the concept. The information retrieval system uses the standard BM25 retrieval model to retrieve the top ten documents. Elasticsearch is used to index the documents.

Additionally, to get the concepts closest to the query from the large-scale ontology, the system performs an exact, fuzzy, and TF-IDF match. If no concept is found, the system uses semantic search to get the closest concept to the query request. Afterward, using the retrieved concepts as initial nodes, the system retrieves any related concepts. The semantic space built by the ontology concepts is based on BERT vectors. The system uses the SciBert [18] pre-trained model to compute the concepts and the query embeddings.

5.2.2 Research Paper Classification and Concept Map Filtering

During the data preprocessing stage, CSO-Classifier [131] was employed, a tool that automatically classifies research papers based on their research topics. This classification helps establish a direct connection between documents and the concepts in the ontology. The Classifier assigns keywords (CSO concepts) from the concept map's domain to each document in the collection. A filtering process was implemented to avoid overwhelming the graph with excessive information. Some concepts have numerous related concepts, both general and in-depth, which could lead to a cluttered graph, especially for those new to the topic. As a solution, I modified the system to display concepts on the concept map that are associated with at least one document in the standard list-based results. In this way, only concepts that were assigned to the documents in the result list are shown on the concept map, ensuring relevance and clarity for users.

5.2.3 Resources

The interfaces show information from these three resources:

1. **Document Collection**: Documents shown on the result list are from a sub-set collection of the DBLP-Citation-Network Version 13 [169], which includes 200K English language documents with titles, authors, year of publication, and full abstract, and integrates the publication meta-data from online databases such as DBLP bibliography, ACM Digital library, and CiteSeer.

2. **Concept Map**: The resource of the concepts and their relationships are from the Computer Science Ontology (CSO) [149], which is a large-scale, automatically generated ontology of research areas that include about 26K topics and 226K semantic relationships, which was created by applying the Klink-2 algorithm to a significant 16M scientific articles dataset. The concept map is part of the exploratory interface only.

3. **Wikipedia**: Whenever a searcher hovers over a concept in the concept map, a definition snippet appears from Wikipedia articles.

Both interfaces were developed using Python 3.9 and Django 3, and support document indexing within an internal database implemented with Elasticsearch. I utilised

GoJS[1], a JavaScript web framework, for the interactive concept map and applied the DoubleTreeLayout extension layout for diagram arrangement.

The independent variable in the studies is the interface. Also, I adopt a mixed methods approach, where quantitative and qualitative data are collected using diverse methods and instruments, including questionnaires, log systems, interviews, and ratings of literature review outlines. This comprehensive approach aimed to leverage the strengths of each method while minimising their respective limitations.

5.3 Study 1: User Interface Influence

This is a within-subject study where 30 participants were exposed to two interfaces: the ESI and the SSI that I introduced in the previous section. The topics of the tasks for this study were assigned. Further details on this study's task, procedure, recruitment, and participants are provided in the following sub-sections.

5.3.1 Study Task: Literature Review Outline

I designed an exploratory search task in two topics following Wildemuth and Freund [193] and [105] guidelines, and they were presented as simulated work tasks [19]. The task focused on learning and investigative search goals and was general and open-ended. The task was motivated by ill-defined problems and involved uncertainty. Figure (5.2) shows the exact wording of the work/search task. I asked the participants to use the different interfaces to learn about the two different topics and provide me with outlines of literature reviews on the provided topics. The topics chosen for the tasks were *Opinion Mining* (OM) and *Pattern Recognition* (PR).

5.3.2 Instructions

To maintain uniformity among participants, I gave explicit guidelines for using the ESI and SSI interfaces. These instructions covered querying, browsing search results, reading full abstracts, and accessing complete documents. Specifically for the exploratory interface, I instructed participants to interact with concept nodes by clicking and hovering over them, and I clarified the associated colour codes. I encouraged my participants to employ any strategies they found effective in completing the task and to follow their

[1]Copyright 1998-2023 Northwoods Software: https://gojs.net/latest/

Suppose you are working on an Introduction to Graduation Project module in your final year of university. For this module, you need to conduct a literature review for your graduation project about **(X)** topic. We will provide you with a system to learn and familiarise yourself with **(X).** Since you have a limited time, we will not ask you to write a complete literature review. Instead, we will ask you to provide an outline/ structure/ overview/ skeleton/ headlines/ sub-headlines/ main points of a literature review about the topic.

Task Instructions:

- Using the provided system, spend 20 minutes learning about **(X)** Explore the topic and find more related topics/ sub-topics/applications/challenges/issues/fields that interest you and you would want to study and investigate further for your literature review report.
- Remember that you need to demonstrate your familiarity with the topic and the scholarly context. Learn as much as you can about the given topic using the system.
- Please add the outline/ structure/ overview/ skeleton/ headlines or sub-headlines of your literature review, including any concept/topic/keywords/key terms - you think your literature review should include. To fill in the following field, you can go forward and backward between this form and the system.

Figure 5.2: Wording of the assigned search tasks of the within-subjects study

usual search habits. I introduced each interface right before its corresponding task/topic began.

5.3.3 Study Workflow

The user study procedure, as illustrated in Figure (5.3), is structured as follows: Each study session involves a single participant. The session starts with me introducing and explaining the purpose of the experiment. The participant is then presented with a consent form and given ample time to review and decide whether to agree or decline. Following this, the participant is offered the option to refresh their understanding of literature reviews by reading a prepared text on the concept and how to conduct one effectively. Next, participants are requested to complete a pre-task questionnaire. Following the questionnaire, participants are guided to utilise the first system, accessed remotely through the first author's device, for the initial task.

This task involves crafting an outline for a literature review on a specific topic. Upon task completion, participants are required to fill out a post-task questionnaire. The process repeats for the second task/topic using the second interface. Upon successful completion of both tasks, participants are prompted to complete a demographic questionnaire. Finally, the session culminates with a semi-structured interview conducted with the participant. The subsequent sub-sections provide in-depth information regarding the questionnaires, *Literature Review* (LR) outlines, interviews, and the various tools and methods employed for data collection.

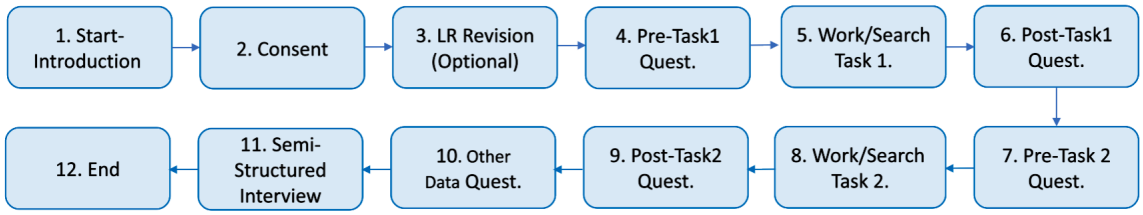

Figure 5.3: Overview of the user study procedure

5.3.4 Instruments

I used multiple instruments, including questionnaires, interviews, system logs, and LR outlines to fully understand users' behaviours, perceptions, experiences, and search outcomes. The questionnaires and the task are included in Appendix B.1. The following are the different instruments I used:

5.3.4.1 Questionnaires

I shared various questionnaires with the participants at different stages of the study sessions, such as pre-task, post-task, and other data questionnaires. Many of the statements in these questionnaires mirrored or were akin to those employed in study 1 in chapter 4, which aimed to grasp users' perceptions and experiences during conducting literature reviews. The primary motive for utilising these statements and questions was to assess whether the exploratory interface influenced key exploratory characteristics and supported exploratory users in the context of literature review tasks. This served as a critical component in addressing RQ1(a).

- **Pre-task**: Participants filled out this questionnaire before the beginning of each task. This questionnaire included these questions: a) if the participant was already an expert on the provided topic, b) already knew the right keywords and concepts to use when querying/searching for this topic, c) had a clear plan for finding relevant results, and d) if they have an idea of an outline/structure of a literature review about the topic. Participants were asked to express their level of agreement with the statements in the questionnaire by selecting one of five options on a Likert scale: strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, or strongly disagree. To better understand how the interface affected the participants, I included similar questions to those four questions in the post-task questionnaire. This allowed us to compare the participants' answers before and after using the interface.

- **Post-task**: Participants filled out this questionnaire after each task. This questionnaire included four questions similar to the ones in the pre-task questionnaire but in the present tense: a) I am an expert on the provided topic, b) I know the right keywords and concepts to use when querying/searching for this topic, c) I have a clear plan for finding relevant results, and d) I have an idea of an outline/structure of a literature review about the topic. Mainly, this questionnaire included the following questions: 1) if the participant found surprising or unexpected information, 2) encountered new concepts which they chose to investigate further, 3) only examined result items/documents that the participant was sure were relevant, 4) were able to decide which items/documents were relevant easily, 5) the result items/documents they have read helped them decide what to search for next, 6) were satisfied with the search results that they obtained, 7) stopped searching for documents because the participant found all that they were looking for, and 8) the participant believes that they have retrieved most of the relevant results for the review. Participants were asked to express their level of agreement with the statements in the questionnaire by selecting one of five options on a Likert scale: Strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, or strongly disagree.

- **Other data**: The questions in this questionnaire were designed to gather information about the participants' backgrounds and expertise, including whether they considered themselves experts in conducting literature reviews in general, whether they found the task of conducting literature reviews exploratory, and if they considered it as challenging/difficult.

5.3.4.2 System Logs

The system logs I compiled provided an objective and quantitative perspective on users' behaviours and interactions across the diverse interfaces. The primary aim was to develop a thorough comprehension of how users engaged with the distinct interfaces during their literature review tasks, in order to address RQ1(b). I recorded a range of user interactions (actions), encompassing:

- **Query**: The system registers two types of queries, the searchbox query, which is the query entered or modified in the searchbox, and the concept query, which is generated by clicking on a node in the concept map.

- **Document title click**: The system registers the document title and ID whenever a document title is clicked in the result list.
- **"Show-more" link click**: The system registers the document title and ID whenever the show-more link of an abstract is clicked to view the entire abstract in the result list.

5.3.4.3 Literature Review (LR) Outlines

Participants were given the interfaces (ESI and ESSI), one after another. They were asked to use them to learn about the provided topics and to write outline/structure of literature reviews about the provided topics. I utilised LR outlines/structure to analyse the relevance and usefulness of search results from a user's perspective, which provides insight into RQ1(c).

5.3.4.4 Interviews

I conducted semi-structured interviews with the participants. These interviews were essential for gaining insights into participants' experiences with the different interfaces. I leveraged this qualitative data to shed light on RQ1(d). The interview process commenced by inquiring about the participants' preferences regarding the topics they worked on. Subsequently, I investigated the reasons behind their preferences, with most participants citing the interface as a significant factor. This paved the way for a more detailed discussion about the interfaces, their perceived helpfulness, and the specific advantages of the concept map if they found it helpful. Given that the study sessions were conducted using Zoom technology, I had the capability to record these sessions, and the transcripts from the recorded audio were instrumental in streamlining the coding process.

By using these multiple instruments to collect data, I aim to provide a complete picture of users' perceptions, behaviours, experiences, and search outcomes, which can lead to more accurate and insightful findings.

5.3.5 Recruitment

Since the resources used in the system are mostly related to Computer Science and related fields, I was interested in recruiting students with *Bachelor of Science* (BSc.), *Master of Science* (MSc.), or Ph.D., with Computer Science or related field backgrounds and have

already conducted at least one literature review. I designed a screening questionnaire with basic questions including current academic position, the field of study, and how many times they have ever produced a written report that includes a literature review. I distributed the screening questionnaire via several channels: Mailing lists of students across my university, research forums (e.g., ResearchGate), and social media platforms (e.g., Twitter, Facebook, Linkedin, and Whatsapp). As compensation for the participants' time, they were provided them with online shopping vouchers valued at around 25 Sterling Pounds. The screening questionnaire is included in Appendix B.2.

5.3.6 Participants

Around 90 individuals filled out the screening questionnaire. Only 55 potential participants met my criteria and were eligible for the study. Thirty participants responded to my emails and participated in the user study. The screening survey was used to exclude participants who might have had expertise in the topics provided. The study sessions were all conducted remotely over Zoom. Of the 30 participants, 19 were Ph.D. students, 5 were MSc students, and 6 were BSc. students or fresh graduates. Regarding participants' experiences conducting literature reviews, 14 participants conducted 1 to 5 literature reviews, 13 conducted 6 to 20 literature reviews, and 3 conducted more than 21 literature reviews.

5.3.7 Pilot Studies

I conducted two pilot studies to shape the study's design and evaluation approach. In the first pilot study, 11 participants, including Ph.D., Master's, and undergraduate students in Computer Science or related fields, were asked to spend approximately 20 minutes exploring one of two provided topics. They were tasked with becoming familiar with the provided topic and creating an outline/structure for a literature review in that topic. After completing this task, a discussion was conducted to gather feedback on the interface, its features, and the overall user experience. The second pilot study involved 3 participants who completed the entire user study to ensure that the procedure and system worked as intended. The insights gained from these pilot studies allowed me to refine the task instructions, enhancing participants' understanding of their responsibilities in the study.

5.4 Data Analysis and Results of Study 1

Given that my research questions and study design revolve primarily around understanding how the interface may impact users' perceptions, behaviours, search outcomes, and experiences, I have organised the analysis of the results accordingly.

5.4.1 Users' Perceptions

The "additional data" questionnaire showed that more than 80% of participants either strongly agreed or somewhat agreed that conducting literature reviews is an exploratory and challenging task. This observation holds true even though 50% of the participants identified themselves as experts in the field of conducting literature reviews. This finding is consistent with the understanding of information seeking and retrieval community (who often use conducting literature reviews as an exploratory task example), and it also supports the results reported in Chapter 4.

Table 5.1: Mean (SD) for the difference of participants' answers given the interface type: ESI and SSI.

Statement	ESI	SSI
I am an expert on the provided topic	0.47 (1.17)	0.53 (1.12)
I know the right keywords to use when searching	2.23 (1.41)	1.47 (1.94)
I have a clear plan for finding relevant results	1.0 (1.36)	0.67 (1.49)
I have an idea of an outline of the a report about the topic	1.27 (1.34)	1.27 (1.41)

Using the questionnaire results, I try to answer RQ1(a): How do users' perceptions change when the user interface differs?

5.4.1.1 Pre-Task Questionnaire Analysis

The participants responded to four questions before and after each search session as part of the pre-task and post-task questionnaires. I computed the difference between participants' responses before and after each session to measure any changes. Table 5.1 presents the mean and standard deviation of the differences in answers based on the interface type. While no significant differences were detected, the data suggests that when utilising the ESI, participants tended to express a greater sense of confidence in their knowledge of the appropriate keywords and concepts for searching, as well as in their ability to formulate a clear plan for locating relevant results compared to when using the SSI.

5.4.1.2 Post-Task Questionnaire Analysis

I analysed the answers to the post-task questionnaire. Table 5.2 displays the mean and standard deviation of post-task questionnaire answers grouped by interface types. Although no significant differences were observed, participants using the ESI generally had higher means and lower standard deviation, indicating a consistent trend.

Table 5.2: Mean (SD) for each statement of the post task questionnaire given the interface types: ESI and SSI

Statement	**ESI**	**SSI**
I found surprising or unexpected info	3.47 (0.9)	3.07 (1.11)
I encountered new concepts, I chose to investigate further	4.2 (0.89)	3.67 (1.3)
I only examined result documents I was sure were relevant	3.47 (1.14)	3.23 (1.25)
I was able to easily decide which result documents were relevant	3.93 (1.01)	3.53 (1.14)
The result documents I read helped me decide what to search for next	4.2 (0.89)	3.73 (1.28)
I was satisfied with the search results I obtained	3.3 (1.15)	2.9 (1.32)
I stopped searching for documents because I found all that I was looking for	2.6 (1.16)	2.2 (1.13)
I believe I have retrieved most of the relevant results for the review	3.03 (1.16)	2.73 (1.28)

The participants reported encountering surprising or unexpected information, investigating new concepts, examining results they were sure were relevant, easily deciding on relevant results, being satisfied with their search, and feeling more familiar and certain about their search process and goals. These results suggest that the ESI helped participants structure their search and feel more certain about their search results. These results suggest that the ESI is more likely effective at encouraging knowledge gain than the SSI.

5.4.2 Users' Behaviours

Using the system logs, I try to answer RQ1(b): How do users' behaviours change when the user interface differs? The system registered almost 1K actions during 60 search sessions (30 participants X 2 search tasks/topics). Each log action was saved with a time stamp, task's topic (OM/PR), interface type (ESI/SSI), and participant ID. I calculated the total number of searchbox queries, concept queries, document title clicks, and show-more link clicks for every search session. Participants sometimes re-issued the same query or

Table 5.3: The median for each action given the interface type: ESI and SSI, and the task topic: OM and PR.

Interface	**ESI**			**SSI**		
Action/Task	**OM**	**PR**	**All**	**OM**	**PR**	**All**
Concept queries	6.0	5.5	**6.0***	0.0	0.0	**0.0***
Unique concept que.	3.0	2.0	**3.0***	0.0	0.0	**0.0***
Searchbox queries	3.5	3.0	3.0	3.0	4.0	3.5
Unique searchbox que.	2.0	2.5	2.5	3.0	3.5	3.0
Show more clicks	2.0	6.5	5.0	6.0	4.0	5.0
Unique show more	2.0	5.5	4.5	6.0	4.0	5.0
Doc. title clicks	2.0	3.0	2.5	2.5	4.0	3.0
Unique doc. title	1.5	2.0	2.0	2.0	3.5	3.0
All actions	13.0	21.0	16.0	10.5	15.5	13.5
All unique actions	10.5	14.5	12.0	10.0	12.5	11.5
All queries	9.5	8.5	**9.0***	3.0	4.0	**3.5***
All unique queries	5.0	6.0	**5.0***	3.0	3.5	**3.0***

re-opened the same documents. Thus, I calculated the total number of unique searchbox queries, unique concept queries, unique document title clicks, and unique show-more clicks for each search session. Additionally, I calculated the total number of actions and unique actions for each search session.

5.4.2.1 Logs/Actions Analysis

I used a Kruskal-Wallis H test with Bonferroni correction ($\alpha = 0.05$) [45] to test if there is any significant difference between actions when using the ESI and the SSI. Kruskal-Wallis H test shows a statistically significant difference in all queries, all unique queries, concept queries, and unique concept queries scores between the groups using different interfaces. Table 5.3 shows the median for each log action given the interface type and the task's topic. Rows in the table that are denoted as **bold** and marked with a star (*) indicate that there was a significant difference between the groups ($p < 0.05$). Participants were significantly more likely to query when using the ESI than those using the SSI, mainly because of the concept queries. The analysis suggests that participants actively engaged with the concept map, resulting in an iterative and opportunistic search process as they clicked on concepts they thought would yield more useful results.

5.4.2.2 Query Analysis

The data analysis shows that the total number of issued queries using the ESI is higher than those using the SSI (312 vs. 175 total queries). To better answer RQ1(b), I conducted a more detailed analysis of how participants utilised the different interfaces for querying. I calculated the unique words for all queries using the different interfaces. The data suggest that, in total, participants used more unique queries when using the ESI than those using the SSI (132 vs. 89 unique words). However, the median of the number of the unique word in each query when using the SSI was higher than the ESI (3 vs. 2). I calculated Kruskal-Wallis to test whether the interface type affects the number of unique words in the issued queries of the two groups. The test reveals a significant difference between the two groups ($p < 0.001$); participants entered longer queries using the SSI. Moreover, when using the SSI, participants used "survey" and "definitions" more frequently than the ESI, indicating that they were searching for cues and guidance to complete the task.

Table 5.4: Percentages of the query types given the interface type

Types/Interface	**ESI**	**SSI**
Main queries	14%	22%
Concept map queries	54%	0
New queries	15%	15%
Changed Queries	17%	63%

I also categorised all logged queries into four types: main queries (the first query issued in the search session), concept queries (resulting from clicking a node in the concept map), new queries (resulting from deleting the previous query and entering a new one), and changed queries (resulting from deleting one or more words, adding one or more words to the previous query, or fixing a typo in the previous query). Table 5.4 shows the percentages of the different query types given the interface type. The analysis reveals that when using the ESI, more than half of the queries were concept queries and 17% changed queries, suggesting that participants were learning new keywords and being exposed to more diverse topics and sub-topics with a single click on the nodes. In contrast, when using the SSI, 63% of participants' queries were changed queries. These findings demonstrate that the ESI encouraged an iterative, and multi-tactical exploratory search process allowing participants to discover various concepts and keywords and exposing them to more diverse documents, which may result in a higher information gain.

Table 5.5: Mean (SD) of the summation of the show-more and document title clicks given the interface type and the topic type.

Interface	**ESI**		**SSI**	
Action/Task	**OM**	**PR**	**OM**	**PR**
Show-more & Doc. title clicks	6.0 (5.0)	9.4 (2.5)	8.7 (5.5)	11.0 (6.0)

5.4.2.3 Show-More and Document Clicks Analysis

To understand how participants interacted with the interfaces when accessing the full abstracts or documents, I calculated the total number of clicks on show-more links and document titles. Table 5.5 presents the mean and standard deviation of these clicks for each interface and topic. The results indicate that participants clicked more on these links when using the SSI. It seems that the absence of the concept map led participants to explore the documents and abstracts more extensively, searching for cues and keywords to help them find relevant information and complete their task. The results also show that participants clicked more on the links when working on the PR task.

5.4.2.4 Topic Analysis

To study the search topic impact on participants' behaviours, I grouped the data based on the task topic to see if there were any significant differences between groups based on the task topic regardless of the interface type. The analysis shows a significant difference between the two groups regarding "all unique actions" and "all unique queries" ($p < 0.05$). The data suggest that participants explored more when they worked on the PR task. The PR task seems to encourage participants to issue more queries and explore more. Many participants indicated that the PR task was more challenging. I explore participants' thoughts about the tasks in Section 5.4.4 to understand this behaviour better. Additionally, in Section 5.5, I conduct a study investigating tasks' influence on exploratory searches and behaviours.

5.4.3 Users' Search Outcomes

Using the LR outlines, I try to answer RQ1(c): How do users' search outcomes change when the user interface differs? I collected 60 literature review outlines produced by 30 participants using two interfaces. Two independent senior researchers with experience in rating literature reviews assessed the outlines based on content and structure. They rated them on a scale of 0 to 10, where 0 indicated very poor quality, and 10 indicated

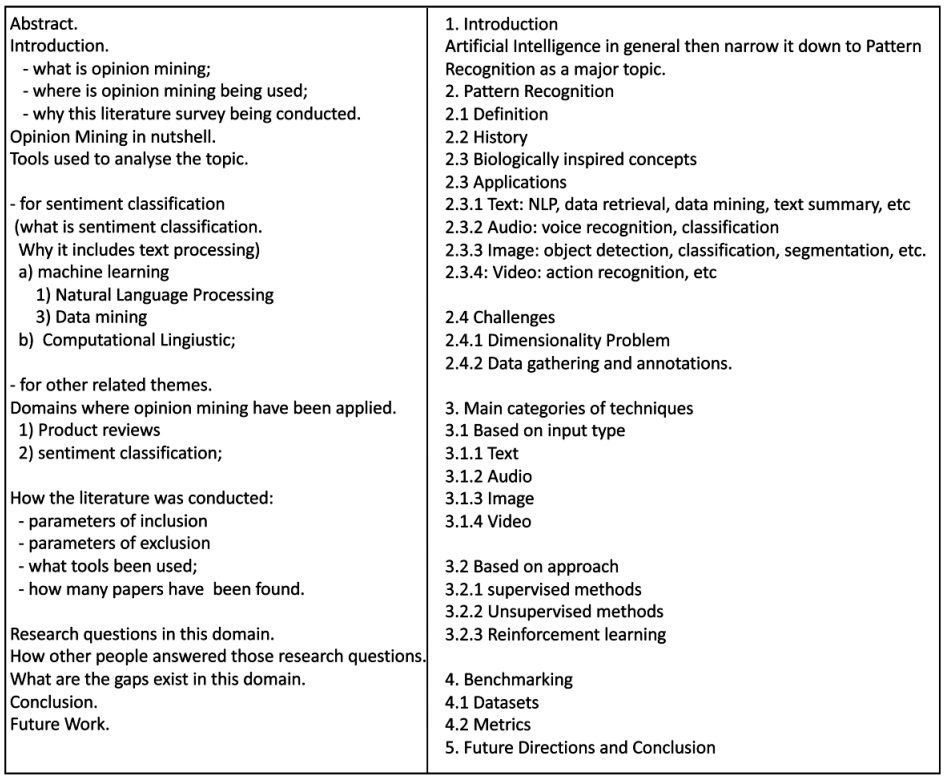

Figure 5.4: Two examples of literature review outlines of OM and PR tasks that the participants provided.

excellent quality. Figure 5.4 shows two examples of literature review outlines that were produced using the ESI (left) and the SSI (right). Both outlines received high ratings from the assessors.

Table 5.6 shows the mean and standard deviation of the scores of the two assessors, the average scores, and the correlation between the assessor's ratings by interface type. The data analysis suggests a correlation between assessors' ratings. Both correlations are significant; therefore, the reviewers' agreement is not random.

Table 5.6: Mean (SD) of the outline assessments given the interface type

	ESI	**SSI**
Assessor 1	6.2 (1.42)	6.0 (1.24)
Assessor 2	6.33 (2.55)	5.43 (2.45)
Average Rating	6.27 (1.76)	5.72 (1.63)
Correlation	0.54 ($p < 0.001$)	0.51 ($p < 0.002$)

Despite the absence of statistically significant differences between the two groups, based on the average scores, it is noteworthy that approximately 47% of the outlines

created using the ESI achieved scores of 7 or higher. In contrast, only about 23% of the outlines generated using the SSI reached this threshold. This observation suggests that participants using the ESI tended to produce more higher-scoring outlines. This might be attributed to the ESI exposing participants to concepts and keywords in a structured manner, along with their relationships. Consequently, the higher number of outlines achieving scores of 7 or above can be linked to the enhanced support provided by the ESI. When I analysed the data based on the task topic, I found no significant difference between the groups regarding the average ratings. I found that the average rating for the OM outlines (mean=6.1, SD=1.71) was higher than the PR task (mean=5.88, SD=1.72).

5.4.4 Users' Experiences

Using the interview data, I try to answer RQ1(d): How do users' experiences change when the user interface differs? Based on the data analysis of the interviews, nearly 90% of the participants preferred the ESI. They described the interface as helpful, straightforward, and easy to navigate when searching for information. The majority agreed that the concept map (which is included in the ESI) provided a high-level overview of the topic and helped them understand the relationship between the topics and subtopics. Additionally, participants noted that the concept map provided related search terms and definitions when clicking on concepts, making it easier for them to explore the topic further. During the interviews, participants mentioned feeling stressed when conducting literature reviews in new fields due to unfamiliar terminology, "*when I have to read a paper in a different field, I almost panic a bit because I do not necessarily immediately understand all the terminology*" (p1). The concept map helped them organise their thoughts and feel more confident in their search, "*it does give you that confidence that you are in the right context of the topic*" (p2). Participants suggested that the concept map guided them toward related keywords and topics "*so if I wanted to understand something more, I think it just gave me the impression that I know where I am*" (p3). Also, some mentioned how supportive the concept map was in guiding them in the right direction, "*without this graph, I would be lost*" (p4).

When participants were asked about their interactions while working on the task using the SSI, they mentioned that they were searching for keywords, concepts, and relationships between them. They also reported reading more abstracts and documents to make their own concept map to aid their literature reviews, which explains why they clicked more on document titles and abstracts. Regarding the task topics, some participants found the topics and results related to the OM task more relevant and easier

to comprehend than the PR task, which was more challenging, as they reported. They stated that they needed to conduct more exploration and reading to find additional cues and keywords that could aid them in completing the task, which could explain their approach to the PR task, where they produced more unique actions and unique queries.

Overall, the results confirm that the ESI was well-received and boosted participants' familiarity with the topic, and certainty in their search process, search outcomes, as well as encouraging an iterative and opportunistic search process.

5.4.5 The impact on the Exploratory Search Conceptualisation

The previous findings shed light on this research question RQ2: How does the interface affect the conceptualisation of Exploratory Search? Participants were more likely to feel confident in their grasp of the right keywords and concepts for effective searching when using the ESI than the SSI. Participants proactively clicked on concepts they believed would yield valuable results, issuing more queries containing a greater variety of unique words. Furthermore, participants using the ESI reported greater satisfaction with their search experiences. They heightened familiarity and certainty regarding their search objectives and processes. These participants tended to produce outlines with higher scores, indicating a more effective outcome in organising their search efforts. This success contributed to increased confidence in their choice of keywords and search concepts and a clearer strategy for uncovering relevant results than those using the SSI.

This revelation opens up captivating possibilities, hinting at the potential inclusion of users' preferences of the interface as a fifth dimension within the conceptual model of exploratory search. Such an addition is significant as the interface preference has demonstrated the capacity to elevate the level of exploratory engagement across the problem context, search process, and users. In practical terms, it holds promise for participants in the sense that it can substantially enhance their knowledge acquisition and foster a heightened sense of familiarity, certainty, and decisiveness concerning their information needs. Furthermore, it encourages the adoption of a more iterative, opportunistic, and systematic search approach. This has the potential to render their perception of the problem more structured and specific, thus amplifying the overall effectiveness of their exploratory search endeavours.

Indeed, it appears that there is a significant piece missing from the current understanding of exploratory search –the interface preference dimension. Integrating this dimension promises to enrich the comprehension of exploratory search significantly. It can empower the search community by designing more effective support interfaces meaningfully en-

hancing search tasks' exploratory dimension.

The preceding section outlined the design of the first study to investigate the impact of the interface on users' perceptions, behaviours, search outcomes, and overall experiences during exploratory searches, where participants interacted with both the Exploratory Search Interface (ESI) and the Standard Search Interface (SSI) with assigned tasks. In the subsequent section, I describe my second study, which investigates the influence of a real, more naturalistic task on users' experiences and behaviours.

Within-subject designs are advantageous for minimising errors associated with individual differences by keeping the participant constant and varying the interface [121]. However, a notable drawback is the potential for participation in one condition to impact performance or behaviour in all other conditions [87]. Given the specific concern that participants might deduce the independent variable, particularly the presence of the concept map in the ESI, the second user study I designed is a between-subject study. Further details regarding the study design and additional objectives are explained in the subsequent section.

5.5 Study 2: Real Task Influence on Exploratory Searches

I designed a between-subjects user study where the independent variable is the interface. I employed a mixed methods approach, similar to the previous study, to collect both quantitative and qualitative data using diverse methods and instruments. Three main differences distinguish this study from the previous one: 1) Each participant was exposed to only one interface, 2) Participants were tasked with working on their own chosen topic instead of being assigned a specific topic, and 3) Participants were given as much time as they desired, and no time limit was set for their engagement with the search task.

The only condition specified was that the chosen topic should be unfamiliar, reflecting a subject of personal interest they would like to explore further. Participants were encouraged to focus on their Master's project, ensuring they had not previously conducted a literature review on the chosen topic. Moreover, the primary objectives of this study are twofold:

1. To validate the findings observed in the previous study when participants were assigned a more naturalistic task, requiring them to work on their Master's project

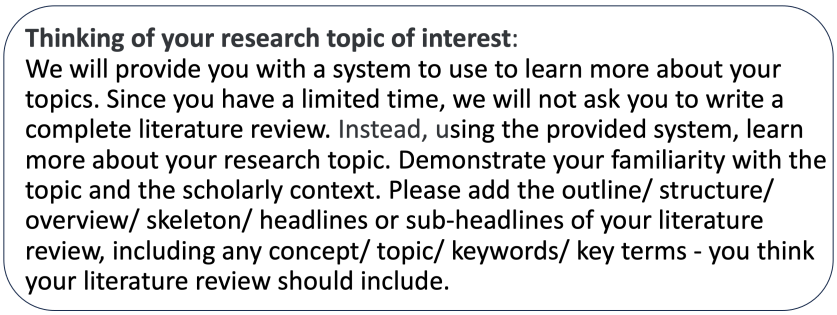

Figure 5.5: Wording of the search task of the between-subjects study

topic.

2. To investigate participants' strategies, approaches, and behaviours during literature reviews through in-depth semi-structured interviews conducted at the end of the search session (results of this is in Chapter 6).

The interfaces, resources, instructions, measurements, and questionnaires used in this study were identical to those in the previous study. Half of the participants were exposed to the ESI, while the other half interacted with the SSI. Additionally, the semi-structured interviews in this study were more in-depth and focused on participants' experiences in conducting literature reviews in general.

5.5.1 Real Task: Literature Review Outline

The search task remained consistent with the previous study; it focused on a literature review. However, in this study, participants were instructed to choose a topic of their preference. They were verbally highly encouraged to work on the topics of their MSc. projects. Figure (5.5) shows the wording of the task. Most participants chose to work on their MSc. project topics for the tasks in this study. A few participants worked on other unfamiliar topics but were interested in exploring them. Some of the titles of the literature review outline that the participants provided were: "Visual Question Answering using Machine Learning," "Technologies in the Future of Cyber Security," "Facial Recognition Analysis in Images," "AI Conversational Agents," and "Computer Generated Visual Arts."

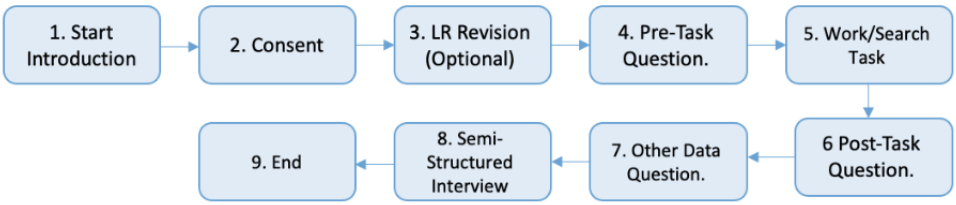

Figure 5.6: The between-subjects study workflow

5.5.2 Study Workflow

As illustrated in Figure (5.6), the study procedure is structured as follows: The study session involves a single participant. I began by introducing myself and explaining the purpose of the study. The participant is then presented with a consent form and given ample time to review and decide whether to agree or decline. Following this, the participant is offered the option to refresh their understanding of literature reviews by reading a prepared text on the concept and how to conduct one effectively.

Next, the participant is requested to complete a pre-task questionnaire. Following the questionnaire, the participant is guided to utilise the provided interface (ESI or SSI), accessed remotely through my device, to work on the topic of their preference. The task involves crafting an outline for a literature review on a topic they are interested in. Upon task completion, participants are required to fill out a post-task questionnaire. Upon completing the task, participants are prompted to complete a demographic questionnaire. Finally, the session culminates with a thorough semi-structured interview about participants' experiences, behaviours, and approaches when conducting literature reviews in general. Questionnaires and the task used in this study are included in Appendix B.3

5.5.3 Recruitment

As the resources used in building the user search interface of this study were mainly related to computer science, I specifically recruited Master's students with backgrounds in Computer Science or related disciplines, all of whom had completed at least one literature review. To select the participants, I created a screening questionnaire with essential questions. These questions covered whether participants were currently enrolled as Master's students, their field of study, whether they were required to conduct a literature review for their Master's project, details about their MSc. dissertation/thesis topic (either the title or a broad idea), their progress on their Master's projects (measured

on a scale from 0 to 100), and how many times they had previously produced a literature review.

The screening survey was designed to ensure the recruitment of Master of Science students, primarily from the field of computer science or related disciplines. This criterion was crucial to maintain a relatively uniform educational background among the participants and to confirm that they lacked prior experience with their Master's projects. The intention was to encourage them to work on literature review tasks related to their actual projects. I distributed this screening questionnaire through various channels, including university student mailing lists and social media platforms such as Twitter, Facebook, and LinkedIn. As a token of appreciation for their time and participation, participants were offered online shopping vouchers worth approximately 20 Sterling Pounds. The screening questionnaire used for this study is included in Appendix B.4.

5.5.4 Participants

A total of 96 individuals completed the screening questionnaire. However, only 56 potential participants met the established criteria and were considered eligible for the study. Following this, 44 participants responded to my emails, and ultimately, 33 actively participated in the user study. Three participants were part of the pilot study, and the data from 30 participants were included in the final analysis. All study sessions were conducted remotely via Zoom.

Regarding the participants' academic background, all were enrolled as master's students in programs such as Computer Science, Advanced Computer Science, Machine Learning, Information and Library Sciences, Information Management, Software Engineering, Data Science, Data Analytics, Technology Policy and Management, and Quantitative Finance.

In terms of participants' experience with literature reviews, 8 of them conducted literature reviews only once, 5 conducted it twice, 10 participants engaged in 3 to 4 literature reviews, 1 conducted it 5 times, 2 six times, 1 eight times, and 3 participants conducted literature reviews 20 or more times.

5.6 Data Analysis and Results of Study 2

The following sections detail the results of this study and compare them with the results from the previous one.

5.6.1 Users' Perceptions

The "additional data" questionnaire revealed that 90% of the participants either strongly agreed or somewhat agreed that conducting literature reviews is an exploratory and challenging task. Conversely, the remaining 10% of participants expressed either a somewhat disagree or neither agree nor disagree stance regarding the exploratory nature of the task. No participants strongly disagreed that the task was not exploratory. This finding aligns with the prevailing understanding within the information-seeking and retrieval community. It is also consistent with my earlier findings from the first two studies of this PhD research, which emphasised that conducting literature reviews is generally perceived as an exploratory task.

5.6.1.1 Pre-Task and Post-Task Questionnaires Analysis

As in the previous study, I calculated the difference between participants' responses before and after each session to gauge any changes in their answers to four questions. This was done as part of both the pre-task and post-task questionnaires. Consistent with the findings from the previous study, no significant differences were detected. I also analysed the responses to the post-task questionnaire. Similar to the previous study, no significant differences were observed. No consistent trend was evident between the groups that used the different interfaces. Table B.1 in Appendix B showcases these differences' mean and standard deviation, and Table B.2 displays the mean and standard deviation of answers, both grouped by interface types.

5.6.2 Users' Behaviours

The log data processing was consistent with the previous study. For this study, I computed the total number of searchbox queries, concept queries, document title clicks, show-more link clicks, and the total number of actions for the 30 search sessions. More details on the log analysis follow.

5.6.2.1 Logs/Actions Analysis

I employed the Mann-Whitney U test with Bonferroni correction ($\alpha = 0.05$) [45] to examine if there are significant differences in actions between the use of the Exploratory Search Interface (ESI) and the Standard Search Interface (SSI). The Mann-Whitney U test is suitable for comparing two samples when their distributions are not normal, and the sample sizes are small. The test revealed a statistically significant difference

in concept query scores between the groups utilising different interfaces. The median values for each log action based on the interface type are presented in Table 5.8. Rows in the Table denoted as **bold** and marked with a star (*) indicate a significant difference between the groups ($p < 0.05$).

Table 5.7: The median for each action given the interface type: ESI and SSI

Action	ESI	SSI
Concept queries	**1.8*** (2.01)	0.0 (0.0)
Searchbox queries	7.93 (5.08)	12.4 (9.61)
Show more clicks	8.4 (6.36)	11.07 (9.15)
Doc. title clicks	4.27 (2.89)	6.53 (5.36)
All queries	9.73 (5.08)	12.4 (9.61)
All actions	26.4 (13.02)	30.0 (17.46)

Participants actively utilised the concept map when available but also actively entered queries in the search box, clicking on the "show more" link to read full abstracts and actively opened documents to read in full. A trend similar to the previous study emerged: when using the SSI (without the concept map), participants demonstrated more engagement with the interface, entering more queries in the search box, clicking more on the "show more" link to read the full abstract, and clicking more on document titles. In total, participants generated more logs when using the SSI than the ESI.

While no significant difference was observed between the two groups based on the interface, considering the task goal of providing an outline for a literature review on a topic of their interest, the results suggest that the ESI may have aided participants in crafting the final output without the need to read as many documents or enter as many queries as with the SSI.

5.6.3 Users' Search Outcomes

In this study, 30 literature review outlines were collected, 15 of them were produced using the ESI. Same as in the previous study, two independent senior researchers with experience in rating literature reviews assessed the outlines based on content and structure. They rated them on a scale of 0 to 10, where 0 indicated very poor quality, and 10 indicated excellent quality. Table B.3 in Appendix B shows the mean and standard deviation of the scores of the two assessors, the average scores, and the correlation between the assessor's ratings by interface type. The data analysis suggests a correlation between assessors' ratings. The correlation of the ratings of the outlines produced using the ESI

is significant; therefore, the reviewers' agreement is not random. But it's not the case for the SSI scores.

Although no statistically significant differences were observed between the two groups based on average scores, it is notable that approximately 26% of the outlines created using the ESI achieved average scores of 7 or higher. In contrast, only about 6% of the outlines generated using the SSI reached this threshold. This observation implies that participants using the ESI tended to produce higher-scoring outlines. While these rates are lower than those observed in the previous study, the consistent trend in the results suggests a noteworthy impact.

5.6.4 Users' Experiences

This study differed from the previous study by incorporating a more in-depth semi-structured interview. Participants were questioned about their experience using the provided interfaces for their specific task. On the other hand, they were probed about their general experiences, approaches, and strategies in conducting literature reviews. Participants were even asked to walk through their thought processes while working on literature review tasks. A methodology was employed to code the qualitative data using deductive and inductive coding, enhancing the understanding of reviewing academic literature as an exploratory task. Consequently, the next chapter is solely dedicated to the analysis and findings derived from this semi-structured interview data.

However, this section presents some preliminary results related to the user search interface. On this section, I aim to address RQ3 partially: How does a more real task influence users' experiences and behaviours? I will continue addressing this question in the following section. I identified and coded all text pieces related to participants' perceptions of the interface and their experiences using it during the search session. Regardless of exposure to the ESI or the SSI, many participants expressed that the experience was beneficial for their own research. Participants were queried about their experience working on the task using the provided system. Most of the participants who were exposed to the Exploratory Search Interface (ESI) mentioned the concept map. Participants' comments on the ESI mainly revolved around the following aspects:

- Introducing New Search Terms: Participants noted that the concept map exposed them to entirely new search terms they were not familiar with before. One participant stated, "*I get to know new terms which I did not know before.*" (p5)

- Understanding Root Element Structure: The concept map was acknowledged for helping participants comprehend how the root element is divided and structured. As one participant mentioned, "*I think that the map helps you focus and ensure that you do not get distracted by all the information.*" (p6)

- Revealing Concept Relationships: Participants appreciated the concept map for revealing relationships between concepts. One participant noted, "*Some concepts are related concepts, but you wouldn't think of them straight away, so it is quite nice to have them up.*" (p7)

- Facilitating a General, Clear Idea: The concept map was reported to aid in creating a general, bigger picture, providing a clear idea of the overall topic.

- Assurance: Some participants mentioned that seeing the higher-level concepts was reassuring.

These findings align with the feedback and comments I gained from the first study, where the support system helps participants find new terms and keywords for future searches. This specific exploratory system aids them in learning new concepts and their relationships, boosting their confidence through reassurance.

The recorded logs also indicate that participants were highly engaged in the task. Driven by the motivation that the topic aligns with their real-life work, participants worked diligently, searched for documents, and read them, resulting in approximately double the number of logs compared to participants who worked on assigned tasks, more details on this is on Section 5.6.5. Some participants highlighted that they discovered papers they intend to utilise in their actual literature reviews for their Master's project. A few even requested that I send them some of the documents they found using the provided system. Their dedication to the task, with some spending up to one and a half hours on it, and the doubled number of logs produced when compared to working on assigned tasks indicate the importance of the task in user experiments.

One participant highlighted that they incorporated some concepts shown in the concept map directly into their outline by merely examining them. Others noted that the concept map provided them with the essence of information without needing to open and read the full documents. This observation might help elucidate why participants exposed to ESI produced fewer logs than those using the SSI. Nevertheless, there were also criticisms of the concept map. Some participants expressed concerns that the concepts were not updated or were biased towards the computer science area. As their topics

Table 5.8: The summation of logs for each action given the Type of the task (assigned and real), interface type (ESI and SSI), and the task topic (OM and PR when available)

Study	**Assigned Task**						**Real Task**	
Interface	SSI (N=30)			ESI (N=30)			SSI (N=15)	ESI (N=15)
Action/Task	OM	PR	All	OM	PR	All	-	-
Concept queries	0	0	0	111	77	188	0	27
Searchbox queries	72	103	175	61	63	124	186	119
Show more clicks	89	95	184	51	89	140	166	126
Doc. title clicks	33	81	114	45	42	87	98	64
All queries	72	103	175	172	140	312	186	146
All actions	194	279	473	268	271	539	450	396

sometimes lay at the intersection of computer science and other fields, the displayed concepts were perceived as less relevant. Consequently, these participants only clicked a little on them or explored them further.

5.6.5 Assigned Tasks vs Real tasks Logs Analysis

To answer RQ3: How does a more real task influence users' experiences and behaviours, I calculated the total number of actions/logs for the different action types for each user study, distinguishing between the first study with assigned tasks and the second study where participants were asked to work on their own tasks. The logs were categorised based on the interface (ESI and SSI). In the first study, an additional classification level was applied to showcase the logs based on the task topic (OM and PR).

Table 5.8 presents the total number of logs categorised into concept clicks, search box queries, show more abstract link clicks, document title clicks, all queries (including concept clicks and search box queries), and all logs. I also summed the logs of both OM and PR topics and displayed them under "All" column. In the first study (assigned task), the 30 participants worked on the topics of the two tasks (OM and PR) using the two interfaces, resulting in 60 search sessions. However, in the second study, the participants produced 30 search sessions working on their own tasks, divided between the two interfaces.

The system recorded nearly 850 actions across the 30 search sessions of the second study. The first study registered around 1,000 actions for the 60 sessions. In the second study, where participants explored topics related to their real literature review task for their master's project, the average number of logs per session was twice that of the

previous study, where participants worked on assigned tasks. Participants were observed working hard on their literature review outlines, producing more logs when working on the topics of their choice compared to when they worked on topics assigned to them. Working on their real topics and on a literature review that was required from them in the following semester gave them the incentive to explore more and interact with the provided interfaces more.

The data reveals a consistent trend in both the first and second user studies. Participants produced more logs using the SSI than the ESI. The absence of a concept map in the SSI might have motivated participants to click more on the "show abstract" link and explore documents to search for keywords and cues. However, in the first study, it seems that people explored the concept map much more than they did when they had to work on their own tasks. This difference might be attributed to the fact that participants came with their own specific tasks, and the concept map did not provide them with as many relevant concepts as it did in the tasks of Opinion Mining (OM) and Pattern Recognition (PR). Further details on this and participants' experiences in general were discussed in the previous section.

5.7 Discussion and Conclusion

This chapter investigated the influence of user search systems on users' perceptions, behaviours, outcomes and experiences, and the influence of a real task on users' experiences and behaviours. By utilising an exploratory support interface and conducting two user studies (within subjects with assigned tasks and between subjects with real tasks), utilising various instruments for data collection, such as questionnaires, interviews, system logs, and literature review outlines, this chapter tried to provide answers to the research questions presented earlier.

The results showed that the exploratory search interface positively impacted searchers' exploratory search behaviour. The interface allowed searchers to better understand the topic they were searching for by providing a high-level view of related concepts. This, in turn, encouraged them to explore more concepts and navigate the search space more efficiently with a single click. As a result, searchers reported feeling more confident about their search goals and processes. Many of the literature review outlines that they provided using the support interface got better scores than the ones provided by the standard search interface. This holds particularly significant implications for novices, as the initial stages of information-seeking often bring uncertainty, potentially impeding

progress and causing confusion among searchers [102]. It is evident that the interface influences users' perceptions, behaviours, and experiences during exploratory searches. Therefore, it becomes important to consider the possibility of incorporating the interface preference as a fifth dimension in the conceptual model of exploratory search.

It is crucial to recognise that the exploratory and standard search interfaces employed in the user study inherently provide differing interaction possibilities, which may result in a greater inclination towards interaction with the concept map. However, it is important to emphasise that participants could only utilise the searchbox and the list results. A few participants showed a preference against the concept map, finding it less beneficial, and thus chose to refrain from engaging with it. Conversely, most participants actively utilised the concept map that the exploratory search interface provided, with their feedback broadly expressing positivity. Many participants indicated that the exploratory search interface helped them have a firm standpoint and helped them explore the information space in the domain they were searching in. Many wished they had such an interface when working on their real literature reviews.

In the within-subject user study discussed in this chapter, there are some potential limitations to consider. For instance, it was not easy to design two tasks or topics with precisely the same level of complexity despite efforts to select similarly exploratory tasks/topics. Some participants found one topic more challenging than the other. Additionally, ensuring that all participants had identical prior knowledge of the topics they worked on was challenging. Although screening surveys were used to recruit participants unfamiliar with the tasks/topics, some still had differing levels of unfamiliarity with the topics. These limitations are common when working with human subjects due to individual variations.

In the between-subject study, where participants worked on their own tasks, there were both positive and challenging aspects. On the positive side, participants engaged in more naturalistic tasks and settings. I observed that participants were highly engaged in the task, generating double the number of logs per search session compared to the previous study. Some participants expressed that the search session was beneficial for their ongoing studies, emphasising their intention to incorporate the same documents they found through the provided system into their work. However, working on their own topics introduced a considerable variance in other factors, such as the difficulty of the topic, participants' familiarity with the subject matter, and the availability of relevant documents in the resources integrated into the system—both in terms of documents and concepts in the concept map. This complexity in the study context might contribute to

the limited identification of significant differences in the data analysis.

Overall, these studies have raised many questions that need further investigation. The interface plays a significant role in shaping users' behaviours and experiences during the search process. The findings suggest that the interface type can affect users' perceptions of the exploratory nature of the task. Hence, including interface preference as one of the main attributes that affect exploratory searches is worth considering. Prior research aimed to connect multistage information-seeking models with search systems and interfaces for intricate searches [77, 78]. Building on that, potential future investigations could explore whether the exploratory interfaces prove beneficial in distinct stages of exploratory search. Additionally, it would be valuable to examine how different features in the support interface might influence experiences, behaviours, and perceptions across various phases of exploratory search in different ways.

Chapter 6

Understanding Exploratory Search Behaviours in Literature Reviews

Having introduced, validated, and extended the conceptual model of exploratory search and having studied the influence of interface attributes on exploratory searchers in the previous chapters, this chapter marks a continuation of my exploration into the concept of exploratory search. In this chapter, my focus shifts to a specific example of exploratory search: literature searching. I concentrate on gaining insight into the specific strategies, behaviours, decision-making processes, and knowledge acquisition involved in conducting literature reviews. This chapter exclusively examines the qualitative data obtained from the between-subject study outlined in Chapter 5 (Section 5.5). I employ deductive and inductive coding methods to analyse the data (Section 6.2.2 and 6.2.3) and present my insights and findings (Section 6.3).

6.1 Introduction

In the realm of Information Seeking and Retrieval, searching the literature for relevant references in the context of academic work, such as theses or publications, is widely recognised as an exploratory search task [74, 96, 123, 159, 166], as I empirically validated in the previous chapters. To help address the growing need for supporting exploratory search endeavours, researchers have developed exploratory search models and support user interfaces. However, while much attention has been given to conceptualising exploratory searches or proposing support interfaces, little focus has been placed on understanding the specific approaches and behaviours that searchers employ during conducting literature reviews.

Hoeber et al. [74] hypothesised search scenarios and investigated the information-seeking models utilised in those scenarios. While Athukorala et al. [3], classified five primary motivations driving computer scientists' engagement in literature reviews. Prior research about academics' information seeking behaviour mostly centred around their responses to emerging electronic information tools and the influence of factors like demographics, environmental contexts, and academic disciplines on their information behaviour, as evident in works by Brown [22] and Niu and Hemminger [126]. Further studies explored different facets, including changes in academics' information seeking strategies, challenges when using new electronic tools, and preferences for resources and channels [158]. Moreover, some studies focused on specific academic groups, such as computer scientists [3], data scientists [122], social scientists [50, 120, 158], or graduate students [53].

In some previous studies, the examination of the actual information seeking behaviour of students in a digital scholarly environment was primarily based on system logs. For instance, the study of Nicholas et al. [125] revealed a distinctive form of information seeking behaviour specific to students. It highlighted differences between their behaviour and that of other academic community members. However, it is worth noting that this study focused on academics utilising various systems to read scholarly papers. The system logs were collected independently of specific search tasks with an output, such as a literature review report.

In another study, Yu et al. [201] sought to identify students' strengths and weaknesses in locating, retrieving, and citing information effectively. The study revealed that different student groups cited varying numbers of items in total, with some groups citing more books and journal articles more than others. However, again, the data were collected independently of specific tasks, and the study did not provide insights into the exact approaches, experiences, and step-by-step processes students follow when conducting a literature review.

Previously, Vakkari et al. [183] studied the changes in search terms and tactics while writing a research proposal. In another work, Vakkari [178] investigated cognition and sources in the context of writing a research proposal. Additionally, Pennanen and Vakkari [138] examined students' conceptual structure, search process, and outcomes during the preparation of a research proposal. Several models exist to describe information-seeking behaviours among academics, including Ellis's model [50], Bates' berry-picking model [13], and Vakkari's model [180].

However, these important studies did not examine the academic context through the

lens of exploratory search. While the studies mentioned above have contributed insights into various aspects of academic information seeking, they do not offer a comprehensive understanding of searchers' behaviours, approaches, decision-making processes, and knowledge acquisition when they engage in exploratory searches during academic tasks. The current literature lacks comprehensive insights into the search behaviours and practices involved in the exploratory search, specifically in academic contexts and when searching for literature. As demonstrated in the previous chapters, exploratory search is a multifaceted concept comprising various dimensions and characteristics. Therefore, it is crucial to study searchers in the academic context from the perspective of exploratory search, which is precisely what this chapter aims to accomplish.

This chapter aims to bridge this gap through semi-structured interviews with 30 Master's students who conducted literature review tasks. The study focuses on the exploratory behaviours and the varied approaches employed in literature reviews, yielding several novel findings. I have provided comprehensive definitions for the fundamental exploratory characteristics from the recent conceptual model specific to literature review tasks. Additionally, I have pinpointed potential factors that could influence these characteristics, introduced new exploratory dimensions and extended my comprehension of existing ones. I also have unearthed a spectrum of approaches used in literature reviews, shedding light on how individuals rely on specific paper sections to measure their relevance. Furthermore, I have highlighted essential facets of knowledge acquisition in the context of literature search.

This chapter answers my fourth general research question: RQ4 - What are the key exploratory characteristics that come into play when users search for literature in a new domain? I go further and answer the following specific research questions:

RQ1. What are the key exploratory characteristics that come into play when users search for literature in a new domain?

RQ2. What are the main strategies and approaches that users use when conducting literature searches in unfamiliar domains?

RQ3. How do users evaluate the relevance of documents when they are searching for literature in a new domain?

RQ4. What are the processes users employ in acquiring knowledge during literature searches?

6.2 Methodology

To investigate the primary strategies and approaches individuals employ when conducting literature searches in unfamiliar domains, explore the key exploratory characteristics relevant to such searches, understand how users assess the relevance of documents during literature searches, and explore the knowledge acquisition process during these searches, I conducted semi-structured interviews with 30 Master's students who engaged in literature review tasks. This data collection was part of the second study (between-subject) reported in Chapter 5.

6.2.1 Data Collection

I gathered quantitative and qualitative data for that user study through system logs, questionnaires, and semi-structured interviews. However, this chapter concentrates solely on the qualitative data obtained from the semi-structured interviews and observations. Observing participants' interactions with the provided systems and how they conducted literature reviews during the search session offered valuable contexts and insights. These observations guided the formulation of specific and relevant questions during the interviews.

During the interviews, I inquired about participants' experiences when using the provided interfaces for literature review tasks, and whether the approach they employed aligned with their general literature review practices. I asked participants to provide a detailed overview of their typical approaches when conducting literature reviews in real-life scenarios. I asked them what resources they rely on, what tools they use to conduct literature reviews, and if they are experts in the task. The interviews also aimed to uncover participants' criteria for determining the relevance of research papers, and factors influencing their choices in selecting and reading specific papers.

The semi-structured interviews primarily focused on prompting users to recollect their experiences when conducting literature reviews from memory. The user study sessions were recorded via Zoom technology, enabling the generation of transcripts from the audio recordings. The transcripts underwent a thorough review involving careful listening to the recorded interviews to ensure the accuracy of the transcripts for subsequent data analysis. The interviews' duration varied between 10 to 20 minutes for each participant.

Chapter 5 outlined the user study setup, workflow, recruitment, and participants. Therefore, the following sections present the methodology used for deductive and inductive

coding of the data collected from the semi-structured interviews, offering more detailed insights.

6.2.2 Deductive Coding: Key Exploratory Characteristics when Searching for Literature

To address my first research question (RQ1), I conducted a deductive coding process that involved constructing a coding scheme rooted in the 14 characteristics of the conceptual exploratory search model that I proposed in chapter 4. That conceptual model primarily focuses on exploratory search in a broad context. In this chapter, I tailored the model to align with the specific demands of literature review tasks. This adaptation involved the transformation of the 14 characteristics into a codebook, a critical tool during the deductive thematic analysis of the interview transcripts. For every characteristic of the 14 exploratory characteristics, I provided a customised version of its definition to make it contextually relevant to literature review tasks.

The codes generated underwent multiple iterations and were subject to review by my supervisors, who possess expertise in thematic analysis and literature reviews. This review aimed to ensure the clarity and accuracy of the provided explanations and examples. The validation process played a crucial role during the deductive coding phase. The codebooks for user dimensions, problem context, and search process used during the deductive coding stage are presented in Table C.1, C.2, and C.3 in Appendix C.

To apply this codebook, I utilised the NVivo software program, a tool used for qualitative and mixed-methods research. I reviewed the transcripts of the semi-structured interviews line by line. During this process, I assigned codes based on the existing codebooks, drawing connections between the textual data and predefined codes. This detailed coding approach aimed to systematically analyse and categorise the content of the interviews, ensuring a comprehensive exploration of participants' responses. The outcomes of this customisation are detailed in section 6.3.1.

6.2.3 Inductive Coding: Exploring Literature Review Strategies

To answer my second, third, and fourth research questions of this chapter (RQ2, RQ3, and RQ4), I employed an inductive thematic analysis approach. The primary objective was to unveil underlying patterns and establish codes within my data. I wanted to explore the factors guiding participants' paper selection and how they structured their

literature reviews by navigating the complex information landscape. It was imperative to explore these aspects as they substantially contribute to my holistic comprehension of the exploratory strategies, behaviours, and decision-making processes inherent in the literature search process for constructing a literature review. To facilitate this, I formulated a set of dimensions and accompanying examples. These dimensions underwent a review process, including modifications made over several iterations in consultation with my supervisors. Here are the steps I followed while coding:

1. I identified and coded all text pieces related to participants' behaviours, approaches, and strategies when conducting literature reviews.

2. I identified and coded all text pieces related to the criteria that influenced participants' paper selection.

3. I identified and coded all text pieces related to the process of knowledge acquisition during literature reviews.

I conducted further iterations on each of these codes. This allowed me to understand the various approaches participants took while conducting literature reviews, including whether they prepared an outline or structure before searching for literature. I also examined how they progressed through the task, and how they decided which papers to read. Furthermore, I explored how participants used papers they considered relevant and their methods for acquiring and utilising knowledge during the literature review process. The findings of this analysis are elaborated upon in the results section.

6.3 Data Analysis and Results

The results of the deductive analysis are presented in section 6.3.1 while the results of the inductive analysis are showcased in section 6.3.2.

6.3.1 Key Exploratory Characteristics

The findings presented in this section address my first research question (RQ1): "What are the key exploratory characteristics that come into play when users search for literature in a new domain?". Here, I elucidate the information behaviours and search processes within the context of the conceptual model of the exploratory search that I presented in chapter 4. As previously mentioned, I adapted the conceptual model to suit the specific demands

of literature review tasks. This involved translating the 14 exploratory characteristics into a codebook, which I utilised during the coding process. I structured my presentation of findings for the deductive thematic analysis by focusing on each exploratory dimension and its associated characteristics.

Moreover, I forge connections between these characteristics and the experiences, behaviours, and approaches articulated by users throughout their literature searches, as revealed in the insights shared during the semi-structured interviews. This approach offers an exploration of how these dimensions and characteristics were reflected in participants' experiences. Furthermore, I identify and highlight the key exploratory characteristics of the user dimension based on the insights derived from the qualitative data I collected and analysed.

6.3.1.1 User Dimension:

The exploratory conceptual model outlines four characteristics within this dimension. The subsequent insights pertain to this dimension.

Domain Familiarity/Unfamiliarity: This attribute assesses users' familiarity with the domain in which users are searching and reflects their existing familiarity or lack of it in terms of concepts, keywords, authors, sources, topics, knowledge, expertise, understanding of the domain and the topic. Through the data analysis, a prevailing theme emerged: the majority of participants openly admitted to their limited expertise in the field they were investigating. For instance, one participant stated, "*I am not an expert in this field in AI*" (P1), while another mentioned, "*The topic was completely new*" (P2). Some participants revealed that while they were familiar with certain terms and concepts in their chosen field, they were entirely unfamiliar with other aspects they encountered during their searches. One participant commented, "*I knew what the topic is about, but not how it was being done*" (P3). This outcome was expected since I deliberately tasked the participants with exploring a topic they had no prior knowledge about. This scenario mirrors real-life situations where individuals often find themselves conducting searches in entirely new domains.

Goal Certainty/Uncertainty: This attribute pertains to users' certainty level regarding their search objectives, the content they seek, the search structure, and the expected outcomes. Users might exhibit varying degrees of goal certainty. Some may possess uncertain or ambiguous goals, be unsure about the outcomes they anticipate, or deal with the challenge of pursuing answers that lack clarity. From the study findings, some participants revealed that they initially grappled with uncertainty regarding how to

approach the task and doubted their ability to make meaningful progress. Throughout their search process, they encountered episodes of uncertainty at different stages. As one participant put it, "*At the beginning, I was a bit, what do I use now? I didn't think I was going to make so much progress*" (P4). Additionally, participants noted that it was easy to become sidetracked by the numerous subtopics they encountered during their literature reviews. One participant explained, "*When you're writing a literature review, it is easy to get side tracked among the many various subtopics that happen.*" (P5). Conversely, some participants demonstrated a higher level of certainty when defining their search objectives. They were more precise in specifying the content they were seeking and exhibited a structured approach to their searches. It is worth noting that several of these participants mentioned receiving training in conducting literature reviews and had prior experience performing them. This raises questions about additional factors that may influence goal certainty, which I will explore further in the discussion section.

Information Need Clarity/Fuzzy: This attribute relates to the extent of clarity users have regarding their information requirements – specifically, how clearly they can define the information or data they seek during a particular step of their search. Exploratory users often contend with vague, unclear, or imprecise information needs, making it challenging to articulate the information necessary to fulfil their goals precisely. The data analysis unveiled a recurring theme: Participants frequently needed to invest time in exploration to grasp the available information fully. Many had to sift through multiple papers to learn and determine how to proceed to the next phase. Participants often encountered situations where, after reviewing specific papers, they found themselves uncertain about their subsequent steps. Some even described struggling to address their information needs effectively. For instance, one participant articulated this challenge as, "*..You know what you want, but you do not know how you're supposed to address it*" (P4). Similar to the previous attribute, certain participants displayed a distinct sense of direction and exhibited confidence in their information requirements. They demonstrated a clear understanding of how to progress from one step to the next in their search process.

Information Need Decisive/Dynamic: This attribute pertains to the dynamic nature of users' information needs as they progress through the search process. It encompasses how their search objectives, understanding, and answers may evolve and transform during exploration. Users invest time refining their comprehension and knowledge as they search, leading to a shifting focus on their information needs. Additionally, users may adapt and modify their search queries, including keywords, as they proceed further into their search process. The findings highlight two key facets of this characteristic including

1) dynamic information gathering: participants indicated that when they lacked prior knowledge about a topic, they searched for relevant keywords or picked up terminology from the papers they read. Consequently, they often moved from one paper to another, with each new source altering their understanding and information needs; 2) evolution of documentation: participants mentioned that their notes, summaries, or the structure they were developing for their literature review changed as they progressed in their search. For instance, one participant stated, "*..after going through those papers, I did get an idea of where I needed to go next*" (P4). Another participant explained, "*..I would say it's a lot of updating of this structure,..., every time I find something interesting then I say, oh, where can I write this in my structure.*" (P6). These two aspects reflect how participants adapted and refined their information-seeking and documentation strategies while navigating unfamiliar topics during their literature reviews.

When discussing users conducting literature reviews in a new domain, it is clear that their familiarity with the topic is limited, a fundamental aspect of exploratory search. Regarding the nature of information needs, it is evident that this is a central characteristic of exploratory search. Participants continuously engaged in exploration, learning, investigation, and relearning throughout the search sessions. However, the level of goal certainty and information need clarity varied among participants despite their shared unfamiliarity with the subject. This variance could be linked to participants' prior experiences in conducting literature reviews, raising questions about how these experiences and training in conducting literature reviews influence this characteristic.

6.3.1.2 Problem Context Dimension:

The exploratory conceptual model outlines five characteristics within this dimension. The subsequent insights pertain to this dimension.

Open/Close-Ended: This attribute pertains to the nature of the problem and the desired output. In the context of a literature review task, there can be multiple potential answers or outcomes. Additionally, it highlights the continuous evolution of literature in the field being researched, the extensive volume of available information, the inherent limitations in searches, and the impossibility of encompassing all aspects of a topic. Based on my findings, it was evident that some participants perceive their fields of interest as highly dynamic and subject to continuous change. For instance, one participant emphasised the rapid evolution of their field by stating, "*Because natural language processing definitely is a cutting-edge technology, so every day it is changing.*" (P7). None of the participants viewed literature review as a closed-end problem with only one answer.

Multi/Single Faceted: This attribute characterises outcomes that involve multiple sub-tasks or cover various aspects or concepts within the explored domain. It relates to conducting a comprehensive exploration that spans different facets of the topic. According to the findings, participants generally viewed the literature review task as multifaceted. They discussed two primary strategies for tackling this complexity. Some participants mentioned breaking the task down into smaller sub-tasks while others emphasised the identification of various topics and sub-topics relevant to their research area. They then assembled these relevant topics and concepts to construct their literature review. One participant said, "*It was like trying to piece together the relevant kinds of topics and concepts, and then taking it from there to understand how it all fits together*" (P8). It was uncommon to encounter participants who described literature reviews as single-faceted tasks.

Multiple/Single Item: This attribute refers to outputs that involve multiple documents or resources. It also describes an information goal that is typically achieved by combining information from various sources encountered during the search. The research findings reveal a common pattern in the literature review process. Participants often initiate their review by reading a single paper. Subsequently, they frequently expand their exploration by delving into additional papers, usually prompted by citations or when searching for specific keywords and concepts that they initially encountered in the first paper. One participant mentioned bringing eight books from the library related to their literature review's domain. As one participant put it, "*I think it is like the Rabbit Hole technique where you find one paper, and you find like seven different terms, and these lead to seven different papers*" (P8). However, it is important to note that participants read many papers, some of which may not have been directly related to their final literature review. One participant mentioned, "*I spent time reading about 55 papers, but in the end, I used only around 26 to 30 of them.*" (P9). I did not encounter participants who mentioned relying on only one paper or resource to construct a literature review on a particular topic. However, participants may come across an "inspirational paper" closely related to their topic, prompting them to follow its structure or citations for guidance. This characteristic was one that many participants reflected on.

Structured/Ill-Structured: This attribute pertains to the requirements of the literature review task, which can often be unclear, imprecise, or subject to significant changes during the search session. Consequently, participants frequently encounter challenges in comprehending the task and often seek support in navigating its inherent unclarity and ambiguity. The findings show that some participants found it challenging to initiate the

task, primarily because the requirements were not specific. They perceived it as receiving a broad topic and being tasked with creating an outline, but they were uncertain about how to proceed. One participant expressed this by saying, "*At the beginning, I was a bit unsure about what to use, ..., it felt like I was given a topic and asked to create an outline*" (P10). It is important to highlight that most participants found the task instructions for this specific exercise clear. I addressed their questions and ensured their understanding of the task, which involved creating an outline for a topic of interest in an unfamiliar domain using the provided interface. However, in real-life tasks, they might not find the same support.

General/Specific: This attribute characterises a task that is presented with a broad and unclear description, resulting in general and vague answers. This situation often relates to the literature review task, where the information needed lacks specificity and clarity. Additionally, there is ambiguity in defining the scope of the search and identifying the specific aspects of the domain that should be the primary focus. Some participants shared that when conducting a literature review in an unfamiliar domain, they begin with the most general information and gradually narrow down their focus. For example, one participant mentioned, "*I would start from the most generic stuff.*" (P4). What I observed here is the potential for participants to take various routes or approaches when addressing the same specific topic. This indicates the open-ended nature of the task, highlighting that multiple solutions or answers can exist. This might hint at a new characteristic related to the possibility of pursuing different directions in the search process to arrive at the final output, indicating a multi-directional search process. More on this will be discussed in the results of the search process.

I consider the aforementioned characteristics to be the primary exploratory elements within the problem context. Nonetheless, the results provide further depth and establish connections that enhance the comprehensive understanding, particularly regarding the multi-item and multi-faceted characteristics.

6.3.1.3 Search Process

The exploratory conceptual model outlines four characteristics within this dimension. The following are the tailored versions of them.

Iterative/ Not-Iterative: This attribute describes the iterative and evolving nature of exploratory search. Users typically begin with a tentative or imprecise query and then gradually refine their search through multiple iterations. User may follow this iterative approach, progressively narrowing down the scope of their information needs to

obtain more relevant and useful results. The findings revealed that many participants described their approach to conducting a literature review as starting with an initial query, reading some initial paper(s) to gain preliminary knowledge, and then actively searching for related concepts or topics mentioned in those papers. This often led to what could be described as a "rabbit hole" effect, where they moved from one paper to another, gradually deepening their understanding. Participants mentioned that they would conduct additional searches to clarify their understanding when encountering something they did not fully comprehend, such as an unfamiliar term or concept. One participant explained, "*Whatever I do not understand in that paper, what I do is I try to find those phrases and words and topics and papers around that.*" (P11). Additionally, participants noted that they iteratively refined their queries to find relevant information. Some participants mentioned that they occasionally identified gaps in their knowledge during the actual writing process. In response, they paused their writing to conduct additional searches to fill these gaps. One participant stated, "*There are points where I am writing, and I realise I do not have enough information on this topic... I will pause the writing to do another quick search just to fill that out.*" (P8). The analysis reveals another aspect of this characteristic: the multi-query approach. Participants described using multiple queries to gather information on various facets of the topic. This approach differs from issuing different versions of the same query to align more closely with their information needs. The multi-query approach is related to the multi-directional search, as participants, while reading and learning about the topic, have the option to steer their research in different directions by issuing new queries, either more general or more specific, to gather relevant information for the final output they are working on. It is worth noting that this characteristic, with its new facets, was frequently mentioned, and many participants reflected on it.

Opportunistic/ NotOpportunistic: This attribute describes users' willingness to take greater risks with the expectation of potentially obtaining valuable information from reading or searching for documents. The findings show that some participants described a somewhat spontaneous approach to their literature review process. They mentioned that they would randomly select a paper to start with and then explore further based on what they found in that initial paper and its references. In this way, they allow their exploration to be guided by the content they encounter. Additionally, participants noted that they often focus on specific sections of papers, particularly those they deem relevant to their research interests. For instance, one participant explained, "*There have been papers on..., so it is completely off to me, not something that I want to use, but out of*

curiosity I go and read about it,..., and then I decide whether I can use it" (P9). Another facet of this characteristic is following a speculative approach while searching for relevant information. Some participants mentioned starting the search to see what the interface would show them, and based on the results, they decided what to read and where to go.

Systematic/Unsystematic: Based on the conceptual model, this attribute is related to the presence or absence of a systematic pattern or structured approach during the search process. Exploratory users may follow unpredictable and non-linear paths in their searches, often deviating from predefined search strategies. The findings demonstrate that some participants described a more systematic method while searching the literature. They would begin with one paper, explore others related to it, and then return to the original paper. This systematic approach often involved tracing the development of ideas over time, resembling a study of the history and progression of a concept. As one participant put it, "*I start with the original paper, I will branch out, based on what I find, but I keep coming back to the original until I am finished."* (P8). In contrast, others followed a more unsystematic approach. They might jump from one paper to another without necessarily completing any of them. One participant expressed this approach, saying, "*I am trying to read a paper, but then... I just lose track of what I was actually looking for,..., sometimes I finish a paper, sometimes (usually) I do not."* (P12). The analysis highlights the presence of both systematic and unsystematic approaches to the search process. Regardless of the chosen approach, participants actively engaged in exploration activities, including finding, investigating, learning, and navigating between different information sources. Therefore, for this specific exploratory search task, this characteristic might not be suitable to differentiate exploratory search processes. This is because exploratory users engaged in various activities that showed different patterns of systematic and unsystematic search approaches.

Multi/Single tactical: This attribute pertains to a search approach where users use different systems, strategies (methods of finding documents), or tools to access relevant information and adapt search tactics in response to evolving information needs. The findings reveal that the majority of participants utilise various tactics during their literature reviews. They frequently discover papers by tracing citations from one paper to another, searching for keywords and concepts, and conducting quick Google searches. This multifaceted approach helps them gather a comprehensive set of resources for their literature reviews. Furthermore, they leverage diverse tools and resources, including Google, Google Scholar, Wikipedia, their university library, digital libraries, and reference management software like Mendeley. Some participants extended their searches beyond

papers to include non-paper resources in their literature review process. Some participants incorporate books and YouTube videos into their information-gathering process. One participant mentioned, *"I go from one paper to another from like the citations of one to another."* (P6). Another one said, *"If I do not understand something, I will just read Wikipedia and then go back."* (P13).

Long/Short term: This attribute describes the duration of the literature review task that may take place over multiple sessions, and it can be long as hours, days, or even months. The participants emphasised that conducting a literature review is a time-consuming task, often requiring more time than initially anticipated. Examples: *"If I had more time, of course I would have spent more time"* (P10).

In literature review searches, users utilise iterative, evolving, and multi-query processes to cover various aspects of their topics, including different, subtopics, and sometimes unconventional themes. The multi-query approach is frequently overlooked in discussions of exploratory search processes. Also, contrary to common descriptions of search processes as unsystematic, my findings indicate that users in literature searches may employ both systematic and unsystematic approaches while exploring the literature.

6.3.2 Literature Review Strategies

As mentioned earlier, in the inductive thematic coding, I focused on understanding how participants conduct literature reviews, acquire knowledge, determine paper relevance, and explore their behaviours, and approaches in detail. The main aim here is to answer my research questions: RQ2, RQ3, and RQ4.

6.3.2.1 Literature reviews approaches

Here I try to address my second research question (RQ2): What are the primary behavioural approaches employed when searching the literature in a new domain? The analysis revealed two main approaches that participants utilise when conducting literature reviews:

- Predefined Structure: Some participants begin with a preliminary outline, structure, or framework before starting their literature search. Depending on their familiarity with the domain, these structures can be quite generic, outlining main sections such as introduction, background, methods, approaches, etc. They might also structure topics and sub-topics if they possess some initial knowledge. These structures are

dynamic and evolve as they proceed further into their search and acquire new insights.

- Evolving Structures: Some other participants initiate their literature review without a predefined structure or outline. They start their search and reading process without a rigid framework in mind. However, as they read various papers, they gradually identify patterns and sometimes discover foundational concepts or core methodologies. It is not uncommon for them to encounter what they refer to as an "inspirational paper", one that resonates with their goals, and they might use this paper's structure as a guide when they begin crafting their literature review.

6.3.2.2 Paper Relevance

In response to my third research question (RQ3), which investigates, "How do users evaluate the relevance of documents when they are searching for literature in a new domain?" The findings emphasise the critical role of the abstract. For many participants, the abstract serves as the primary focal point when deciding a paper's relevance. They carefully assess the abstract to ascertain whether it contains the points or concepts they seek. If the abstract aligns with their research needs, they proceed to explore the paper further. Some participants have a specific process: they begin with the abstract, proceed to the conclusion, and, based on these sections, decide on the paper's relevance.

Another group mentioned reading both the abstract and the introduction before deciding. A few participants base their decision on the paper's title while others rely on the paper's keywords. A minority mentioned looking at the results section mainly. Even when participants decide that a paper is relevant, many often employ a strategy of skimming the paper, searching for specific information. They might revisit the abstract, introduction, and conclusion during this process. Unless a paper is particularly "inspirational" or highly pertinent to their research, they typically do not read the entire paper. Instead, they selectively focus on specific sections such as methods, models, approaches, or other targeted information that aligns with their research objectives.

6.3.2.3 Learning and Knowledge Gain

In response to the fourth research question (RQ4), which explores the process involved in acquiring knowledge during literature searches, the findings highlight several key aspects:

- Keyword Acquisition: Participants noted that the papers they read often provide them with keywords, terms, phrases, and concepts to search for in subsequent steps. These terms serve as entry points for deeper exploration.

- Intermittent Searching: During the reading process, participants frequently pause to conduct searches related to keywords or concepts they encounter. These searches may range from quick Google searches for basic information to more comprehensive searches involving other papers or resources. In some cases, they explore papers referenced in the initial paper.

- Rabbit Hole Strategy: Some participants employ a "rabbit hole" strategy, moving from one paper to another or from one resource to another, sometimes without returning to the original source. This approach allows them to follow threads of information to gain a deeper understanding.

- Repetition for Understanding: Participants may encounter certain concepts across different papers or resources multiple times. It often takes repeated exposure to fully comprehend these concepts. They search for new topics and concepts, hoping to grasp them, but understanding often comes after encountering them several times.

- Note-Taking and Summarising: Many participants take notes or create summaries of the papers they read. These notes are dynamic and subject to frequent updates and changes as they continue their search. These summaries serve as valuable resources for the eventual literature review, although sometimes participants need to revisit the original paper if their notes are insufficient.

- Selective Citation: Participants may read a substantial number of papers but end up citing only a subset, typically those most relevant to their research objectives. They might read papers out of curiosity or to gain a broader understanding of the general topic before delving into more specific sources. Overall, the process of acquiring knowledge during literature reviews is dynamic, involving continuous searching, reading, note-taking, and revisiting sources. Participants adapt their strategies as they progress through the research process, seeking to build a comprehensive understanding of their chosen topic.

6.4 Discussion and Conclusion

While prior research has mainly centred on understanding and supporting exploratory searches through frameworks and search systems tailored to this task, this chapter studied a specific task of exploratory search: literature reviews.

First, regarding the characteristics of the user dimensions; in terms of the problem context dimension, I found that participants often adopt various routes or approaches as they progress in their search and gain more insights into their topic of interest. This implies the existence of multiple directions towards the relevant information that contributes to the final output. This expands the understanding of the open-endness nature of the problem context. Regarding the search process dimension, the findings indicate that adopting a less methodological or systematic approach does not necessarily make the search more exploratory when searching the scholarly literature. Some participants followed a systematic approach, such as exploring references in a paper and conducting keyword searches. On the other hand, other participants pursued an unsystematic, unstructured approach as they explored the information space, moving between papers. Nevertheless, both groups were still engaged in exploration. This implies that the systematic/unsystematic search process might be a relatively minor characteristic in the context of exploratory searches. Furthermore, prior literature has discussed how users often commence their search with a tentative or imprecise query, subsequently honing their search through multiple iterations. However, what is often overlooked is the multi-query nature of the search process. Participants employ a range of queries to gather information that encompasses the multifaceted and diverse aspects of the problem. This enhances the understanding and expands the definition of the exploratory search process, and suggests the emergence of a new characteristic within the search process, which relates to using multiple queries.

Second, regarding the literature review strategies, I have identified various approaches to conducting literature reviews. Furthermore, this research revealed that individuals primarily rely on specific parts of papers to determine their relevance. I also highlighted some key knowledge acquisition aspects. This underscores the importance of designing support interfaces tailored to assist individuals engaged in tasks like literature reviews.

Third, regarding the information seeking behaviours when conducting literature reviews, I consider conducting literature reviews as a sense-making problem, and the key exploratory characteristics elucidate the bridge proposed by Dervin [48]. The results provide a detailed account of users' information seeking activities when searching the

scholarly literature to make sense of the surrounding information space for their tasks. Also, the findings empirically describe the Information Foraging Theory [140] as it applies to information seeking. I illustrate how participants interact with patches of information (papers and resources) and employ these patches to navigate to other sources of information. Additionally, I investigate how they leverage these patches of information to acquire knowledge and construct outlines and structures for their literature reviews. Furthermore, the research contributes to a better understanding of Ellis's Behavioural Model of Information Searching Strategies [50]. This model categorises information seeking patterns among social scientists into six major categories: starting, chaining, browsing, differentiating, monitoring, and extracting. I contextualise these activities within the literature review task and provide a comprehensive account of the activities themselves and how they are utilised for knowledge acquisition and decision-making patterns.

Overall, the above findings significantly contribute to the understanding of the information seeking approaches and behaviours in exploratory search, particularly within the context of conducting literature reviews. The results provide detailed insights into the actual approaches, the key exploratory characteristics employed during literature reviews, resource assessment methods, and the patterns of knowledge acquisition. This richness in exploratory search concepts and its multifaceted nature presents challenges. However, it also underscores the potential for effective support. Some implications of my findings pertain to the design of user support interfaces for exploratory searches. This chapter encourages the research and design community to carefully consider the discussed findings when developing user interfaces intended to support users in conducting exploratory searches, especially literature review tasks. Given the diverse approaches and experiences revealed by the findings, interfaces should offer various support options to cater to users who follow different approaches or have different levels of experience.

User interfaces should aid users in handling the multi-item and multi-faceted nature of problems by presenting a visual map of various facets, topics, and sub-topics within a specific domain alongside a list of relevant papers. Additionally, support systems could enhance the iterative and systematic nature of the search process by introducing features that facilitate the exploration of additional papers or concepts related to the initial paper and allow users to track their progress effectively within the initial papers. Support interfaces also could incorporate features that cater to individuals' different approaches during their literature review process. However, since all researchers eventually aim to produce a written literature review, there could be interfaces specifically designed to

facilitate note-taking and the construction of the review's structure and outline.

Many of the current academic search engines and digital libraries typically display lists of papers with basic information like the title, authors, publication year, and brief snippets of the abstract. Based on the research findings, it would be beneficial to provide users with the option to access the full abstract, introduction, and conclusion with a single click before opening a document. This would allow users to quickly glance at these key sections and make informed decisions about whether they want to explore the paper further or not.

In conclusion, my main contribution to this chapter lies in conducting a comprehensive examination of the behaviours and information seeking patterns exhibited by 30 Master's students while engaging in a specific exploratory search task: literature review. One limitation of this work is the potential for different interpretations of the collected data and various perspectives on the findings. However, I adapted my proposed exploratory search model framework to the new context, establishing it as the core framework for understanding how people approach, behave, and interact during literature searches. I believe this framework provides a foundational basis for comprehending and studying exploratory searches in this specific context.

While this study is tailored to literature review tasks, further investigations should encompass a broader spectrum of exploratory search tasks. This would facilitate an assessment of the generalisability of the present results to various tasks. It is worth noting that while I believe the findings in this chapter could be generalised to traditional or narrative literature reviews that are part of essays, dissertations, theses, or reports, this may not necessarily apply to other types of literature reviews in the medical domain or systematic reviews in general.

There is still room to understand users' affections while working on conducting literature review tasks. Studying users' emotions during the search was beyond the scope of this research. However, it would be interesting to explore and connect these emotions to Kuhlthau's ISP model, particularly in the context of literature review tasks conducted in an online space. Additionally, I believe various factors may influence exploratory characteristics, such as experience and previous training in conducting literature reviews. Future studies should investigate other user-related factors that may impact exploratory behaviours.

Chapter 7

Discussion and Implications

In this research, I proposed a conceptual model of exploratory search based on the existing literature. I validated and extended the model by conducting three user studies. These studies uncovered the various dimensions, characteristics, and attributes associated with exploratory searches. I also introduced a customised version of the exploratory search for literature review tasks. The findings, discussions and implications on these aspects are presented in detail in Chapters 4, 5, and 6. This chapter offers a general discussion and highlights implications derived from the previous findings.

7.1 Introduction

Previous research studies on exploratory search, whether examining user behaviour, proposing solutions and interfaces, or evaluating interfaces, often lack explicit definitions of exploratory search. When definitions are offered, they typically emphasise a problem context that is general, ill-structured, and open-ended, along with a search process that is iterative, opportunistic, and involves learning and investigation [187, 188, 191, 192]. While these definitions are valid, this research contends that the concept of exploratory search is more than that. In Section 7.2, I discuss the richness, complexity, and multifaceted nature of exploratory search as revealed by this research. In Section 7.3, I argue that grasping the richness and complexity inherent in the concept of exploratory search could inform the design of more effective user search interfaces. Finally, in Section 7.4, I explore the potential of studying a distinct information behaviour model for academic literature searching, focusing on the concept of following a rabbit hole strategy. This strategy has the potential to deepen our understanding of previous information models, such as the Bates' Berry-Picking model [13], and other models [44, 47, 102, 151] within the context

of exploratory search.

7.2 Unveiling the Richness and Complexity of Exploratory Search

The depth and complexity of exploratory search go beyond the primary dimensions of problem context and search processes that the existing literature [116, 187, 188] provides. Additional characteristics, dimensions, and attributes contribute to the multifaceted nature of this information-seeking behaviour. The additional elements play crucial roles in shaping the dynamics of exploratory search. Exploring these diverse dimensions and attributes enhances understanding of the rich and multifaceted nature of exploratory searches.

Chapter 4 of this thesis introduces a conceptual model grounded in previous literature with three primary dimensions. However, the exploration reveals additional characteristics in the problem context and the search process. Users engaged in exploratory searches show specific characteristics that can impact search strategies. The initially proposed conceptual model, featuring three dimensions and fourteen characteristics, is expanded to incorporate the knowledge gain dimension. In Chapter 5, another exploratory attribute, interface preference, is introduced. This complexity underscores the presence of at least five dimensions and attributes within the exploratory search, each with numerous characteristics. The tailored conceptual model for literature review tasks in Chapter 6 emphasises exploratory search's specificity and multifaceted nature.

Recognising the richness and multifaceted nature of the concept of exploratory search is crucial. Comprehending exploratory searches necessitates the consideration of multiple factors. The proposed conceptual model and the later work of revealing more dimensions, attributes, and characteristics, as well as proposing a specific version of the exploratory search model tailored for literature review tasks, benefit researchers working on exploratory and complex searches. Acknowledging the richness of this conceptualisation helps the community better understand it, providing more options to select from and helping them focus on specific dimensions and characteristics, which enhances the clarity and contribution of the research outcomes in this field. This comprehensive understanding of the diverse facets and richness of the exploratory search concept significantly influences the development of solutions and interfaces designed to support users engaged in exploratory searches. The subsequent section explores further the implications of this understanding on the design and evaluation of such interfaces.

7.3 Support Interfaces Design Consideration

Many existing studies in the field of exploratory or complex search support interfaces consistently highlight the limited support provided by current search engines for exploratory searches [72, 189]. This often results in searchers handling collected information and ideas using tools separate from the search system. Researchers assert that their proposed interfaces address the challenges of ill-structured, open-ended problems and iterative exploratory searches [49, 72, 92, 142, 145, 155, 159, 200]. However, these interfaces may only provide a partial solution to the complexities associated with exploratory search. Acknowledging the rich and multifaceted nature of exploratory searches implies the necessity of a targeted focus on specific dimensions or characteristics. Developing comprehensive solutions tailored to the diverse aspects of these tasks requires an interface that aligns with the complexities of exploratory search. While it remains possible that a single solution can address the multifaceted and rich conceptualisation of exploratory search, it must live up to the claim. In other words, the interface should genuinely accommodate the various dimensions, characteristics, and attributes inherent in exploratory search.

In Chapter 6, I studies the various approaches users may adopt when engaging in exploratory search tasks, such as literature reviews. I explored some services that a supportive user interface can provide to enhance exploratory searches. It is crucial to highlight that recognising and acknowledging the diverse characteristics and attributes influencing exploratory searches can open up a broader spectrum of options for creating innovative solutions and tools. On the one hand, this allows for the development of targeted interfaces and features addressing specific characteristics or challenges within the realm of exploratory searches. On the other hand, the effectiveness of the proposed interfaces may impact exploratory behaviour, depending on the support these interfaces offer. For instance, certain interfaces may prompt users to explore various avenues, concepts, and topics within their area of interest, fostering a broad exploration of the information space. Conversely, other interfaces may assist users in delving deeply into their chosen topics, encouraging a more focused search and narrowing down the scope within their information space.

7.4 Rabbit Hole Strategy

In Chapter 2, I reviewed several models within the field of information-seeking behaviour. One such model, Bates' model [13], that challenges the traditional approach to infor-

mation retrieval (IR), which typically involves matching a single query to document representations stored in an IR system. Bates' berry-picking model is noteworthy for its pioneering approach to exploratory search [154]. This model posits that each new piece of information encountered by users sparks new ideas and directions, leading to a re-conception of the query. While Bates' model is a prominent information-seeking model that generally describes searchers' behaviours when using information retrieval (IR) systems, the findings from Chapter 6 reveal a distinct strategy employed during exploratory search in the academic context, particularly in literature searching. The "Rabbit hole Strategy" involves navigating from one paper or resource to another, often without returning to the original source. This strategy enables searchers to follow threads of information to gain a deeper understanding of a topic.

The Rabbit Hole Strategy may utilise moves, tactics, or strategies mentioned in existing information-seeking behaviour models and theories, such as following forward and backward citations or searching for terms and keywords found in the paper being read. However, I argue that there are distinct activities and behaviours tailored to the exploratory search task within the academic context, particularly in literature review tasks. While the findings of this thesis may uncover aspects of this approach, further investigation is necessary. It may be beneficial to compare this approach with existing information-seeking models and theories discussed in the background chapter.

7.5 Conclusion

In summary, embracing the richness and multifaceted nature of exploratory searches provides researchers and designers with opportunities to innovate and improve the overall user experience and effectiveness in navigating complex exploratory information-seeking tasks. Additionally, being more specific when introducing solutions and tools allows for better-defined testing and evaluation processes, ensuring their effectiveness. This, in turn, might increase the likelihood of adoption by major search engines. Furthermore, comprehending the distinct strategies employed during literature searches, such as the rabbit hole strategy, could pave the way for extensive research in the field. This research has the potential to influence the design of support interfaces within the academic context.

Chapter 8

Conclusion

Throughout this research, I have addressed the overarching general research questions introduced in Chapter 2, alongside specific research questions posed in the three user studies delineated in Chapters 4, 5, and 6. I also provided a general discussion and implication in Chapter 7.

This chapter provides thesis summary (Section 8.1), thesis contribution (Section 8.2), conclusion (Sections 8.3), limitation and insights (Section 8.4), and future work (Section 8.5).

8.1 Thesis Summary

This research establishes a fundamental comprehension of exploratory search. It begins by identifying the primary dimensions highlighted in existing literature and proposing a conceptual model encompassing three key dimensions. Subsequently, this model is empirically validated and extended through a user study, exploring the potential inclusion of a new dimension, such as knowledge gain. The complete explanations of fourteen characteristics, alongside the attributes of knowledge gain detailed in Chapter 4, establish a foundational understanding of exploratory search. Chapter 4 addresses RQ1 and RQ2: What are the primary dimensions and characteristics of exploratory search? And how do individuals perceive the various dimensions and characteristics of exploratory search during a literature review? This chapter helps in reducing ambiguity surrounding the exploratory search concept and contributes to its clarity and definition.

Instead of proposing new interfaces to aid exploratory searches and adding one to the myriad of proposed ones, this thesis examines the impact of various user search interfaces on exploratory searchers (Exploratory vs standard interfaces). It investigates how these

interfaces influence searchers' behaviours, perceptions, experiences, and outcomes. Chapter 5 addresses RQ3: How do users' behaviours and overall experiences change when the user interface differs? This chapter discusses the possibility of considering the interface preference as a fifth dimension of exploratory search, and it discusses that while providing support interfaces to exploratory searchers holds promise, it is crucial to specify the type of support these interfaces offer and which exploratory characteristics they target. Additionally, the results from this chapter indicate that the assigned or original task type affects searchers' behaviours. This insight should guide researchers in designing user studies within the interactive information retrieval field.

Given that conducting literature reviews serves as an example of exploratory search, in Chapter 6, I addressed RQ4: What are the key exploratory characteristics that come into play when users search for literature in a new domain? I tailored a version of the exploratory search conceptual model specifically for searching the literature for a written review in reports or publications. Furthermore, I studied this task's approaches, decision-making processes, and knowledge acquisition. The insights in this chapter could prove valuable for researchers interested in understanding behaviours, interactions, and the learning process, as well as for those aiming to support searchers engaged in this specific exploratory search task.

8.2 Thesis Contribution

A key contribution to this thesis is the introduction of a conceptual model for exploratory search. The model offers comprehensive definitions of the exploratory characteristics based on the existing literature. The conceptual model is then empirically validated through my first user study, providing one of the initial in-depth examinations into the nature of exploratory literature review searches.

Another significant contribution to this thesis lies in the exploration of how the interface impacts users' perceptions, behaviours, search outcomes, and overall experiences within the domain of exploratory searches in the academic field. This thesis presents two laboratory user studies, examining the influence of user interfaces on exploratory searchers and investigating how integrating a more real-life search task impacts users' experiences and behaviours, particularly during literature review tasks.

The ultimate key contribution to this thesis involves offering thorough definitions for the foundational exploratory characteristics outlined in my proposed conceptual model, with a specific focus on literature review tasks. The last part of this thesis introduces

new exploratory characteristics and extends the comprehension of existing ones. It also investigates the approaches employed in literature reviews, decision-making processes when selecting papers to read, and knowledge acquisition during exploratory searches for academic tasks.

In sum, this thesis serves as a critical bridge between theory and practice. It commences with a thorough review of existing literature on exploratory search, synthesising the insights into a model featuring three primary dimensions and fourteen characteristics. Subsequently, through three user studies that combine quantitative and qualitative data, the model was evaluated. The exploration encompassed identifying key exploratory characteristics, scrutinising the impact of supportive user interfaces on exploratory searches, and delving deeper into the task of literature reviews. The implications of this work are extensively discussed in Chapters 4, 5, 6, and 7. In essence, this thesis lays a foundational understanding and support framework for exploratory and complex searches, offering intricate details on dimensions, characteristics, attributes, influencing factors, approaches, and behaviours. Additionally, it provides valuable insights for designing more effective and supportive user interfaces.

8.3 Conclusion

I believe that the concept of exploratory search is important in gaining an understanding of searchers' behaviours and strategies while searching in a new domain for them. Thus, the concept of exploratory search provides a framework for analysing and developing information access in general and for analysing and designing information retrieval systems in particular. However, the concept of exploratory search was vaguely defined in previous studies in information seeking and retrieval. Therefore, this PhD research aimed to identify the main dimensions and characteristics of the exploratory search beginning with a review of existing literature on information behaviour and interactive information retrieval. The journey progressed through three user studies, helping to understand the richness and complexity of exploratory search. This exploration paves the way for investigating additional dimensions, attributes, factors, and methods for designing support interfaces to assist searchers in utilising exploratory search strategies.

As mentioned in the earlier chapters, exploratory search is a distinct task within the broader spectrum of information-seeking and retrieval tasks. Some researchers categorise tasks into work, information-seeking, and information-search tasks [31]. However, I argue that the concept of exploratory search tasks exceeds these classifications. It is more fluid

and can encompass aspects of all three task categories. Exploratory search involves facets related to emotions and feelings. While exploring searchers' emotions throughout the process was not within the scope of this research, some participants mentioned feeling panicked or anxious when engaging in exploratory search tasks, such as conducting literature reviews in a new domain. This could be linked back to Kuhlthau's ISP model [103]. However, the richness and multifaceted nature of exploratory search extends beyond the boundaries of any single classification or model of information seeking and retrieval. As discussed in the previous chapter, a new information behaviour model, such as the rabbit hole strategy, emerged when examining a specific example of exploratory search (literature reviews). This indicates that the concept is vast and cannot be confined to a single model or definition.

In conclusion, the concept of exploratory search encompasses the understanding of its dimensions, characteristics, attributes, and factors discussed throughout this research. I believe that this helps to clarify the ambiguity surrounding the definition of exploratory search. However, it also lends a fluid nature, allowing it to intersect with various aspects and concepts in information-seeking and retrieval.

8.4 Limitation and Insights from User Studies in Exploratory Search

The concept of exploratory search is complex and multifaceted, characterised by numerous dimensions, characteristics, and influencing attributes. This complexity poses challenges when designing user studies and experiments in the field. Throughout this PhD research, I conducted three user studies. Engaging participants (human subjects) is inherently challenging, and this complexity is compounded when dealing with a multifaceted concept such as exploratory search tasks.

One notable limitation encountered in this research was the variability in participants' levels of familiarity with the provided topics and their diverse experiences in conducting the task or using the employed tools. To address this challenge, specific criteria were established for participant selection, and a screening survey was designed to filter out individuals who did not meet these criteria. Despite these efforts, achieving a uniform level of familiarity and experience among participants proved challenging.

Various attributes must be considered when studying exploratory searches. The choice of tasks used in the user studies is among the most critical factors. In Chapter 5, I investigated the distinctions in user behaviours during exploratory search tasks,

specifically comparing assigned tasks to real tasks. Despite both tasks involving crafting a literature review outline within the academic search domain, this exploration prompts questions about how users might vary in their behaviours and strategies when tasked with different types of literature reviews, such as a systematic review in the medical field.

8.5 Future Work

One of the principal contributions to this PhD research lies in offering an understanding of exploratory search. The provided conceptual model establishes a framework comprising multiple dimensions and numerous characteristics. While the model presented here is a valuable foundation, there remains room for refinement and expansion.

Future work could improve the model by examining the specific characteristics of the knowledge gain dimension in greater detail. Additionally, the research could explore how various visualisations and support interfaces impact users' behaviours and approaches during exploratory searches and how they affect them. Questions to consider include: Do different designs or visualisations encourage searchers to explore more deeply or broadly? Furthermore, does the choice of interface design ultimately matter in the search process, and how exactly?

Investigating various types of exploratory search tasks besides the academic context, tasks across different fields, and everyday life scenarios could enhance the comprehension of the concept and potentially enable us to generalise our findings to other domains and fields. Additionally, there is an opportunity to develop customised solutions, interfaces, and features that cater to specific characteristics within the identified dimensions. This presents avenues for continuous exploration and refinement within the realm of exploratory search. Furthermore, there is scope to investigate the rabbit hole strategy discussed in the previous chapter further.

The new *Artificial Intelligence* (AI) tools and generative AI applications can potentially revolutionise how users search and learn. However, there is limited understanding of their impacts on exploratory searches. Exploring the influence of generative AI applications, such as ChatGPT (a language model developed by OpenAI), Bard (a Chat-Based AI tool from Google), and other similar solutions, on exploratory search is indeed an intriguing avenue for research. Investigating how these tools influence users' information-seeking behaviours and strategies could provide valuable insights. Key questions to explore include whether the dimensions and characteristics of the conceptual model and its tailored version remain applicable in the context of generative AI tools. Additionally,

it would be interesting to examine whether these tools reduce the time required for conducting literature reviews in new domains, how they affect knowledge acquisition, whether users' search processes exhibit similar characteristics, and if there are perceptual differences in how users approach and understand the exploratory problem context. This research could shed light on the evolving landscape of exploratory search by integrating generative AI technologies.

Appendix A

A.1 Complete Version of the Questionnaire used in Chapter 4.

Block 1: Consent

Study title: **Experiences of Conducting a Literature Review**

• This questionnaire aims to learn about your experiences when reviewing the literature to produce written reports.
• It will take approximately 10-15 minutes to complete.
• Your participation is voluntary.
• You may withdraw at any time by closing your browser window.
• Your responses are anonymous.
• The Department of Computer and Information Sciences Ethics Committee (ethics@cis.strath.ac.uk) approved this study.

Electronic Consent

You can read the complete consent form for further details about the study. You may print it for your records.
Clicking on the "**Agree**" button indicates that:
• You have read the consent form.
• You voluntarily agree to participate.
• You are 18 years of age or older.

Agree

Disagree

Block 2: Number of previous Literature Reviews

a. How many times have you ever produced a written report that includes a review of the literature? (e.g., a paper, a journal, a thesis, a dissertation, a proposal, or any academic/industrial report where you

have cited the literature).

0

1-5

6-20

21-50

51+

Bock 3: Basics info about the literature review

Thinking of your **most memorable** or the **latest** time you produced a written report that includes a review of the literature (e.g., a paper, a journal, a thesis, a dissertation, a proposal, or any academic/industrial report where you have cited the literature), please respond to the rest of the questions based on this experience:

a. What was it for?

Study (e.g, thesis/dissertation/proposal for PhD/masters/undergrad)

Academic Publication (e.g, journal/conference/workshop)

Scientific/Project Report

Funding Proposal/Grant

Policy Document

Other

b. What was the topic of it?

c. What was the type of it?

- Quantitative/qualitative meta-analysis review
- Systematic review
- Narrative review
- I don't know
- Others

d. When did you perform it?

- Few weeks ago
- Few months ago
- A year ago
- More than one year ago

e. Approximately how many references/papers did it contain?

- Less than 10
- 10-30
- 31-50
- 50+

f. How many words approximately was the review?

- 1000 words or less (2 pages single-spaced)
- 1000-5000 words (2-10 pages)
- More than 5000 words (10+ pages)

g. Roughly, how long did it take you to finish it? (Between starting and finishing, even if you were doing other things)

- Few days
- Few weeks
- Few months
- A year or more

Block 4: Statements P1

h. Given the review you just described, please indicate your level of agreement with the following statements (part 1/3):

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
1. Before starting the search, I was already an expert on the topic.	○	○	○	○	○
2. Before starting the search, I already knew the right keywords and concepts to use when querying\searching.	○	○	○	○	○
3. From the start, I had a clear plan for finding relevant documents.	○	○	○	○	○
4. I knew from the start what literature would go into the report.	○	○	○	○	○
5. At the start, I knew how to divide the review task into various sub-tasks\activities.	○	○	○	○	○
6. During the search, I learned new keywords and concepts related to the review's topic.	○	○	○	○	○
7. During the search, I found information that was surprising or unexpected.	○	○	○	○	○

8. During my search, I encountered new concepts which I chose to investigate further.	○	○	○	○	○
9. During the search, I only examined result items/documents that I was sure were relevant.	○	○	○	○	○
10. I was able to easily decide which result items/documents were relevant.	○	○	○	○	○

Block 5: Statements P2

h. Given the review you just described, please indicate your level of agreement with the following statements (part 2/3):

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
11. I changed (reworded) the search query many times while searching.	○	○	○	○	○
12. As I searched, what I thought was relevant, changed over time.	○	○	○	○	○
13. I was very thorough in checking through results/documents to find relevant items.	○	○	○	○	○
14. The review's topic changed in response to reading some of the retrieved documents.	○	○	○	○	○
15. When searching, I wanted very specific and detailed information relating to the topic.	○	○	○	○	○
16. The result items/documents I read helped me decide what to search for next.	○	○	○	○	○

17. I knew which sources/databases contained the information/documents I needed.	○	○	○	○	○
18. When reading a document, I looked up/examined items that were cited in it.	○	○	○	○	○
19. When reading a document, I often checked to see who had cited it.	○	○	○	○	○
20. My supervisors and colleagues were able to suggest me relevant documents.	○	○	○	○	○

Block 6: Statements P3

h. Given the review you just described, please indicate your level of agreement with the following statements (part 3/3):

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
21. I used different tools to search for relevant results/documents (e.g., Google Scholar, Digital Libraries, the University Library, Mendeley, etc.).	○	○	○	○	○
22. I searched for result items/documents using different query fields such as author names, date of publishing, etc.	○	○	○	○	○
23. New materials on the topic are constantly being published.	○	○	○	○	○
24. I had to run multiple searches to retrieve all the information that I wanted.	○	○	○	○	○
25. I was satisfied with the search results that I obtained.	○	○	○	○	○

26. I was able to judge that I had retrieved most of the relevant results/documents for the review.	○	○	○	○	○
27. The review included literature from multiple sub-topics.	○	○	○	○	○
28. It took me a long time to complete the entire review.	○	○	○	○	○
29. I stopped searching for documents because I found all that I was looking for.	○	○	○	○	○
30. I stopped working on the review because of a deadline or other tasks to work on.	○	○	○	○	○

Bock 7: Demographic

i. Given the review you just described, please indicate your level of agreement with this statement:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I would describe this review task as being an exploratory task.	○	○	○	○	○

j. What is your main discipline?

Biology, Medicine and Health

Engineering, Technology and Physical Science

Social Sciences

Art and Humanities

Management, Economic, and Business

Law

Other

k. Which of these best describes your primary position/role?

Masters Student

PhD Student

Postdoctoral Fellow

Lecturer/ Assistant Professor

Senior Lecturer/ Associate Professor/ Reader

Full Professor

Non-Academic Researcher

Other

l. How would you describe your gender?

Male

Female

Non-binary/third gender

Prefer not to answer

m. What is your age?

18-25 years old

26-35 years old

36-45 years old

46+ years old

Prefer not to answer

n. Is there anything else you want to tell us about the questionnaire or doing a literature review?

A.2 Full version of the consent form used in Chapter 4.

Study Title: **Experiences of Conducting a Literature Review**

You are invited to participate in a web-based online questionnaire. This questionnaire aims to learn about your experiences when searching for academic references used to produce written reports (**conference papers, journal articles, theses, dissertations, proposals, etc.**). Your response to the questionnaire will help us better understand and design systems to help people when searching the literature. The questionnaire will take approximately 10-15 minutes to complete, and you will have the chance to win a £50 shopping voucher.

This research project is conducted by Ayah Soufan, a Ph.D. student at the University of Strathclyde researching how people search for literature. If you want to learn more about the study, you can contact Ayah via email at ayah.soufan@strath.ac.uk.

This study was approved by the Department of Computer and Information Sciences Ethics Committee who may be contacted at ethics@cis.strath.ac.uk

PARTICIPATION

Your participation in this questionnaire is **voluntary**. You may refuse to take part in the research or exit the questionnaire at any time without penalty.

BENEFITS

You will receive no direct benefits from participating in this study. However, you can choose to enter a prize draw to win one of **five** Amazon shopping vouchers worth **£50**.

RISKS

The possible risks or discomforts of answering this questionnaire are minimal.

CONFIDENTIALITY

Your questionnaire answers will be sent to a link at qualtrics.com, where data will be stored in a password-protected electronic format. Qualtrics does not collect identifying information such as your name or email address. Therefore, your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether you participated in the study or not. If you provide contact information such as your email address, your responses will be stored independently in a separate survey. And so, no names or identifying

information will be linked to your identity, nor will any identifying information be included in any publications or presentations based on these data. Email addresses of the participants who agree to be contacted for further studies will be kept until I pass my thesis. Email addresses of the participants who choose to enter the draw will be destroyed once we have done the draw. But we will keep a record of the draw winners. All personalized and identifying information will be deleted once I pass my thesis. A form of the data without any personalized or identifying information will be saved at the institutional repository for five years and deleted. In sum, your responses to this questionnaire will remain strictly confidential.

CONTACT

If you have questions at any time about the study or the procedures, or if you have any concerns or complaints that you wish to address, you may contact my research supervisor, Professor Ian Ruthven, via email at ian.ruthven@strath.ac.uk.

FUNDING

The DOSSIER project funds this work under European Union's Horizon 2020 research and innovation program, Marie Skłodowska-Curie grant agreement No 860721.

ELECTRONIC CONSENT

Please select your choice from the web-based online questionnaire. You may print a copy of this consent form for your records.

Appendix B

B.1 Questionnaires of Study 1 of Chapter 5.

Block 1: Consent

Study title: **Exploratory Search Interfaces for Academics**

• This study is about Exploratory interfaces to help academics while searching the literature.
• The experiment will take up to 90 minutes.
• Your participation is voluntary.
• You may withdraw at any time from the interview and the questionnaire.
• Your responses to this questionnaire are anonymous.
• The Department of Computer and Information Sciences Ethics Committee (ethics@cis.strath.ac.uk) approved this study.
• As compensation for your time, we will send you an amazon voucher worth £25.
• We will process the payment in bulk, so you should expect to hear from us in 2 to 3 weeks.

You can read the complete consent form for further details about the study. You may print it for your records.
Clicking on the "Agree" button indicates that:
• You have read the consent form.
• You voluntarily agree to participate.
• You are 18 years of age or older.

Agree

Disagree

Task-LR

From here you can familiarise yourself with the definition of a literature review, or you can skip this if you want and go directly to read the task instructions:

A literature review is a piece of academic writing demonstrating knowledge and understanding of academic literature on a specific topic. Usually, a literature review forms a section or part of a dissertation, thesis, conference paper, journal, long essay, etc. A literature review has two main objectives:

- Surveying scholarly sources on a specific topic and providing an overview of current knowledge, allowing one to identify relevant theories, methods, and gaps in existing research.
- Evaluating the material critically: conducting a literature review establishes one's familiarity with and understanding of current research in a particular field before carrying out a novel investigation.

After doing a literature review, one should know what research has already been done and be able to identify what is unknown within the topic of interest. The following are some guidelines to help students learn how to conduct good literature reviews:

- Introduce the main topic;
- Choose sources/articles which are most relevant to the topic of study.
- Summaries, analyse, and synthesise previous research and theories;
- Identify areas of controversy and contested claims; and
- Highlight any gaps that may exist in research to date.

Task-SW-Intro-Pre

PR Task:

Now suppose you need to conduct a literature review for your graduation project about the **Pattern Recognition** topic. We will provide you with a system to learn and familiarise yourself with the **Pattern Recognition** topic.

Since you have a limited time, we will not ask you to write a complete literature review. Instead, we will ask you to provide an outline/ structure/ overview/ skeleton/ headlines/ sub-headlines. But before starting the search, we would like to ask you to fill in the following questions.

Please indicate your level of agreement with the following statements:

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
1. I am already an expert on the provided topic.	○	○	○	○	○
2. I already know the right keywords and concepts to use when querying\ searching for this topic.	○	○	○	○	○
3. I have a clear plan for finding relevant results.	○	○	○	○	○
4. I have an idea of an (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) of the a report about the provided topic.	○	○	○	○	○

5. I know how to divide the task into various sub-tasks\activities.	○	○	○	○	○

Task-SW-Inst

Task Instructions:

- Using the provided system, spend 20 minutes learning about the **Pattern Recognition**. Explore the topic and find more related topics/ sub-topics/applications/challenges/issues/fields that interest you and you would want to study and investigate further for your literature review report.
- Remember that you need to demonstrate your familiarity with the topic and the scholarly context. Learn as much as you can about the given topic using the system.
- Please add the outline/ structure/ overview/ skeleton/ headlines or sub-headlines of your literature review, including any concept/topic/keywords/key terms - you think your literature review should include. To fill in the following field, you can go forward and backward between this form and the system.

Task-SW-Pos

Given the task you just worked on, please indicate your level of agreement with the following statements:

		Neither agree		

	Strongly Agree	Somewhat agree	nor disagree	Somewhat disagree	Stron disag
a. I am an expert on the topic.	○	○	○	○	○
b. I have a clear plan for finding relevant documents.	○	○	○	○	○
c. I know what (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) that would go into the report.	○	○	○	○	○
d. I learned new keywords and concepts related to the topic.	○	○	○	○	○
e. I found information that was surprising or unexpected.	○	○	○	○	○
f. I encountered new concepts which I chose to investigate further.	○	○	○	○	○
g. I only examined result items/documents that I was sure were relevant.	○	○	○	○	○
h. I was able to easily decide which result items/documents were relevant.	○	○	○	○	○
i. The result items/documents I read helped me decide what to search for next.	○	○	○	○	○
j. I was satisfied with the search results that I obtained.	○	○	○	○	○
k. I stopped searching for documents because I found all that I was looking for.	○	○	○	○	○
l. I believe I have retrieved most of the relevant results for the review.	○	○	○	○	○

Task-SW-ES

Given the task you just worked on, please indicate your level of agreement with this statement:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I would describe this review task as being an exploratory task.	○	○	○	○	○

Interface Type:

With-concepts

Without-concepts

Task-SA-Intro-Pre

OM Task:

Now suppose you need to conduct a literature review for your graduation project about **the Opinion Mining** topic. We will provide you with another system to learn and familiarise yourself with the **Opinion Mining topic**.

Since you have a limited time, we will not ask you to write a complete literature review. Instead, we will ask you to provide an outline/ structure/ overview/ skeleton/ headlines/ sub-headlines/ main points of a literature review about the topic. But before starting the search, we would like to ask you to fill in the following questions.

Please indicate your level of agreement with the following statements:

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
1. I am already an expert on the provided topic.	○	○	○	○	○
2. I already know the right keywords and concepts to use when querying\ searching for this topic.	○	○	○	○	○
3. I have a clear plan for finding relevant results.	○	○	○	○	○
4. I have an idea of an (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) of the a report about the provided topic.	○	○	○	○	○
5. I know how to divide the task into various sub-tasks\activities.	○	○	○	○	○

Task-SA-Inst

Task Instructions:

- Using the provided system, spend 20 minutes learning about the **Opinion Mining**. Explore the topic and find more related topics/ sub-topics/applications/challenges/issues/fields that interest you and you would want to study and investigate further for your literature review report.
- Remember that you need to demonstrate your familiarity with the topic and the scholarly context. Learn as much as you can about the given topic using the system.
- Please add the outline/ structure/ overview/ skeleton/ headlines

or sub-headlines of your literature review, including any concept/topic/keywords/key terms - you think your literature review should include. To fill in the following field, you can go forward and backward between this form and the system.

Task-SA-Pos

Given the task you just worked on, please indicate your level of agreement with the following statements:

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
a. I am an expert on the topic.	○	○	○	○	○
b. I have a clear plan for finding relevant documents.	○	○	○	○	○
c. I know what (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) that would go into the report.	○	○	○	○	○
d. I learned new keywords and concepts related to the topic.	○	○	○	○	○
e. I found information that was surprising or unexpected.	○	○	○	○	○
f. I encountered new concepts which I chose to investigate further.	○	○	○	○	○

g. I only examined result items/documents that I was sure were relevant.	○	○	○	○	○
h. I was able to easily decide which result items/documents were relevant.	○	○	○	○	○
i. The result items/documents I read helped me decide what to search for next.	○	○	○	○	○
j. I was satisfied with the search results that I obtained.	○	○	○	○	○
k. I stopped searching for documents because I found all that I was looking for.	○	○	○	○	○
l. I believe I have retrieved most of the relevant results for the review.	○	○	○	○	○

Task-SA-ES

Please indicate your level of agreement with this statement:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I would describe this review taskI just completed as being an exploratory task.	○	○	○	○	○
Generally, I consider myself as an expert in conducting literature reviews.	○	○	○	○	○
Generally, conducting literature reviews is a challenging/difficult task.	○	○	○	○	○

Interface Type:

With-concepts

Without-concepts

Current Position

BSc Student / Undergraduate

MSc Student

PhD Student

Other

Roughly, how many times have you ever produced a written report that includes a review of the literature? (e.g., a paper, a journal, a thesis, a dissertation, a proposal, or any academic/industrial report where you have cited the literature).

0

1-5

6-20

21-50

51+

Field of Study:

B.2 Screening Questionnaires and task of Study 1 of Chapter 5.

Default Question Block

Sign up for a user study on search behaviours when conducting literature reviews

I appreciate your interest in this study!
I am Ayah Soufan, a 3rd-year Ph.D. researcher at Strathclyde University interested in building systems to help scholars conduct literature reviews.
If you are a Master's student in Computer Science or any related field, working on your literature review of your MSc project? And if you are searching for, reading, and making sense of papers on your topic? I would love to speak to you!
Please fill out this survey!
Once your eligibility for the study is determined, I will contact you as soon as possible to set a date\time that suits you for the study session.
This study will take place on Zoom for up to 1.5 hours with a £20 compensation (online voucher).

Full Name:

Email:

Field of Study (e.g., Computer Science):

Are you currently enrolled as MSc. student?

- Yes
- No

Do you have to conduct a literature review for your MSc. dissertation?

- Yes
- No

Please describe your MSc. dissertation topic (the title or the broad idea).

Have you started working on your MSc project's literature review? What is your progress today? (0%: still need to start, 100%: completed it).

0 10 20 30 40 50 60 70 80 90 100

Work progress

How many times have you ever produced a written report that includes a review of the literature? (e.g., a paper, a journal, a thesis, a dissertation, a proposal, or any academic/industrial report where you have cited the literature).

B.3 Questionnaires and task of Study 2 of Chapter 5.

Block 1: Consent

Study title: **Exploratory Search Interfaces for Academics**

• This study is about Exploratory interfaces to help academics while searching the literature.
• The experiment will take up to 90 minutes.
• Your participation is voluntary.
• You may withdraw at any time from the interview and the questionnaire.
• Your responses to this questionnaire are anonymous.
• The Department of Computer and Information Sciences Ethics Committee (ethics@cis.strath.ac.uk) approved this study.
• As compensation for your time, we will send you an amazon voucher worth £20.
• We will process the payment in bulk, so you should expect to hear from us in 2 to 3 weeks.
• We will video record the session.

You can read the complete consent form for further details about the study. You may print it for your records.
Clicking on the "Agree" button indicates that:
• You have read the consent form.
• You voluntarily agree to participate.
• You are 18 years of age or older.

Agree

Disagree

Task-LR

From here you can familiarise yourself with the definition of a literature review, or you can skip this if you want and go directly to read the task instructions:

A literature review is a piece of academic writing demonstrating knowledge and understanding of academic literature on a specific topic. Usually, a literature review forms a section or part of a dissertation, thesis, conference paper, journal, long essay, etc. A literature review has two main objectives:

- Surveying scholarly sources on a specific topic and providing an overview of current knowledge, allowing one to identify relevant theories, methods, and gaps in existing research.
- Evaluating the material critically: conducting a literature review establishes one's familiarity with and understanding of current research in a particular field before carrying out a novel investigation.

After doing a literature review, one should know what research has already been done and be able to identify what is unknown within the topic of interest. The following are some guidelines to help students learn how to conduct good literature reviews:

- Introduce the main topic;
- Choose sources/articles which are most relevant to the topic of study.
- Summaries, analyse, and synthesise previous research and theories;
- Identify areas of controversy and contested claims; and
- Highlight any gaps that may exist in research to date.

Task-SW-Intro-Pre

Thinking of your research topic of interest:
We will provide you with a system to use to learn more about your topics. Since you have a limited time, we will not ask you to write a complete literature review. Instead, we will ask you to provide an outline/ structure/ overview/ skeleton/ headlines/ sub-headlines of **a literature review in your research interest**. But before starting the search, we would like to ask you to fill in the following questions.

Thinking of your research topic, please indicate your level of agreement with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
1. I am already an expert on the topic of my interest.	○	○	○	○	○
2. I already know the right keywords and concepts to use when querying\ searching for the topic.	○	○	○	○	○
3. I have a clear plan for finding relevant results.	○	○	○	○	○
4. I have an idea of an (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) of the a report about the provided topic.	○	○	○	○	○

Task-SW-Inst

Task Instructions:
Using the provided system, learn more about your research topic. Demonstrate your familiarity with the topic and the scholarly context. Please add the outline/ structure/ overview/ skeleton/ headlines or sub-headlines of your literature review, including any concept/ topic/ keywords/ key terms - you think your literature review should include.

To fill in the following field, you can go forward and backward between this form and the system to continue search.

Task-SW-Pos

Given the task you just worked on, please indicate your level of agreement with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
a. I am an expert on the topic.	○	○	○	○	○
b. I have a clear plan for finding relevant documents.	○	○	○	○	○
c. I know what (outline/ structure/ overview/ skeleton/ headlines and sub-headlines) that would go into the report.	○	○	○	○	○

d. I learned new keywords and concepts related to the topic.	○	○	○	○	○
e. I found information that was surprising or unexpected.	○	○	○	○	○
f. I encountered new concepts which I chose to investigate further.	○	○	○	○	○
g. I only examined result items/documents that I was sure were relevant.	○	○	○	○	○

test

Given the task you just worked on, please indicate your level of agreement with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Stron disag
h. I was able to easily decide which result items/documents were relevant.	○	○	○	○	○
i. The result items/documents I read helped me decide what to search for next.	○	○	○	○	○
j. I was satisfied with the search results that I obtained.	○	○	○	○	○
k. I stopped searching for documents because I found all that I was looking for.	○	○	○	○	○
l. I believe I have retrieved most of the relevant results for the review.	○	○	○	○	○
n. I know how to divide the task into various sub-tasks\activities.	○	○	○	○	○

Task-SW-ES

Given the task you just worked on, please indicate your level of agreement with this statement:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I would describe this review task as being an exploratory task.	○	○	○	○	○

Please indicate your level of agreement with this statement:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	NA
The concept map shows a comprehensive/thorough overview of concepts in my topic of interest.	○	○	○	○	○	○

How relevant were the papers on the results list to your search queries?

- Very relevant
- Somewhat relevant
- Fair
- Poor
- Very poor

Describe your satisfaction with the papers in the results list:

- Very satisfied
- Satisfied
- Neither satisfied / dissatisfied
- Dissatisfied
- Very dissatisfied

How relevant were the concepts on the concept map to your search queries?

- Very relevant
- Somewhat relevant
- Fair
- Poor
- Very poor
- NA

Describe your satisfaction with the concepts in the concept map:

- Very satisfied
- Satisfied
- Neither satisfied / dissatisfied
- Dissatisfied
- Very dissatisfied
- NA

How would you describe your gender?

- Female

Male

Non-binary/third gender

Prefer not to answer

What is your age group?

18-25 years old

26-35 years old

36-45 years old

46+ years old

Prefer not to answer

What is your University/Institute:

What is your country of residency?

User ID

B.4 Screening Questionnaire of Study 2 of Chapter 5.

Default Question Block

Sign up for a user study on search behaviours when conducting literature reviews

Thank you for your interest in this study!

I am Ayah Soufan, a research at Strathclyde University interested in building systems to help scholars conduct literature reviews. Once your eligibility for the study is determined, we will contact you as soon as possible to set a date\time that suits you for the study session. This study will take place on Zoom for 1 to 1.5 hours with a £25 compensation (online voucher).

Email:

Full Name:

Field of Study (e.g., Computer Science, etc.):

Current Academic Position (e.g., Master's student, Doctoral student, etc.):

How many times have you ever produced a written report that includes a review of the literature? (e.g., a paper, a journal, a thesis, a dissertation, a proposal, or any academic/industrial report where you have cited the literature).

B.5 Some Extra Results of Chapter 5

Table B.1: Mean (SD) for the difference of participants' answers given the interface type: ESI and SSI.

Statement	**ESI**	**SSI**
I am an expert on the provided topic	0.2 (0.86)	1.0 (0.76)
I know the right keywords to use when searching	0.93 (1.28)	1.2 (1.21)
I have a clear plan for finding relevant results	0.53 (0.83)	1.0 (1.13)
I have an idea of an outline of the a report about the topic	1.07 (1.22)	1.4 (1.35)

Table B.2: Mean (SD) for each statement of the post task questionnaire given the interface types: ESI and SSI

Statement	**ESI**	**SSI**
I found surprising or unexpected info	3.4 (0.74)	3.73 (0.96)
I encountered new concepts, I chose to investigate further	4.2 (0.86)	4.27 (0.88)
I only examined result documents I was sure were relevant	3.73 (1.1)	4.13 (0.64)
I was able to easily decide which result documents were relevant	4.13 (0.74)	3.93 (1.16)
The result documents I read helped me decide what to search for next	4.47 (0.52)	4.6 (0.51)
I was satisfied with the search results I obtained	3.6 (1.18)	3.07 (1.03)
I stopped searching for documents because I found all that I was looking for	2.73 (1.28)	2.53 (1.25)
I believe I have retrieved most of the relevant results for the review	3.07 (1.44)	2.87 (0.99)

Table B.3: Mean (SD) of the outline assessments given the interface type

	ESI	**SSI**
Assessor 1	4.63 (1.58)	4.1 (1.26)
Assessor 2	7.07 (2.01)	6.93 (1.85)
Average Rating	6.27 (1.76)	5.72 (1.63)
Correlation	0.59 (0.02 ¡0.05)	0.16 (0.58)

Appendix C

C.1 Codebooks used in Chapter 6

Table C.1: Codebook of the User Dimension

Updated Explanation with Examples
The **"Domain_familiarity_unfamiliarity"** code is applied to participants' comments on their level of familiarity with the domain in which they are searching. They may either comment on their lack of familiarity or their existing familiarity. This familiarity or lack of it may be expressed in terms of concepts, keywords, authors, sources, topics, etc. They may mention their knowledge, schol Example: "I have no knowledge on some of these concepts."
The **"Goal_certainty_uncertainty"** code is applied to participants' comments regarding the certainty of their search goals (answers, contents, structure, end results). They may indicate that they have uncertain or vague goals, are unsure about their end results, or that the answer they are seeking is not clear-cut. Additionally, they may comment on having clear goals and answers and being sure about their end results. Examples: "I don't know what I want, exactly".
The **"Information_need_clarity_fuzzy"** code is assigned to participants' comments when they discuss the clarity of their information needs (information/data they are seeking at some point of their search). This code is used when they express what they look for is vague, unclear, or imprecise. They may mention spending time exploring to understand what information is available in the domain. When users' comments indicate that they can't clearly describe the information that would fulfil their goal, it signifies a fuzzy information need. Conversely, some participants may indicate having a clear and precise information need, accompanied by knowing the right keywords to employ. Examples: "I just go through at least 10 papers before realizing what I need".
The **"Information_need_decisive_dynamic"** code is used for participants' comments about the nature of their information needs. It is applied when participants mention that what they seek evolves and changes as they engage in the search process. They may mention spending time refining their understanding, knowledge, and answers during the search. Participants may also mention using evolving keywords during their search queries to explore available information or that their output is developing as they search. Conversely, some participants may state that their information needs remain constant and precise throughout the search process. Examples: "As the research goes on, the main headings will change to cater to the research accordingly".

Table C.2: Codebook of the Problem Context Dimension

Updated Explanation with Examples
The **"Open_close_ended"** code is used for participants' comments on the problem and the answer. They may also highlight the existence of numerous potential answers. Also, they could point out the ongoing development of literature in their field, the vast expanse of information, the inherent incompleteness of searches, and the impossibility of containing all aspects of a topic. Conversely, some participants might indicate that they've thoroughly addressed all dimensions and obtained a comprehensive answer. Example: "There is always new papers in my topic, it keeps changing".
The **"Multi_single_faceted"** code is used for the text describing results that encompass multiple sub-tasks or various aspects/concepts of the explored domain. It is used for comments related to comprehensive exploration spanning various facets of the topic. Conversely, it may be used when participants mention a single-faceted answer, indicating a narrower perspective or isolated sub-task. Example: "I just start the search by breaking the topic into subtopics".
The **"Multi_single_item"** code is used for text describing results that encompass multiple documents/resources. It is also used for text describing an information goal that is likely to be satisfied through a combination of information encountered during the search, using multiple documents/resources. Conversely, it may be used when participants mention a single item answer using a single resource. Example: "I literature review results from reading different papers."
The **"Structured_unstructured"** code is used for text describing the LR task's requirements as unclear, imprecise, or subject to significant changes during the search session. They may indicate encountering challenges in understanding the task and seek support to navigate the unclarity and ambiguity. Thus, they may follow a search process that is on fly instead of a structured one. Conversely, the opposite is true for comments about structured problem context with clear requirements. Example: "I was not sure what to do or grom where to start"
The **"Generic_specific"** code is applied to text that describes a task with a general and vague description and general answers. This code is used when participants' comments suggest that the LR task they are working on lacks specificity and clarity regarding the information needed. They may indicate encountering challenges in defining the scope of their search and identifying the specific aspects of the domain they should focus on. The opposite is true for comments about specific tasks with clear and well-defined information needs. Example: "My topic is very abroad, I can go to any direction"

Table C.3: Codebook of the Search Process Dimension

Updated Explanation with Examples
The "**Iterative_not_iterative_query**" code is applied to text that reflects the iterative and evolving nature of the search. This code is used when participants' comments describe starting with a tentative or imprecise query and progressively refining their search through multiple iterations. Participants may mention following this iterative approach and gradually narrowing down the scope of their information needs to obtain more relevant and useful results. Conversely, the opposite is true for comments indicating a more direct and non-iterative search approach. Example: "I start with initial search, from what I get I search for specific topics"
The "**Opportunistic_not_opportunistic**" code describes text related to participants' willingness to take greater risks with the expectation of potentially obtaining valuable information from reading or searching for documents. Conversely, this code applies to comments indicating a search approach unwilling to take risks even if there might be valuable opportunities. Examples: "I just spent a good amount of time just reading through it, see what I could get from it, and then I use that to search more."
The "**Systematic_unsystematic**" code describes text indicating a lack of a systematic pattern or structured approach while searching. Participants may mention following an unpredictable non-linear path during the search and not adhering to predefined search strategies. Conversely, this code applies to comments reflecting a more systematic, structured, and methodical search approach. Example: "I start with the original paper. I'll branch out, but I keep coming back to the original."
The "**Multi_single_tactical**" code describes text indicating that participants employ multiple search approaches, tactics and strategies to find the information they need. It applies when they mention the use of different systems, strategies (ways of finding documents), or tools to access relevant information and modify their search tactics based on emerging information needs. Conversely, comments suggesting a more singular and fixed approach to the search process. Examples: "I'm improving how I'm querying, sometimes I search for things that are not papers."
The **"Short_long_term"** code is used to describe text related to the duration of the task that may take place over multiple sessions, and it can be long as hours, days, or even months. Examples: "Conducting literature reviews take a lot more than this."

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