

Designing Robot Aesthetics: A Human-Centred Toolkit

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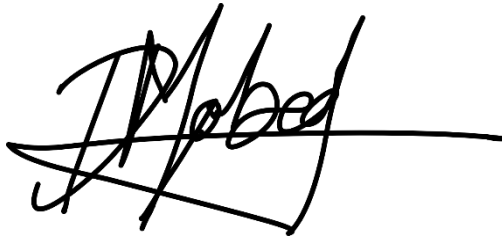
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Dated: 10/06/2026

Abstract

This thesis positions robot aesthetics as a fundamental component of robot design, demonstrating that morphology, styling, and perceptual experience shape how robots are interpreted, trusted, and accepted by users. Although Human–Robot Interaction research has typically prioritised functional performance or anthropomorphism, aesthetic meaning remains comparatively underdeveloped. To address this gap, the thesis constructs taxonomies across four domains: Aesthetic Philosophy, Design Aesthetics, Human-Robot interaction and Robot Aesthetics where separate taxonomy diagrams were designed for each knowledge area. Providing a coherent structure for later phases of the research.

A multimethod research design was employed, combining image-sorting experiments, art-based sketching, and a Linkographic Thematic Analysis approach. Seven robot morphologies and three bipolar aesthetic styling dimensions were tested, with results showing that six morphologies and all three dimensions were reliably perceived by participants. Findings indicate that morphology and styling form independent yet interacting layers of aesthetic meaning, and that designers interpret robots through a progression of visceral reactions, analogous reasoning, and setting into judgement. These insights informed the development of a model of robot aesthetic experience, capturing how meaning is constructed from form.

Drawing from these empirical results, the thesis develops an aesthetic taxonomical framework that integrates the four knowledge areas and informs a human-centred design toolkit. The toolkit translates theoretical and perceptual insights into practical methods for defining, ideation, development, prototyping, and finalising robot concepts. Tested with product designers, design engineers, and roboticists, it supports coherent aesthetic decision-making across diverse robot morphologies with skill-appropriate design processes tailored to varying project durations.

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GLOSSARY OF TERMS

Abstract Fallibilism: The view that knowledge is both abstract and fallible but can be agreed upon.

Aesthetic Humanism: That the beautification of human life is the central goal in any action.

Aesthetic Pragmatism: Beauty and aesthetic being of central important and applying it pragmatically to a context.

Aesthetics: is the thought and practice devoted to understanding and expanding rational and sensual experiences in the pursuit of beauty.

Affective: an emotional response to stimuli.

An aesthetic: a philosophical idea(s)/movement(s) embodied through artefacts and experiences.

Asynchronous: relating to an activity happening at different times.

Co-located: relating to an activity happening in the same place.

Design Engineer: A designer and engineer with a holistic understanding of the design and development of objects.

Design: is planning for different purposes such as analysis, problem, solution, and giving meaning to an object or system.

Distributed: relating to an activity happening in different places.

End-Effector: a tool attached to a robot that effects the environment.

Meaning: the intended, expressed or interpreted signified through a modes or modes of communication.

Morphology: the structure and form of something.

Product Designer: A designer focused on the design and development of objects that fulfil user needs and commercial goals.

Robot: is a device that can be reprogrammed and has multifunctional manipulators designed to move matter and items through programmed motion for different tasks.

Roboticians: An engineer focused on the design and development of robots.

Styling: the use of design aesthetic elements to achieve affective responses without guiding philosophical ideas.

Synchronous: relating to an activity happening at the same time.

Taxonomy: a naming and classification of elements being studied and their relation to each other.

Transcendental Culturalism: Acknowledges the changing nature of culture and it's central and powerful role it what is consider attractive or repulsive.

Valence: positive or negative quality of emotions.

Working Envelope: the area of maximum extension of a robot and its limbs.

1. The aesthetics of robot design: towards a classification of morphologies:
 - Robots are becoming increasingly prevalent in the workplace. As Industry 5.0 pursues human-centric technologies, a greater understanding of what effects aesthetics has on those interacting with robots is needed. This paper sets out robot morphology as a way to characterise key form types, and proposes seven classifications: anthropomorphism, zoomorphism, phytomorphism, artemorphism, functiomorphism, amorphism, and neomorphism. Through an assessment of the current robot aesthetic landscape, design dimensions are identified with examples that can inform future robot design.

Mobed, D.A.O., Wodehouse, A. and Maier, A., 2024. The aesthetics of robot design: Towards a classification of morphologies. *Proceedings of the Design Society*, 4, pp.2413-2422.

2. **[UNDER REVIEW – The Design Journal]** Defining robot design aesthetic principles
User perception and guidance for human centred robot morphologies and stylings:
 - Design aesthetics shape how humans interpret, relate, and accept robots, yet researchers have rarely established how to design appropriate affordances into robotic objects. To address this, we investigate how morphologies and stylings act as carriers of meaning. Drawing on design theory, cognitive psychology, and human–robot interaction literature, we identified different morphologies and stylings in order to evaluate their utility and perceptibility. We report on a three-phase study using both qualitative and quantitative methods using Linkography with Thematic Analysis, and sketch-based evaluation to understand aesthetic interpretations across the identified morphologies and bipolar stylings. Findings show that morphology and styling are perceived as weakly coupled layers shaping emotional responses, interpretations of meanings, and functionality. We propose a novel morphology–styling map, and usable principles for robot design aesthetic designers.

Chapter 1 – Designing Robot Aesthetics

1. Introduction

This thesis positions robot aesthetics as a fundamental component of robot design, demonstrating that morphology, styling, and perceptual experience shape how robots are interpreted, trusted, and accepted by users. Aesthetics itself is how we see meaning embodied through matter and experience (Dewey, 1934). The visual appearance of a design communicates the concept and drives ideas to the perceiver and user, such as whether it seems functional, aesthetically pleasing, meaningful, as well as being symbolically important when related to cultural tastes (Crilly, et al., 2004). This view of aesthetics is rarely applied to robotics as much of the literature is focused on assuming that anthropomorphism (human-like characteristics) should be used as the main inspiration for robot design and aesthetics when creating more human-centric designs.

In particular, service robots frequently incorporate anthropomorphic features, which involves using human like behaviours to fulfil cognitive requirements this results in the robot being perceived as intelligent. Yet researchers lack a coherent theoretical framework explaining the effects and mechanisms of anthropomorphism in human–robot interaction. Even though there is a need for the design of service (social) robots, there also needs to be a balance between functionality and aesthetic consideration. As anthropomorphism becomes more common in robotics, robots need a distinct identity that reflects their specific role or purpose (Xin and Liu, 2025). Designers also seek to use it to enhance elements of trust in relation to performative and moral dimensions (Jessup et al., 2025). In addition, anthropomorphism aims to foster meaningful responses, interactions, and relationships between humans and robots. However, the concept remains poorly defined, and the processes through which these effects occur are still unclear (Kühne, and Peter, 2023). Applied to collaborative robots there has been no beneficial effect to using anthropomorphism, which has had a negative impact on perceived reliability. While it may not enhance trust during faultless interactions, it can result in a substantial loss of trust when interactions are faulty. As such it seems less appropriate for Human-Robot Interaction (HRI) in an industrial setting, given it can distract users and as such is a safety hazard, and therefore it cannot be universally applied (Onnasch and Hildebrandt, 2021).

Although robotic designs vary considerably, many robots exhibit similar aesthetic characteristics, while their physical forms frequently fail to reflect or support their intended functions in both industrial and research settings. The following examples in (Figure 1) were taken from Breazeal, et al. (2016) with more humanoid robots (Top Row), Slamani, et al. (2026) with manufacturing robots (Middle Row), and Oliveira, et al. (2021) with farming robot (Bottom Row). Developing a more effective design approach for robotics across design,

engineering, HRI research, and industry could refine research outcomes, enhance the desirability of robotic systems, and enable robots to offer more suitable solutions to problems than conventional non-robotic objects.

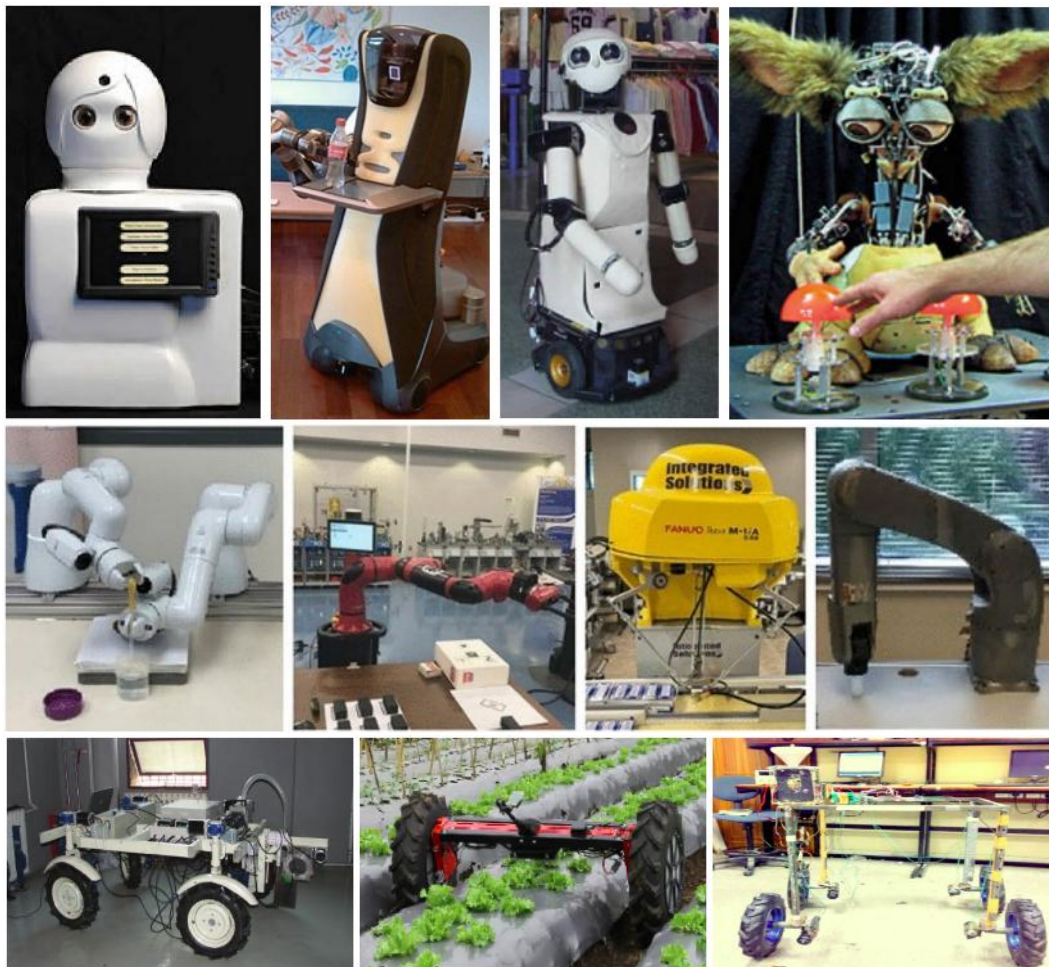


Figure 1 - Robot Examples (Breazeal, et al. (2016) (Top Row), Slamani, et al. (2026) (Middle Row), Oliveira, et al. (2021) (Bottom Row)

This recent research demonstrates the need to examine robot morphology from an aesthetic perspective, including how different forms are perceived, the contexts in which they are most effectively applied, and the ways in which styling choices shape the complex perception of robots.

Aesthetics is experienced through engagement with an artefact and is influenced by pre-existing beliefs, expertise, desires, fears, attitudes, and preferences. These factors can produce positive or negative aesthetic effects on both the experience and the epistemic processes through which the artefact is perceived and understood. The perceptions of aesthetics can be rational, irrational, apt, and inapt. Sometimes the aesthetic perception itself can be hijacked by ‘bad’ aesthetic preferences causing irrational perceptions. As such high and low-level aesthetic properties are determined by what is considered normal (to determine novelty or repulsion) (Tuna and Ion, 2024). With that, aesthetic experiences can have transformative effects where deep experiences can change our perception, beliefs, and

understanding of our reality (Pizzolante, et al., 2024). Although aesthetics is often viewed as less practically necessary than fundamental needs such as shelter or social organisation, it holds substantial cultural value. Its importance is not primarily utilitarian. Instead, aesthetics enriches human existence, and curiosity, whilst also evoking admiration and esteem (Osborne, 1986). While aesthetics may sit below basic needs like shelter in a hierarchy of practical priorities, the human desire to create pleasing environments persists. Beauty and aesthetic experience hold deep cultural and personal significance. They are, in many ways, sacred to our values, embodying ideas through forms and experiences that reflect our morals and ethics.

Aesthetics itself involves both subjective and objective elements, so empirical research incorporates measurable sensory–cognitive factors alongside subjective and contextual influences. Although individuals may judge an experience differently, shared contextual cues can produce consistent group-level responses, such as agreement on stimuli like symmetry. Current research perspectives therefore recognise both objective and subjective dimensions as essential to the field of empirical aesthetics as it must consider both measurable sensory–cognitive factors and the subjective, context dependent aspects of experience (Chamberlain, 2022). This dual perspective explains how group-level aesthetic responses can coexist and where agreement emerges with individual variation as well as identifying shared objective and subjective elements in robot-aesthetic experience.

All these factors tend to be excluded from robotics research even though all objects are perceived through this more ambiguous reality. This is where the industrial design process and design thinking is best applied given its human-centric approach which aligns with the current paradigm shift from industry 4.0 to 5.0.

Compared to Industry 4.0 with advanced technologies like robotics and data, Industry 5.0, proposed by the European commission, focuses on industrial change through values and a human centric approach rather than technology. Although there remains a need for further development and experimentation (Fant-Male and Pieters, 2025). Given the growing focus on Human–Robot Collaboration, it is necessary to examine how robot aesthetics affect human interaction with robots, as well as to develop appropriate empirical and design research methods to study these effects.

To clarify its structure, the thesis develops its contributions in a sequential manner, with each section building on the preceding one. First, four taxonomies were created: Aesthetic Philosophy, Design Aesthetics, Human–Robot Interaction, and Robot Aesthetics. These taxonomies establish the theoretical foundation and define the key concepts relevant to robot aesthetics. Next, these taxonomies were synthesised into a framework, which describes how the four knowledge areas relate to one another and how aesthetic meaning

emerges across them. This framework then informed the creation of a robot-aesthetic design process, which was tested with product designers, design engineers, and roboticists where the brief was centred on the aesthetic experience of the user. Through iterative refinement arising from these tests, the process was expanded into a toolkit, consisting of three versions (short, medium, and long) that support different levels of design expertise and project duration.

This will assist designers in developing human-centred robots, with Table 1 outlining the progression of the work from taxonomies to a framework, to applied processes, and ultimately to a toolkit.

Table 1 - Structure of Design Contributions

Type	Contributions	Impact
Framework (Shared qualities between taxonomies)	The 4 taxonomies: AP, DA, HR, RA.	Theoretical perspectives, guiding terms, and structure for other elements.
Toolkit	The collection of the 3 design processes.	The shared practical structure and system for applying the framework.
Processes	The three individual design processes: Short, Medium, Long.	Specific guidance for designers to apply in clear open phases and steps to their project.

This thesis also proposes refined definitions for morphologies across six empirically established morphological categories and three bipolar styling dimensions, in which morphologies functioned as semantic frames and stylings served as the affective layers. In this framework, styling is decoupled from specific morphologies, allowing for greater contextual adaptation. It also presents a new perception model progressing from visceral, to analogous (complex), to functional/contextual (settling/referential), which aligns with Norman's (2004) model. Along with this, a new set of processes within a toolkit was developed that moves aesthetics to the start of the design process, complete with steps and summaries. Finally, the thesis introduces new methodological innovations, including LTA, the sketching analysis autopsy, and thematic icon grouping for studying robot and design aesthetics.

1.1. PhD Purpose

The purpose of this thesis is to understand how robot morphology and styling shape aesthetic perception, and to develop a structured, human-centred method for designing robot aesthetics.

1.1.1. Design Problem

This thesis investigates robot morphology through the lenses of design aesthetics, perceptual organisation, and meaning, with the aim of identifying categories, themes, and the value of different forms. As robots increasingly adopt forms analogous to living organisms, cultural artefacts, and novel typologies, morphology becomes a central medium for communication. From complex biomorphic designs to adaptive objects, robots can express purpose, context, and underlying aesthetic philosophies through their morphological and stylistic characteristics.

Morphology, and contextual suitability, function as influences on aesthetic perception rather than as components of aesthetic theory itself. Designers draw on it, as well as styling, to shape how a robot's appearance communicates meaning, supports user interpretation and guides expectations, trust, and legibility before a single interaction occurs. The spectrum of robotic forms, from biomorphic to purely functional, each conveys distinct aesthetic and semantic implications, illustrating how morphology, meaning, and contextual appropriateness collectively shape the aesthetic interpretation of a robot.

1.1.2. Significance of Thesis

This thesis addresses a central problem in robotic design, where simplified concepts and forms often fail to align with user expectations. It examines robotic morphology and aesthetic dimensions to establish principles of aesthetic design from both morphological and styling perspectives. On this basis, it proposes multiple design processes to more effectively incorporate aesthetics into robotic design practice.

1.1.3. Scope of Thesis

This thesis examines robot aesthetics with particular attention to how professionals, including product designers, design engineers, and roboticists, perceive robot morphology and styling, with the aim of developing a method to enhance robot aesthetic design. The scope is limited to visual and conceptual aspects of robot form rather than technical kinematics or optimisation. This is because how the robot achieves locomotion is not an important element to the overall perception of it. This reflects the central aim of developing a design process and toolkit grounded in aesthetic perception.

Industrial and product design provides a suitable framework for this research, as the field increasingly emphasises the creation of emotional and pleasurable relationships between users and artefacts (Triberti et al., 2017). They also communicate complex functions and meanings through these objects, as well as methods of interaction, so that users can use them as they see fit (Krippendorff, 2006). This is one of the few fields well positioned to fully explore this topic.

While morphology and its aesthetic qualities are consistently important, there remains a gap in the literature, as these two aspects have not yet been fully examined in combination within robotic design research.

Other theses have investigated robots and their aesthetics. Dustan (2019) clearly pursues robot aesthetics in terms of the morphology but uses play, diagrammatising, and a futurist approach to plan out social robot morphology design where stages of motion are drawn on top of each other. Yet this thesis is more focused on movement than morphology. Jørgensen (2019) investigated how artistic and aesthetics methods would impact the creation of soft robot designs and then explored the results through designing a robot. The author used a wide range of techniques from artistic research to human robot interaction, and soft robotics, finding that the softness of a robot can be expressed in a myriad of ways and through different practices (Jørgensen, 2019). Within this research the morphology is not as important as the materiality of the design although the materiality had morphological implications. Shah (2022) saw robotic skin as a new way of increasing the functionality of a robot using a deformable membrane that can morph and create support structures. This skin can be applied to other soft objects to help turn it into a robot, creating actuators using this robotic skin. This can be used to augment mechanical designs into robots, such as a tensegrity structure or applied to human clothing to create a type of augmented garment (Shah, 2022). This is a trans-morphological approach where the idea of a robot is simply a random assortment of moving parts and electronics is taken to its full potential, and in consequence anything can become a robot and be roboticized. However, Shah's work did not focus on robot morphology or aesthetics.

Given practical limitations, it was not feasible to physically test a wide range of robot designs in a controlled environment. Therefore, images were used in place of physical objects, and participants completed self-reported evaluations. A large image dataset was used to obtain both quantitative and qualitative insights into which categories of robot forms were perceived or not perceived. The key professional designers were chosen due to their established involvement in robotic design. Roboticians generally have a clear technical understanding of all elements of a robot. Design engineers have greater manufacturing knowledge and a wider grasp of design and engineering practices. Product designers typically possess a strong understanding of human needs and desires, as well as creativity, and an orientation toward aesthetics.

To summarise, this thesis positions morphology and aesthetics as its central focus, examining how categories of form and their associated meanings inform design practice. By focusing on perception and aesthetic styling, it develops processes that support designers in integrating human perception and aesthetics into robot design.

1.1.4. Research Questions, Aims, and Objectives

The main goal of this research is to establish a theoretical and empirical foundation for robot aesthetics and to translate this foundation into a practical design toolkit. To achieve this, the research progressed through a sequence of connected activities. First, the study identified and defined robot aesthetic morphologies and styling dimensions. These informed the development of four taxonomies and a related framework. Building on this theoretical foundation, a robot-aesthetic design process was created, tested with practitioners, and refined into a practical toolkit. This progression ensures that the empirical findings and theoretical insights directly support the aim of establishing a human-centred method for designing robot aesthetics. As such the research questions, aims, and objective follow:

RQ1. What are the taxonomies in the four aesthetic knowledge areas?

- a. What is the taxonomy and structure of Aesthetic Philosophy?
- b. What is the taxonomy and structure of Design Aesthetics?
- c. What is the taxonomy and structure of Human-Robot Relations?
- d. What is the taxonomy and structure of Robot Aesthetics and morphologies?

Aim 1: To identify various robot aesthetic morphologies, dimensions, aesthetic taxonomies in philosophy, design and human-robot interaction.

OBJECTIVES

- Determine the taxonomical structure of aesthetics philosophy, design aesthetics, human robot interaction, and robot aesthetics.
- Create diagrams representing the findings and how they interrelate.
- Develop a framework made from taxonomies.

RQ2. How do we perceive the aesthetic experience of robot morphologies and dimensions?

- a. What kind of framework, diagram, or theoretical model can explain how people perceive robot aesthetics, such as shape, style, and design, and how those perceptions are formed?
- b. How does perceiving robot morphology differ from perceiving other objects?

Aim 2: To investigate how we perceive the aesthetic experience of the morphologies and dimensions in the context of robotics.

OBJECTIVES

- Create a method of analysis for robot aesthetics and morphologies.
- Use art-based methods to explore and extract aesthetics and ideas in the image set and participant results.

- Design a study that helps determine what morphologies and what aesthetic characteristics are perceived to verify literature findings.

RQ3. How might we design a framework that incorporates these findings to design a robot?

- a. What would the actual design process look like when the theory is applied in practice?

Aim 3: To create a process for robot aesthetics to aid designers when designing robots and explore their design concepts.

OBJECTIVES

- Design a process from the current research.
- Create a process that can be used by designers when designing robots or modifying them.
- Design the flow of its use.

RQ4. How do the model and toolkit help professionals design robots?

- a. Does it aid designers in producing more coherent and human-centred robot aesthetics?

Aim 4: To test the process on the three key user groups with the same brief to show how the research will be applied.

OBJECTIVES

- Test the robot aesthetic design process with the three key participant groups as teams of three.
- Modify the process based on user feedback and results from the participants.
- Finalise the process into an adaptable toolkit based on user design skill and level of change needed for the brief.

1.1.5. Architecture of Thesis

This thesis is organised into eight main chapters, across which six research phases are distributed. The diagram (Figure 2) illustrates how outputs from each chapter inform subsequent chapters. Although each chapter's results influence the next, they also continue to shape later stages of the research. Further details on the three phases are provided in Chapter 3.

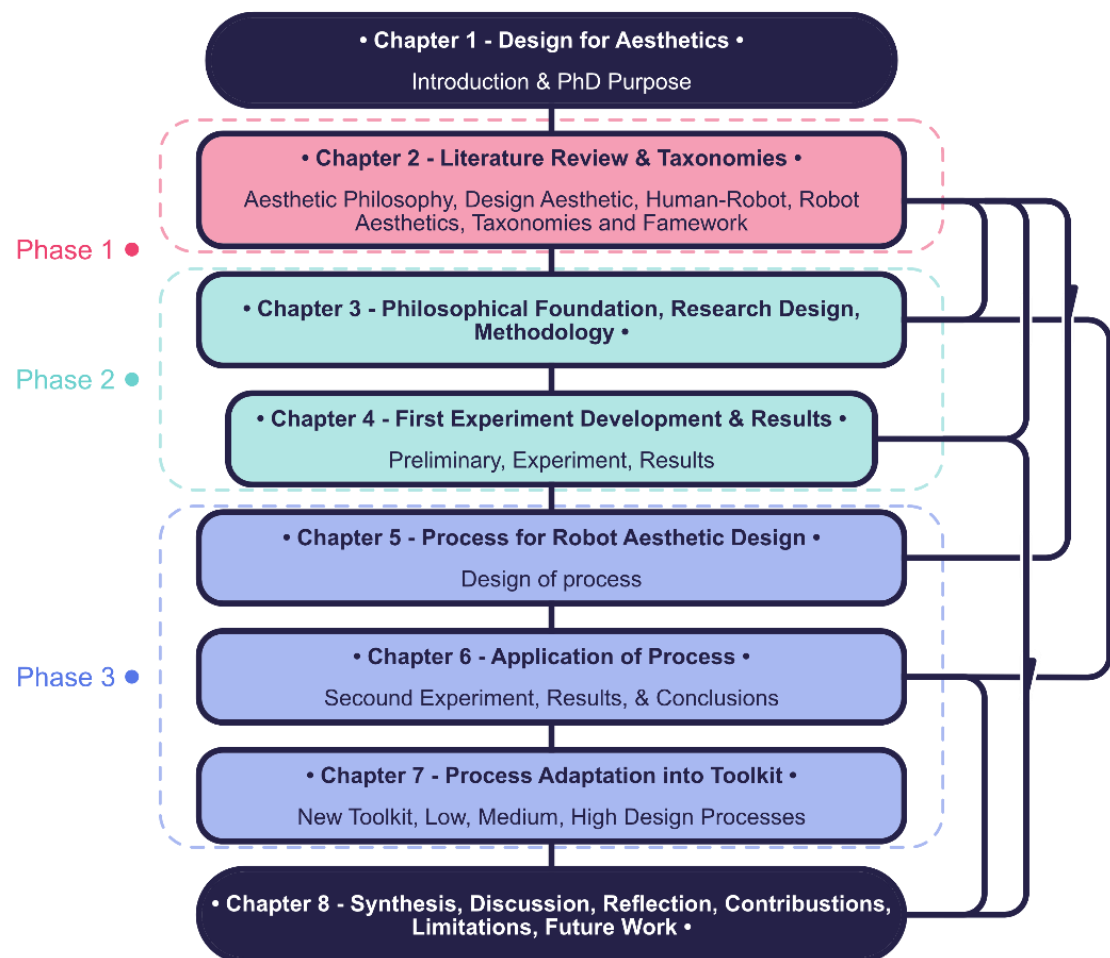


Figure 2 - Architecture of Thesis

Chapter 2 – Literature Review

The introduction established the purpose of the thesis and defined its aims and objectives. This chapter explores the main aspects of the four knowledge areas that support the achievement of the aims and objectives. While Aesthetic Philosophy and Design Aesthetics are not directly concerned with robotics, their theoretical and practical insights remain applicable to robotic objects, since robots are both designed artefacts and objects of human experience. Consequently, transferable knowledge from these fields can inform robot design. Therefore, this literature review begins with aesthetics at its most abstract level: the philosophical perspective, which explores humans and concepts of beauty. It then moves to design aesthetics, where these abstract ideas are applied through design-specific knowledge, focusing on humans and aesthetically pleasing objects. The review subsequently examines the elements that shape human–robot relations, clarifying what is currently understood about how humans relate to robotic objects. Finally, it addresses robot aesthetics, outlining the factors that influence how robots are categorised and perceived as attractive, with a particular focus on humans' perceptions of aesthetically pleasing robots. Consequently, human perception remains central throughout the review, especially in relation to beauty both in general and in the specific context of robotics.

2. Aesthetics from Philosophy to Robots

The concept of beauty originated in ancient Greek philosophy, where beauty was often understood as an observable ideal associated with measurable qualities such as proportion and harmony. In contrast, the sublime refers to experiences that are more transcendental and awe-inspiring, often linked to imagination and emotional intensity (Jiang, 2025). Beauty and design have long been closely associated. More importantly, aesthetically pleasing design has often been regarded as fundamentally ethical, reflecting ideals of human good and wellbeing. Although this relationship has received relatively limited attention from design theorists and philosophers, beauty in design is still widely understood as an embodiment of positive human values. In terms of design, there are many definitions, but the overarching theme is that it is the intentional creation of an artefact, and the practices to create it (Paris, 2025). Traditionally industrial designers have argued that their work has aesthetic value and with recent developments in design philosophy this has focused on user experience. As such beauty to industrial design is beyond surface ornamentation and emerges as values between humans and objects in experiences through attention to detail and emotional attraction. Examples such as a Gothic Cathedral and its interior suggest that cultural connection and beauty function as communication, unification, and a way of participation through sensuous interaction and pleasurable emotions. Therefore, designers should be concerned with beauty and the issues surrounding it, as the aesthetic qualities of artefacts shape human experience and influence ways of life. Technology and artefacts should therefore be humanised in ways that make everyday life enjoyable and meaningful, rather than depriving people of culture or dehumanising them through alienation and ugliness (Lobo, 2012). In the past, Plato emphasised the relationship between beauty and harmony in *The Republic*, where beauty is a central theme throughout the work. Within this perspective, harmony, beauty, and health are closely interconnected, and aesthetic education, both formal (through schooling) and informal (through everyday life), is considered essential to human wellbeing. Plato referred to this harmony as *Harmonia*, describing it as the way in which things fit together cohesively. He also argued that artistic and aesthetic influences are absorbed both consciously through education and unconsciously through immersion in daily life. Similarly, Socrates suggested that external beauty reflects inner beauty. Plato's views have remained highly influential, particularly his belief that beauty is grounded in mathematical truth, a position that contrasts sharply with theories that regard beauty as purely subjective. Moreover, aesthetic experiences can be appreciated superficially rather than understanding the full depths and meanings of a work (Hobbs, 2023). Plato considered aesthetics to be an important component of moral education, whereas Aristotle focused more on its emotional dimensions. During the medieval period, Thomas Aquinas argued that beauty is sensuous and dependent upon perfection, proper proportion, and clarity. Modern

aesthetics later developed through the work of Francis Hutcheson, who emphasised aesthetic judgement as central to aesthetic theory, and Alexander Baumgarten, who developed systematic approaches to poetry and aesthetics in which aesthetic experience was understood as both logical and cognitive. Influenced by Baumgarten, Immanuel Kant regarded aesthetics as a rational process of judgement. Friedrich Schiller further expanded these ideas in *On the Aesthetic Education of Man*, presenting aesthetics as a means of moral and political education through which individuals could realise both personal identity and social belonging. In contrast, Georg Wilhelm Friedrich Hegel adopted a more idealist perspective, emphasising the power of imagination. These ideas later contributed to philosophies of mind and consciousness, where George Santayana shifted attention away from the artwork itself and towards human thought and perception. Related developments can also be seen in movements such as Expressionism and Impressionism. Such as Benedetto Croce who emphasised intuition, arguing that objects possess intrinsic interest and convey lived experience. This intellectual trajectory eventually contributed to Marxist aesthetics, where György Lukács developed more complex forms of literary criticism by integrating Marxist theories of class and society into aesthetic analysis (Munro and Scruton, 2025).

Although this theory has seemingly been applied to everything and has perhaps caused stagnation and assumes something should be critiqued or seen in a critical light consequently motivating change before understanding. Taken together, these historical positions do not produce a single definition of aesthetics, but they do converge on a shared concern with how meaning, value, and experience arise through sensuous engagement with the world.

Returning to discuss this within design, we can consider the Bauhaus which is the most well-known school of art, design, and architecture of the beginning of the 20th century (Aynsley and Cleven, 2022). Founded by Walter Gropius in 1919, the intent was to intertwine the arts and technology where Bauhaus means, building (bau) house (haus) where the arts and industry would collide. In terms of technology Gropius wanted a products' functionality to be emphasised over its form along with the idea of unity between art and technology allowed design to better meet the needs of the time. Gropius also proposed group innovation, where groups develop design and incorporate different perspectives and work together. This humanistic view of technology combined and attempted to harmonise technology and human-centric ideas (Chen and He, 2013). It was essentially founded and focused on a machine aesthetic as well as craft, where handicraft was given a coherent functionalist purpose and helped explore the interaction between art and industry. As such the dominant field in this period was industrial design and was seen as canonical, or widely accepted

within Bauhaus (Charnley, 2020). This fusion between art and technology or pluralistic approach to industrial design or object creation is an essential key element of this thesis. As such this thesis, refutes the idea that ornamentation is secondary and takes a position contrary to that of Adolf Loos in *Ornament and Crime* (1908), where ornamentation was dismissed as meaningless and inappropriate for modern society. As forms imply functions, meaning, relationships, and that human expression and aesthetic needs are not superfluous or “criminal,” but rather valuable and meaningful forms of cultural communication and expression.

As the appreciation of beauty is fundamentally a positive experience, it is closely linked to a product’s usefulness, its ability to meet user needs, and the extent to which it is welcomed and desired by users. Beauty often arises from specific visual features, generating a positive psychological response and contributing to an overall sense of atmosphere with styles evolving over time, shaped by technological progress, fashionable artefacts, and changing artificial environments. Because of this, the pursuit of beauty should be considered a central goal in human creation. Importantly, beauty is neither exclusive nor inherently expensive, it is a universal aspect of life that can be experienced and appreciated by all (Nowakowski, 2024). As such artefacts should derive their aesthetic and cultural significance from a commitment to beauty, expressed both through the experiences they evoke and through their physical form.

When this perspective is applied to robotics, a number of recent designs have adopted explicitly human-like, android appearances, such as Hanson Robotics’ *Sophia* or the humanoid robots developed by Hiroshi Ishiguro. These artefacts are often presented as major design achievements and exemplify the human tendency to anthropomorphise non-human entities. However, such approaches raise significant ethical concerns. Despite their technical sophistication, these robots arguably function less as robots and more as artefacts of industrial design, prioritising visual realism over robotic specificity. In parallel, some roboticists have sought to ascribe moral status to these systems. Others strongly resist this position, arguing that hyper-realistic humanoid design becomes ethically questionable when it implies moral equivalence between an object and a human being (Litwack, 2025). The claim that robots are equivalent to humans in a literal or ontological sense can be understood as a form of category error, insofar as it overlooks fundamental differences between artificial artefacts and human beings. In doing so, it privileges surface-level similarities, such as morphology and communicative behaviour, while neglecting the underlying distinctions between engineered systems and living organisms.

Parviainen and Coeckelbergh (2021) make a related argument, suggesting that the humanoid robot “Sophia,” which was granted citizenship, can be understood as part of what

they term *political choreography*. This refers to the strategic use of public performances and phenomenological approaches within the philosophy of technology to advance specific political and commercial objectives. In their analysis, such practices contribute to promoting the social robotics market by presenting robots as possessing “embodied intelligence,” thereby shaping public perception of their capabilities. In the past automata, created by clockmakers, like the Jaquet-Droz automata, would perform certain acts like writing poems, although there was no existential or metaphysical discussion about creating artificial or mechanical humans (Voskuhl, 2007). Given that “Sophia” was granted Saudi citizenship (Retto, 2017), and considering the surrounding political choreography, there are clear historical precedents in the use of automata to demonstrate novelty and technical skill, such as with clockmakers. These historical examples suggest a continuity with contemporary interest in humanoid robots, as illustrated in Figure 3. However, unlike earlier forms of automata, current developments appear to be more explicitly embedded within political contexts.



Figure 3 – Automata (Left, (Voskuhl, 2007)), and Sophia (Right, (Retto, 2017))

On a more grounded plane, this aesthetics approach of making the ‘strange seem more familiar’ is the opposite to what Gemeinboeck (2021) suggests. Where the differences between humans and robots are made more rational through aesthetics and relationships, where the human robot encounter should be investigated and played with from the earliest point. This brings to the fore, the boundaries between the robot and human as well as how meaning making emerges and can be designed. Aesthetics being central to embodied meaning making for these relational machines by focusing on the technology, the human, and the relationship (Gemeinboeck, 2021). Essentially, this thesis positions aesthetics as central to human life and experience and adopts a broad perspective on robot design that encompasses the human user, the human–robot relationship, and the technological artefact itself. This approach aligns with industrial design practice, in which solutions emerge through processes of creativity, investigation, experimentation, prototyping, and play, rather than through the imposition of a fixed morphology or a universal design approach.

This literature review follows a trajectory that parallels the structure of the overview. At the end of each major section, a taxonomy diagram is presented, mapping the key elements within that area and illustrating how they relate to one another (Figure 39). The review proceeds through four domains: aesthetic philosophy, design aesthetics, humans and robots, and finally robot aesthetics.

The contribution of this thesis is therefore twofold. First, it establishes a taxonomy of robot aesthetics that links philosophical concepts of beauty and the sublime with design traditions and human–robot interaction. Second, it translates this taxonomy into a practical process for designers, after empirical studies on the perception of robot morphologies and styling dimensions. The design process was validated through its application with product designers, design engineers, and roboticists. Through this process, the thesis demonstrates that robot aesthetics are not peripheral embellishments but central to perception, trust, and acceptance. The work also points to broader implications of robots being cultural artefacts which should be designed not only to function effectively but also to enrich human life aesthetically and ethically. Just as Gothic cathedrals or Bauhaus objects embodied cultural values, robots too can embody cultural values, beauty, meaning, and human flourishing. In this way, the thesis contributes to a vision of design in which art, technology, and human values converge. Ensuring that robots are not alienating machines, but relational artefacts embedded within culture and everyday experience.

2.1. Aesthetic Philosophy

This section of the literature review examines how aesthetic meaning is understood, perceived, and experienced, to establish a conceptual structure that can later inform the analysis and design of robot aesthetics.

2.1.1. AP – Abstract Level (RED)

This starts with the abstract level of aesthetic philosophy, which is concerned with the philosophical and conceptual success of the design.

Aesthetics, theoretically and practically, has developed from two main perspectives. Philosophically there is a lot of discussion on what aesthetics is as a subject and how do we as humans, appreciate it. There is a separation between aestheticians and creatives. Those who write about it and intellectualise it and those who create and embody aesthetics through artefacts. These two sides have not generally agreed as they use different modes of expression. Originally aesthetics was seen as the inferior faculty of ‘sensuous’ as opposed to the higher faculty of ‘rational knowledge’ as demonstrated by Leibniz in 1684. A subsequent development was the emergence of a science of “felt behaviour,” which Alexander Gottlieb Baumgarten (1714–62) termed *Aesthetik* (Ogden, 1933). In his 1735 dissertation (Baumgarten, 1735), he established aesthetics as a distinct branch of philosophy. Specifically, this was the philosophy of poetry, and the author claims to have established a set of scientific rules of the philosophy of the poetics to guide the lower sense of aesthetics (Nannini, 2015). Baumgarten was a rationalist philosopher, and this view of aesthetics was a form of logic for ‘lower’ prerational thought explained in a lecture series and subsequently developed into two books, one published in 1750, and one in 1758 (Hlobil, 2009). This later changed to a more philosophical view where problems in aesthetics do not necessarily exist, and Sparshott (1963) states that it should not necessarily be a section of philosophy. ‘Aesthetics’ is attached to the philosophy of art or that of beauty. Others use the term to refer to any inquiry into an art, approached philosophically or scientifically, although making it a science would ignore its essence. Aesthetics exists as a coherent conceptual inquiry rather than being restricted to subject, or paradigmatic presumptions. One agreement of the many paths to enquire and explore aesthetics is that all of them, regardless of how different the approach, take art and beauty seriously and not as mere distractions (Sparshott, 1963).

To move beyond philosophical disagreement toward a workable structure, aesthetic philosophy can be organised around recurring focal areas that clarify what aesthetics attends to and how it is examined. More recently, Levinson (2005) defines aesthetic philosophy as:

“Aesthetics is the branch of philosophy devoted to the conceptual and theoretical inquiry into art and aesthetic experience.” (Levinson, 2005, p.3).

Levinson (2005) proposes that aesthetics has three foci. The first foci being ‘Art’ “*practice or activity or object*” which is the practice of making art, or the activities to make and appreciate art, or the objects that are the works of art. It focuses on perceivable forms and the examination of these forms for their own sake. This originates from Immanuel Kant where he saw an objects’ beauty, and natural phenomenon being linked in their ability to simulate us cognitively and cause “free play” due to their pure spatial and temporal forms without imparting concepts. Another view of ‘Art’ is that it is a means of expression (symbolic), communication (meaning) of dispositions, mental experiences (emotions and thoughts), and their indescribable (non-propositional) content. It is concerned with perceivable forms and the study of these forms as ends in themselves. Ultimately this aims to express and or represent the beauty in the symbolic, emotional, and or real world through pure pleasurable beauty or skilled executions. The second foci, “aesthetic property,” refers to a feature or aspect of aesthetic objects. These may include qualities such as grace, beauty, and dynamism. Aesthetic properties are generally understood as perceptual and observable, forming part of the experienced qualities that contribute to an object’s aesthetic value. However, their precise definition remains contested. Commonly discussed examples include Gestalt qualities (the perception of a coherent whole), judgements of taste, the capacity to evoke pleasure or displeasure, resistance to strict rule-based determination, and the involvement of imagination. Together, these characteristics suggest that aesthetic properties are often best understood in thematic or interpretative rather than strictly literal terms. The third focus, “aesthetic experience,” refers to an attitude, perception, or mode of experience that can be described as aesthetic. It concerns the individual’s state of mind, emotional responses, and the way attention is directed toward what is perceived. In this sense, aesthetic experience is distinguished from other types of mental states by its particular mode of engagement with an object’s form and character, and by the appreciative stance taken toward works of art. These three foci, art, aesthetic properties, and aesthetic experience, are closely interconnected, and ongoing debate concerns which of them is most fundamental to aesthetics, as well as how art and the aesthetic should be hierarchically or conceptually prioritised. Nonetheless, a central aim of aesthetic philosophy remains its focus as a philosophy of art, alongside continued examination of its related dimensions (Levinson, 2005).

With this, firstly we will discuss the aesthetic object, how it is perceived, judged (taste), experienced, what properties are aesthetic, considered knowledge, practiced,

theorised, and what beauty is. Levinsons' (2005) descriptions are more like avenues of exploration. If aesthetics is concerned with how meaning and value are embodied in experience, then the question necessarily shifts to perception, how aesthetic objects are recognised, structured, and made meaningful at all.

2.1.2. AP – Analytical Level (GREEN)

The analysis then moves to a more analytical level of aesthetic philosophy, where the practical outcomes of abstract conceptual decisions are evaluated as a coherent whole.

From artefacts to natural objects there are those that arouse aesthetic emotions and are then considered aesthetic objects (Woods, 1991). Generally, an aesthetic object is understood as something produced as art and often assumed to accrue value. However, for an object to function as an aesthetic object, it must first be perceived. This requires its presence within a context that allows it to be encountered and engaged with directly and meaningfully. Without such perception, an object may remain unrecognised, fail to be constituted as an artwork, or fall outside aesthetic consideration altogether. This positions the aesthetic object within a Gestalt framework and a dynamic subject–object relationship, in which it is constituted through both internal interpretation and external presence. Objects are perceived as distinct from their background, yet this distinction arises through an entanglement of mind, body, and environment, which together afford the boundaries that allow an object to be perceived as an object rather than as part of the surrounding field (Kobyshcha, 2018).

With the discussion of aesthetics, the idea of taste comes into play. Emerging from an 18th century debate between rationalism, applied to beauty, and egoism, applied to virtue. Where rationalists viewed taste to be rational and immediate when arriving at a judgement that something is beautiful. Although perception involves reason, perceiving beauty is something different. Egoists argued that judging something as virtuous arises from the pleasure it provides and the possibility that it serves one's own interests. Moralists, by contrast, claimed that this pleasure is disinterested, not motivated by self-interest. From this debate emerged the branch of aesthetics concerned with aesthetic judgment. Much of aesthetic theory revolves around these two positions: whether aesthetic experience is fundamentally self-interested (immediate pleasure) or disinterested (pleasure without personal gain). Aesthetic judgment is directed at an aesthetic object and involves one's attitude toward it, the experience it produces, and the value attributed to it (Shelley, 2009).

An ecological view towards visual perception from Gibson (2015), proposes that the observer and the environment complement one another. The environment, objects, and tools possess meanings that afford certain possibilities to the organisms within them, including features such as terrain, shelter, fire, and water, as well as artefacts and tools. Humans and

other animals utilise tools such as stones, which can function as extensions of the body, particularly the hand, effectively shifting from environmental objects to embodied instruments. This transition illustrates that the strict separation between subject and object is misleading when treated as absolute, since objects become tools through their affordances. In this sense, it aligns with Kobayshcha (2018) in discussions of aesthetic perception. Objects are perceived through their affordances, and tools specifically afford use and actions, as scissors afford cutting when they are in use. Other objects are human-made displays and artificial objects which present optical information through their surfaces and the affordances they reveal. Displays are surfaces that present information and knowledge about our cultures. This aligns with Green et al. (2008), who argue that objects can serve as sources of collaboration and shared information. Returning to affordances, Gibson's (2015) theory continues to propose that we perceive all the implied meanings and values offered by an object's surfaces, forms, and composition, making those meanings external rather than internal. Whether or not these affordances are beneficial or detrimental, they represent what the environment makes available to us (Gibson, 2015). Meaning can also be perceived through movement, where intentions or "motives" are attributed to moving shapes. In such cases, the characteristics of motion influence how observers interpret the intentions of the moving agent, as well as how surrounding objects are perceived in relation to that action. Objects are therefore evaluated within a contextual field in which both spatial arrangement and dynamic behaviour shape perceived intentionality (Fritz Heider and Marianne Simmel, 1944). Tim Ingold further argues that meaning can be simultaneously solid and fluid, as well as both static and dynamic. This reflects the shifting nature of material forces, which can be understood through analogies such as plasticity, viscosity, and elasticity (Ingold and Simonetti, 2022).

This relates to gestalt theory focuses on how individual elements are organised into parts, how these parts form coherent wholes or objects, and how these objects are perceived as distinct from one another. Key Gestalt processes include figural grouping, segmentation, shape formation, meaning attribution, and the overall organisation of perceptual elements. These processes are governed by what Max Wertheimer (1912, 1922, 1923) described as principles of grouping, including proximity, similarity, good continuation, closure, convexity, symmetry, prägnanz, and past experience. There are also rules of figure-ground organization; surroundedness, size, orientation, contrast, symmetry, convexity, and parallelism by Rubin (1921) (Pinna, 2010). Perceptual grouping and figure-ground organisation arise from a set of classical principles: proximity, similarity, common fate, good continuation, closure, symmetry, and parallelism. This is alongside more recently identified principles such as synchrony, common region, element connectedness, and uniform connectedness. These principles influence contour integration and the perception of

completeness (Wagemans, et al., 2012). Lehar (2003) proposes that perception can be described in terms of four global Gestalt properties. *Emergence* refers to the process by which initially random or unstructured patterns become organised into meaningful forms, allowing objects to be perceived after a brief period of observation. *Reification* describes the perception of implied shapes or meanings that appear to be present, even when they are not explicitly defined by the sensory input. *Multistability* occurs when a single stimulus gives rise to alternating interpretations, causing perception to shift between different meanings. Finally, *invariance* refers to the ability to recognise objects and their meanings despite changes in scale, position, or spatial orientation (Lehar, 2003).

From the perception of what something is, there is then the determination of its value. Aesthetic theory can play a central role in determining what constitutes excellence in art, what art is, what we should look for in it, and what qualities such as emotional depth, truth, or beauty make art good. However, when taken too literally or treated as strict definitions, theories of aesthetics fall short. Instead, they function better as guidelines or recommendations for cultivating qualities in art and aesthetic experience (Weitz, 2017). With aesthetic theory there is also aesthetic knowledge which concerns the properties through which objects are experienced and evaluated aesthetically, and is often distinguished from empirical knowledge, which is typically grounded in perceptual states alone. Within aesthetic theory, an ongoing debate concerns the origin of this knowledge, most notably between “perceptualism” and “affectivism”. Perceptualism holds that aesthetic knowledge arises primarily from perceptual states that can justify empirical beliefs, emphasising what is seen, heard, or otherwise sensed. In contrast, affectivism argues that feelings and appreciative responses are themselves a fundamental source of aesthetic knowledge. From this perspective, the act of feeling is a form of aesthetic apprehension, where emotional responses do not merely accompany perception but actively contribute to recognising aesthetic value. While perception may reveal an object’s factual features, it does not in itself provide experiential significance or value. Affectivism therefore maintains that feeling supplies the evaluative and motivational dimension that transforms perception into aesthetic understanding. The appropriateness of aesthetic emotions is understood to depend on the extent to which they accurately correspond to their object, the manner in which the object is valued, and the responsiveness of the perceiver to that value. This stance challenges traditional divides between affective-conative, conative-cognitive, and cognitive-affective domains, treating feeling not only as emotional response but also as a way of knowing and motivating action. Without the experience of aesthetic value, there would be little reason to preserve or return to beautiful objects and experiences. Aesthetic knowledge therefore emerges through feeling after perception, where affective appreciation completes and deepens perceptual awareness (Gorodeisky and Marcus, 2022).

2.1.3. AP – Practical Level (BLUE)

Finally, the analysis moves to the practical level, which concerns the directly manipulable components that constitute the design itself. Aesthetic experience refers to what it is like to encounter an object and is commonly framed through two main conceptions: first, as a direct, phenomenological experience; and second, as a form of non-inferential, experiential knowledge.

Western and Anglo-American aestheticians have generally sought to explain how aesthetic experience differs from other kinds of experience, aiming to describe it in a way that is independent of earlier conceptions of art. This includes developing specifically aesthetic notions, such as aesthetic objects, concepts, qualities, and justifying them as constituting distinct kinds of experience. It also involves maintaining boundaries between aesthetic, artistic, and non-artistic categories, while acknowledging their interrelations. The phenomenological account struggles to differentiate aesthetic experience from other intense experiences, such as those induced by drugs or sensual stimuli, and therefore cannot clearly define aesthetic experience as a unique phenomenon. The epistemic account, by contrast, allows art and aesthetic experience to be related yet distinct, and it accommodates the possibility of aesthetic experience in nature (Iseminger, 2005). The aesthetic experience arises from the sensuous and sensory engagement with an aesthetic object. Objects may be described as graceful, subtle, or vulgar when they present qualities that evoke such responses. These qualities stem from the object's objective properties, its lines, colours, proportions, and similar formal features. From these properties emerge the object's aesthetic qualities and its metaphysical significance, which can then be judged and evaluated. Aesthetic experience occurs when the associations and imagination of the perceiver are stimulated, producing feelings of beauty and pleasure. The experience counts as genuinely aesthetic only when imagination, memory, cognition, and emotion are involved; without these, the response is merely pleasurable rather than truly beautiful. Context plays a significant role in shaping aesthetic experience. Social, ethical, cultural, political, religious, and aesthetic norms (including taste) all influence how an object is perceived. In addition, external factors such as information about the object, as well as subjective conditions including mood, health, cognitive capacity, and physical proximity to the object, further shape the experience (Fenner, 2003). Aesthetic experiences are ultimately composed of properties and elements that afford particular impressions or appearances, influencing how an object presents itself to a perceiver (Matravers and Levinson, 2005). Aesthetic judgements thus operate as a mediating process between experience and value, enabling interpretations that are both socially shared and individually distinct. Because aesthetic experience involves both felt engagement and reflective understanding, tensions emerge between theoretical accounts of aesthetics and its enactment in creative and design practice. Aesthetic practice is shaped

by what is considered socially acceptable, reflecting prevailing norms. In this sense, what the practitioner regards as “right” becomes internalised and connected to their sense of aesthetic value, influencing judgments of what is appropriate (Kubala, 2021).

From 1750 to 1930, the prevailing view was that the purpose of art was beauty, which was closely aligned with the values of goodness and truth. Enlightenment philosophers saw beauty as embodying moral and spiritual ideals through sensuous form. With the advent of modernism, however, art began to challenge and even desecrate what had previously been considered sacred, to the point where beauty was often regarded as trivial or kitsch. In this context, beauty became something that modern art sometimes found repugnant (Scruton, 2016). Beauty is neither arbitrary nor purely subjective. Rather, it plays an essential role in reasoning and planning by enabling individuals to integrate experiences and environments into a coherent and meaningful way of living. Human beings require beauty in the world, both as a source of meaning and as a medium for communicating value. The neglect of beauty has produced significant cultural, social, environmental, and economic consequences, contributing to various forms of degradation, including environmental harm and the erosion of communities (Scruton, 2018). Although a specific definition of beauty is seen as a rather impossible task in philosophy. With that said, beauty and creativity are a part of the same act and are what artists aim to accomplish. Many cultures use beauty as a form of worship, and it embodies sacred things, from object to our bodies (Scruton, 2015). Beauty also tends to be associated with mystery, drawing people towards it, hides and occluded knowledge of it. It is sensory, experiential, and in part unknowable. Ultimately it is not measurable but can be seen in any object, artificial or natural, and human or animal (Sisti, Aryan and Sadeghi, 2021). Although the previously stated values of goodness, truth and justice are more traditional, originating from the Greek, to the medieval, were of great importance to 18th and 19th century thinkers. The question of whether beauty is subjective or objective raises important philosophical considerations. If beauty were purely subjective, it would imply that nothing possesses inherent meaning. Conversely, if it were purely objective, it would exist independently of any perceiver, detectable but potentially disconnected from human experience. Alternatively, beauty can be understood as something we desire and wish to share, a powerful and intense form of communication that connects people with objects through art and its appreciation. Historically, various perspectives have framed beauty differently. Idealists regarded it as a principle of unity, classical thinkers emphasized perfection and coherence, hedonists saw it as pleasure, and Kant approached it in terms of utility. More recent interpretations focus on beauty as linked to love and longing (Sartwell, 2012).

Extending this discussion to robots as artistic objects, contemporary examples are increasingly prevalent. For instance, Stelarc incorporates robotic systems into body art, as seen in his *Third Hand Project*, which involved the embodied integration of a robotic prosthetic extension (Pagliarini and Hautop Lund, 2009). Others have used robots as part of creative applications and part of the creative process, such as with the Embodied Controlled for Animating Robots (EMCAR) where the robot would follow the path of the stylus of the human user (Gomez Cubero, et al., 2021), (See Figure 4).



Figure 4 - Robot Art Examples, Stelarc, (Left, (Pagliarini and Hautop Lund, 2009)), EMCAR (Right, (Gomez Cubero, et al., 2021))

2.1.4. Discussion on Aesthetic Philosophy

Aesthetics generally refers to the concepts, methods, and artefacts through which beauty is explored and realised. Ultimately, no single philosophical framework can fully encompass beauty, as it is both culturally situated and continually evolving. Experiencing it therefore requires openness, as well as active and immersive engagement. It is often understood in two interrelated forms: the sensuous and the intellectual. Although these are sometimes described separately, privileging one over the other can create tension between practitioners and theorists. Across various debates, a distinction emerges between aestheticians and creative practitioners, who tend to approach aesthetics through different epistemological lenses. The former typically analyse and develop abstract, conceptual knowledge of aesthetics, while the latter engage with and produce sensuous, experiential encounters through creative practice.

Although these positions differ, they converge on a shared underlying premise that aesthetic meaning operates beyond simple distinctions between the objective and subjective, or the real and the experienced. Instead, meaning is fully realised when ideas are embodied in sensuous form in ways that are culturally and socially resonant. In this sense, artefacts can be understood as communicative forms that seek to uplift, improve, and place individuals within a reality. Through pleasure, compassion, moral and symbolic meaning, and attention to composition and flow, aesthetic experience can generate a sense of unity oriented toward the purpose of an artistic work, whether natural or artificial. It can also support experiences that are often described as spiritual, functioning as a complex mode of communication

closely tied to both individual and cultural identity. This process of meaning-making from Gibson (2015) and Kobyshcha (2018) relates to Gestalt theory, as it involves interpreting the visual and holistic significance of artefacts. Where these concepts of perceiving relate directly to knowing, because aesthetic perception is not a passive reception of sensory stimuli but an active process through which meaning, value, and understanding are formed. These concepts of perceiving from Max Wertheimer (1912, 1922, 1923) and Rubin (1921) in Pinna, (2010), and Lehar (2003) relate directly to knowing, in that aesthetic perception is not merely a passive reception of sensory information but an active process through which meaning, value, and understanding are constructed. What is perceived is immediately shaped by prior knowledge and theories, expectations, embodied experience, and contextual cues. This means that perception itself functions as a form of pre-reflective knowing, rather than a neutral input awaiting later interpretation. From the work of Gorodeisky and Marcus (2022).and combining Lehar's (2003) notion of global properties, abstract characteristics that emerge from underlying principles, with the specific principles identified by Wagemans et al. (2012), and Pinna's (2010) components of figural grouping, segmentation, shape, meaning, and their organisation, provides a more structured framework for applying Gestalt theory. These components function as design elements that can be manipulated to generate principles, which in turn shape the perception of higher-level properties. This integrated structure offers a more coherent approach to Gestalt theory than relying on scattered and uncoordinated terminology. Although this framework originates in visual perception, its most significant contribution lies in explaining how meanings are derived from design. Once aesthetic meaning has emerged through perception, it becomes subject to evaluation, giving rise to questions of taste, judgment, and aesthetic experience.

Gestalt theory in a way related to a sense of unity is expressed through the integration of ideals, affective engagement, classical principles, utility, and sensory enjoyment, bringing together multiple dimensions of human experience in relation to art. From this perspective, beauty can be understood as a transcendent experience, embodied through highly complex forms of communication oriented by an intention to elevate human experience toward something that is often described as mysterious and ineffable. It is nonetheless shaped by culture, people, place, and time, reflecting both what they are and what they may become. From the work of Iseminger (2005), Fenner (2003), Matravers and Levinson (2005), and Kubala (2021). One could assert that currently, the overall aim is to create beautiful designs that are appropriate to a specific cultural and contextual setting, thereby adding greater meaning to the lives of users and perceivers. Other contemporary accounts such as Scruton (2015, 2016, 2018), Sisti, Aryan and Sadeghi (2021), and Sartwell (2012) might even be described as 'limerencist,' or loving, highlighting the intense emotional and relational aspects of aesthetic experiences.

Both approaches engage with art, which can embody forms of spiritual beauty, communicate ideas and symbols, and evoke emotional or ineffable experiences. The properties of art are perceptible, thematic, and figurative, as they relate to judgements of taste and contribute to the experience of beauty. These properties are often connected to the intended purpose of the work, while the resulting states of mind they produce are referred to as aesthetic experiences.

The elusiveness of aesthetics remains evident. Rather than seeking a strict definition, understanding aesthetics may be better achieved through intellectual and practical exploration, thought, creation, and immersive engagement. Philosophy often frames concepts as “problems,” and this pattern extends to design, where ideas can be approached either as problems or as creative adventures. Treating them strictly as problems can constrain creative exploration, particularly when researchers attempt to study aesthetics through structured, academic inquiry. This tension highlights the need to distinguish when a concept is a problem and when it is an exploration. Moreover, the limitations of communicating research and exploration through language, experiments, or debate constrain the dimensions of the field, which may explain why certain subjects “resist” overly structured approaches, suggesting the value of flowing with ideas and collaborating with them. Sparshott’s (1963) work, for instance, focuses on the structure and problems of aesthetics rather than its historical development. Many definitions of aesthetics assume it must be a science, be about art, or concern beauty. A more versatile philosophical definition could avoid these biases. This thesis proposes the definition of:

“Aesthetics is the thought and practice devoted to understanding and expanding rational and sensual experiences in the pursuit of beauty.”

One could conclude that aesthetic beauty is based on the moral alignment of an object to an individual and how much knowledge about reality, themselves, and their culture is perceived to be revealed to them by the object. If enough depth and complexity is perceived, as well as revelatory knowledge and exciting the imagination, then this can be considered to be transcendental beauty.

The relationship between robotics and aesthetics is direct, in that aesthetic philosophy informs the development of robot aesthetics. These philosophical positions, along with how aesthetics are conceptualised and produced, have a direct impact on the perceived value and effectiveness of robot design. Although robotics and aesthetic philosophy often originate from different starting points, they are frequently framed in contrasting terms. In

robotics, value is often treated as emerging from the robot as a central and functional artefact, whereas in aesthetic philosophy, value is understood as arising from the interaction between ideas, execution, and perceivers. Despite this difference, the two domains can align. By prioritising human experience in relation to robotic artefacts, it becomes possible to enhance both the aesthetic and functional dimensions of robot design. In doing so, robotics and aesthetics can mutually reinforce one another, contributing not only to improved design outcomes but also to addressing broader philosophical, human, and technical challenges in robotics.

2.1.5. Contribution and Conclusion - Aesthetic Philosophy Taxonomy

From the literature a taxonomical diagram of Aesthetic Philosophy can be created where the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE) for one whole in Figure 8.

As illustrated in **Error! Reference source not found.** the abstract level starts with ‘The Aesthetic’, in which aesthetics is understood as emerging between sensuous and rational thought, as developed in Baumgarten’s (1735) concept of *Aesthetik*. Sparshott’s (1963) critique of scientific reduction further situates this foundation, establishing the field within its 18th-century philosophical origins. Broadly, this trajectory reflects a shift from rationalist frameworks toward more subjectivist accounts of aesthetic experience. This foundation is organised into three interrelated foci: ‘Art’, ‘Property’, and ‘Experience’. ‘Art’ refers to practice, activity, and object, and is often associated with Immanuel Kant’s notion of “free play.” ‘Property’ refers to aesthetic qualities such as beauty, dynamism, and taste-related themes. ‘Experience’ refers to aesthetic attitude, perception, and states of mind. Following this, the ‘Rationalism to Subjectivism’ trajectory provides a brief overview of the historical development of aesthetics, from its origins in rationalist frameworks to more contemporary subjectivist perspectives. Although not represented as explicitly as other components in the diagram, this abstract paradigmatic shift is important, as it informs and influences more practical design and theoretical decisions.

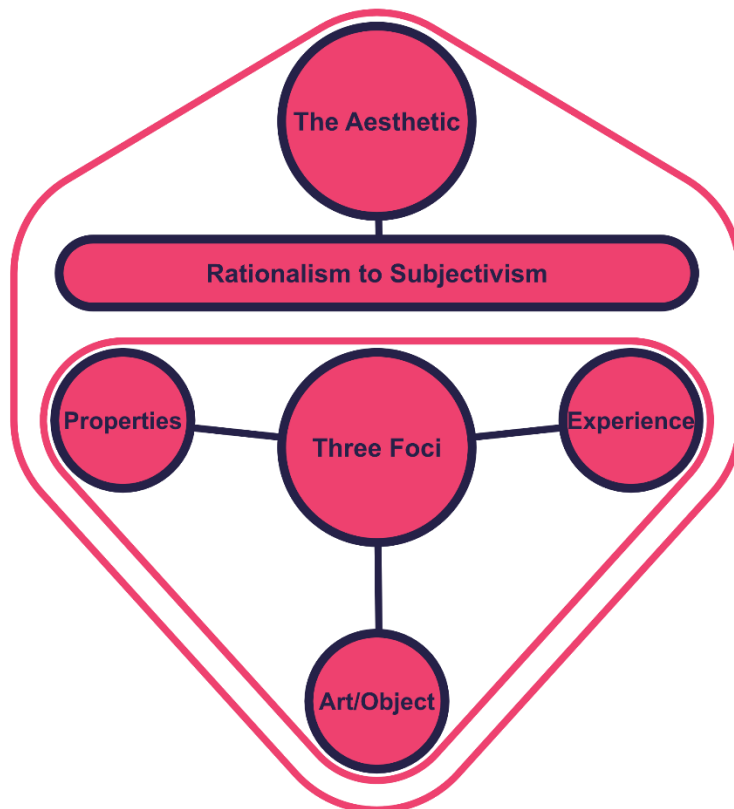


Figure 5 - Aesthetic Philosophy - Abstract Level

Structuring the analytical level in **Error! Reference source not found.**, it starts with ‘Aesthetic Objects and Perception’, which refers to the way in which objects emerge as aesthetic entities through processes of perception. In this view, contextual affordances and relational conditions ground the theory in how artefacts and natural forms become constituted as distinct “aesthetic objects” through perceptual engagement. From an ecological perspective, perceptual systems shaped by evolution influence how we distinguish between threats and safe environments, such as identifying hazards like ledges or recognising artefacts that preserve and communicate culture. These perceptual processes contribute to how aesthetic qualities of objects are formed and understood. ‘Ecological and Affordance Approach’ draws on James J. Gibson’s concept of affordances, understood as the action possibilities offered by object surfaces within an environment. In this view, tools can function as extensions of the body, and perception involves the active pickup of information from an ambient field of environmental flux. This framework links perception to practice by showing how an object’s form and surface simultaneously signal both functional use and aesthetic meaning. This perspective leads into the perceptual foundations of aesthetic philosophy, particularly the Gestalt principles, which emphasise how perception organises elements into coherent wholes. From this standpoint, aesthetic experience is shaped by how parts are structured into unified forms, and how these wholes are perceived as meaningful configurations. ‘Gestalt Principles’ in aesthetics refer to perceptual mechanisms through

which visual elements are organised into coherent forms. These include grouping laws such as proximity, similarity, closure, and good continuation. Gestalt perception is further characterised by processes such as emergence, reification, and multistability, through which meaning and structure arise from perceptual organisation. Additional figure–ground principles, including surroundedness, symmetry, and convexity, help determine how objects are separated from their background. Global properties such as emergence, reification, multistability, and invariance further describe how stable perceptual objects are formed and maintained. Together, these principles provide the perceptual mechanisms through which aesthetic properties and objecthood emerge from basic design elements. They also highlight the relationship between experience and practice on the one hand, and theory and knowledge on the other, suggesting that aesthetic understanding is best developed through their integration rather than privileging one over the other, as both perception and conceptual knowledge contribute to the development of understanding and skill.

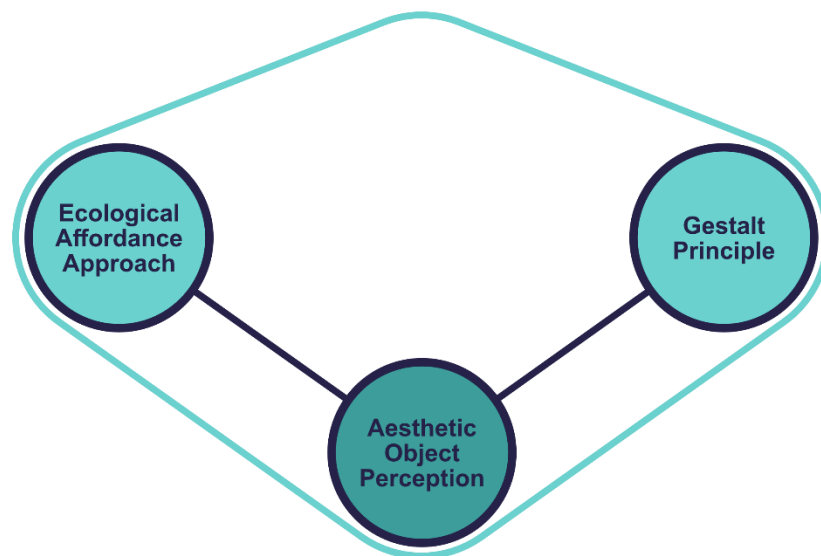


Figure 6 - Aesthetic Philosophy - Analytical Level

The practical level illustrated in Figure 7, emerges from the analytical level where ‘Aesthetic Theory and Practice’ describes how internalised values guide creative production, including socially conditioned norms of aesthetic acceptability, as discussed by Kubala. Within this framework, the debate between affectivism and perceptualism connects theoretical positions directly to creative practice, showing how practitioners both interpret and apply aesthetic principles when generating form, structure, and design decisions. This process also highlights the role of individual and cultural taste in shaping responses to aesthetic objects. ‘Taste and Aesthetic Judgement’ addresses how aesthetic evaluation is formed through a balance of perspectives, including rational immediacy versus disinterested pleasure, and egoistic versus moral accounts of value. In this context, Shelley describes

judgement as an attitude or stance that mediates between perceiver and object, shaping how evaluative positions are formed and how aesthetic value is assigned. Taste therefore influences what is taken to be interesting, pleasurable, or repulsive, with responses that may be authentic or culturally shaped, depending on individual and social conditions. Taken together, these processes contribute to understandings of beauty as a heightened or transcendent aesthetic experience, often characterised by strong pleasure and desirability that motivates individuals to seek out, value, and sometimes acquire aesthetically pleasing objects. At the culmination of this diagram there is 'Beauty as a Transcendental Experience'. Classical and modern debates have wrestled with whether beauty relates to goodness, truth, and unity, or whether it risks becoming kitsch. Scruton emphasises beauty's moral and placemaking dimensions, while contemporary theorists explore its ties to mystery, limerence, and cultural embeddedness. Beauty thus serves as the telos of aesthetics, uniting theory, judgment, experience, and practice in pursuit of a higher purpose.

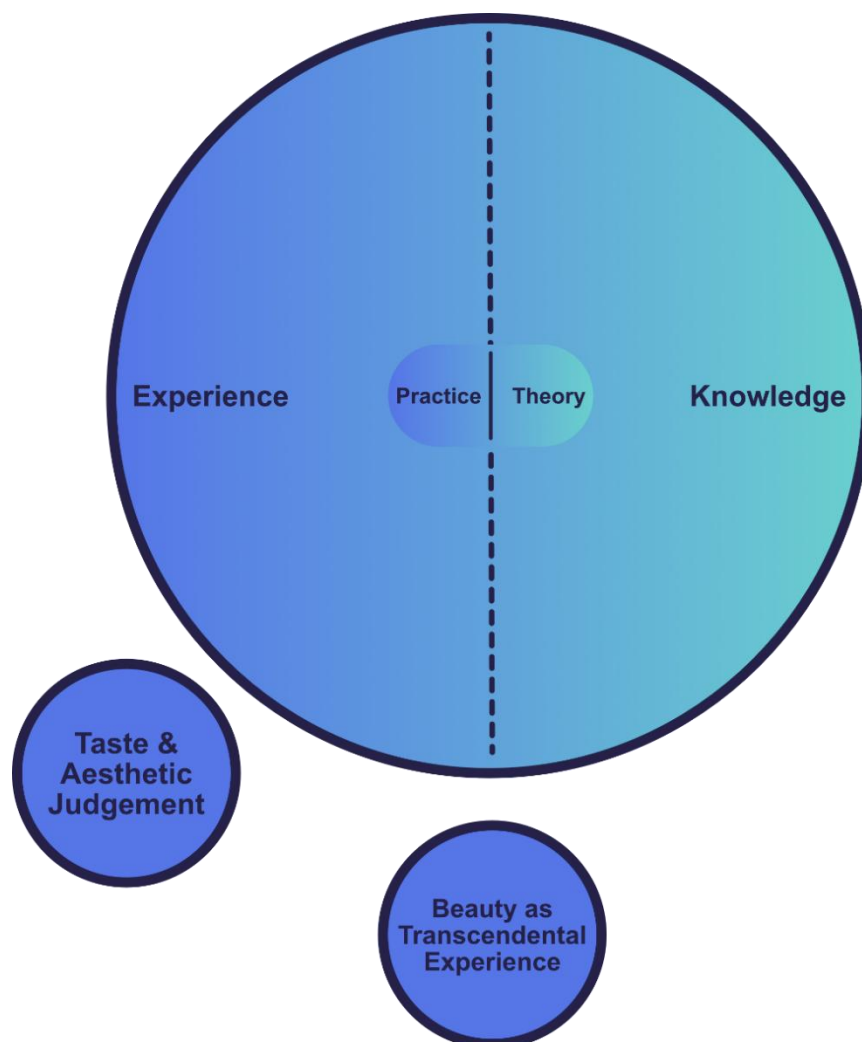


Figure 7 - Aesthetic Philosophy - Practical Level

The preceding discussion establishes three interrelated layers of aesthetic philosophy, conceptual foundations, perceptual mechanisms, and aesthetic experiences,

which are synthesised in the following taxonomical diagram of aesthetic philosophy. This was created to show the structure and main elements of it in Figure 8. The diagram synthesises the preceding discussion by structuring aesthetic philosophy into three interrelated layers: the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE).

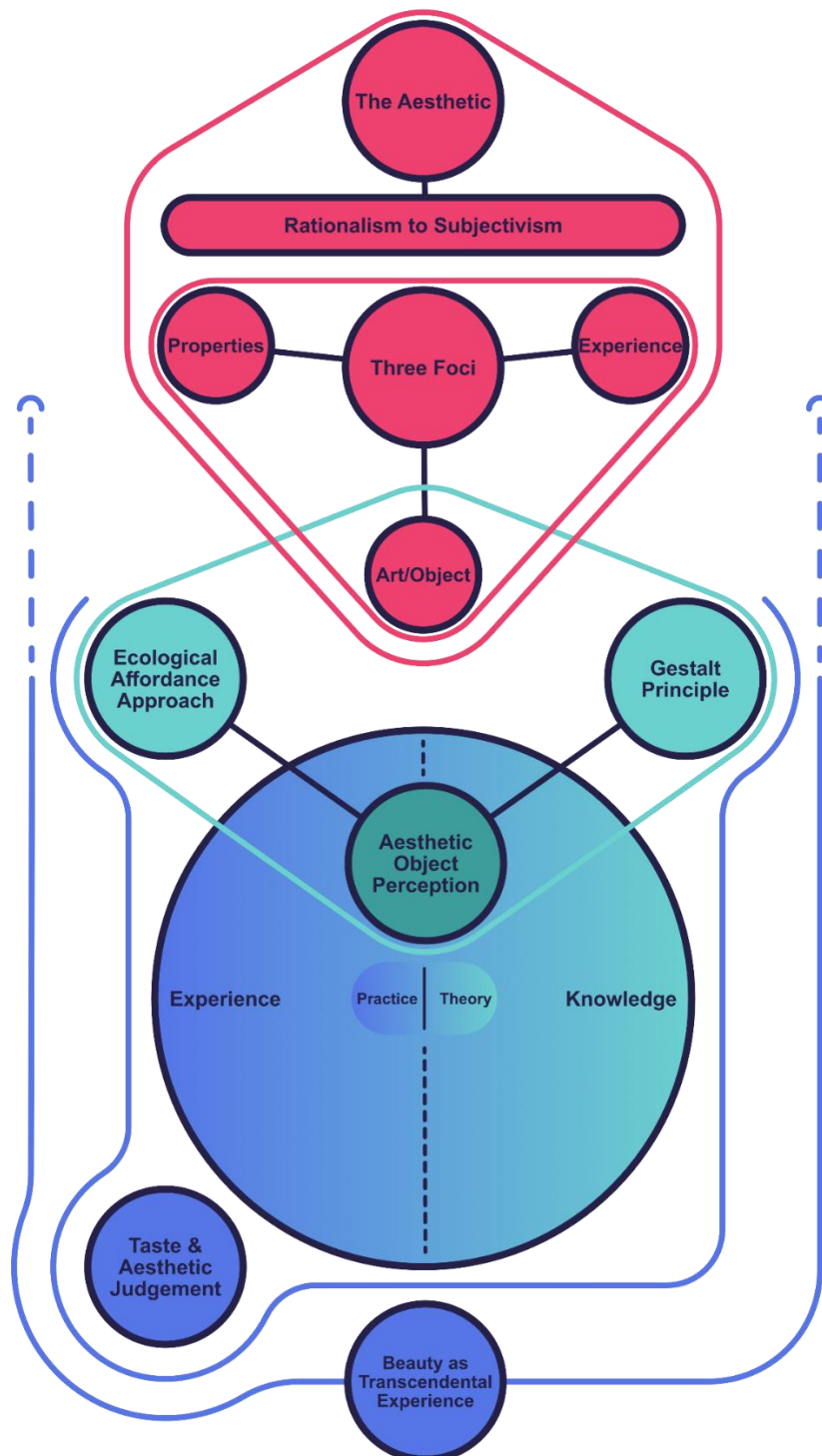


Figure 8 - Aesthetic Philosophy Taxonomy Diagram

2.2. Design first then Design Aesthetics

Having established the taxonomy of Aesthetic Philosophy we need to define Design before we can examine the next area of knowledge related to this thesis which is Design Aesthetics.

Design is the planning for different purposes such as analysis, problem definition, solution creation, and giving meaning to an object or system (Auernhammer, and Ford, 2022). It is concerned with material culture and the skills required to create it, which together constitute its primary repository of knowledge. In contrast, the humanities derive their knowledge from literature, discursive practices, and associated spiritual or interpretative values. Science, by comparison, is grounded in analytical methods and a commitment to understanding phenomena as entities that would continue to exist independently of human presence (Archer, 1979). There are also 'designerly' ways of knowing: where designers tackle real-world and ill-defined problems through solution focused problem-solving methods where the thinking is constructive. Cognitive codes help translate abstract requirements into concrete artefacts, as well as enabling the "reading" and "writing" of non-verbal object languages (Cross, 1982). In this sense, design can be understood as a discipline that studies its own knowledge culture, developing design-specific approaches, theories, and forms of understanding that are grounded in the capabilities and practices of designers. This distinguishes design from other disciplines in both method and epistemology. Therefore, design is concerned with the creation and maintenance of the artificial world, encompassing the act of designing itself, the artefacts produced, their manufacture and making, the teaching of design knowledge, and the reflection on all of these activities (Cross, 2001).

Research into design has evolved in five waves, where the first, (around 1960-1970) originated from the United Kingdom design education developed validity, accreditations, degrees as well as operating internationally. The second wave, (around 1980-1990) is where design education gained more recognition through greater funding and avenues of academic publication with more interest in Europe, USA, the Middle East, and Asia. The third wave, (around 1990-2000) is where the focus moved from education to application of theory to innovation and productivity to tackle industrial and economic issues. The fourth wave (approximately 2000–2010) marked a period in which design was increasingly adopted by researchers outside the traditional field, alongside the integration of multiple theoretical perspectives. During this time, several distinct strands of design research emerged, including: (1) a focus on understanding people and their needs, (2) a shift from tangible design outcomes toward intangible experiences and systems, and (3) an increased emphasis on creativity and competitive innovation. The fifth wave, (2010-2020/present) is where design is seen as being able to change the world through an ethical and trustworthy

collaborative manner (Cooper, 2019). Design research has addressed many ill-defined problems through design thinking, which is often associated with its capacity to engage with “wicked problems,” a term introduced by Horst Rittel and Melvin Webber in 1973. However, this does not imply that design thinking offers a universal solution to all societal problems; rather, it requires an empathetic and committed approach to problem-solving. It can also be argued that design thinking has yet to fully resolve three key dilemmas associated with wicked problems: societal goodness, the dispelling of wickedness, and societal equity. Yet design thinking has been able to handle 1, 2, 6, 7, 8, 9 of the properties of wicked problems and not 3, 4, 5, 10 (Vermaas, and Pesch, 2020). Rittel and Webber created the term ‘wicked’ problems for social policy problems as they are not the ‘tame’ problems that science deals with. The ten properties can be summarised as: (1) *no definitive formulation*; (2) *no stopping rule*; (3) *Solutions to wicked problems are not true-or-false, but good-or-bad*; (4) *no immediate and no ultimate test of a solution*; (5) *every solution to a wicked problem has one chance with no opportunity for trial-and-error*; (6) *no enumerable set of potential solutions*; (7) *every wicked problem is essentially unique*; (8) *every wicked problem can be considered to be a symptom of another problem*; (9) *the explanation chosen for a discrepancy determines the nature of its resolution*; (10) *the planner has no right to be wrong* (Rittel, and Webber, 1973).

2.2.1. Discussion on Design

Although defining design has proven to be an elusive task, as has tracing its foundational origins, this is partly because it transcends clear professional and disciplinary boundaries. This difficulty is reflected in the wide range of methods encompassed by its continually expanding body of knowledge. Design has evolved from a trade to a profession, to a research field, and more recently towards a liberal art of technological culture. In addressing “wicked problems,” it therefore becomes necessary to move beyond rigid disciplinary boundaries and adopt a more interdisciplinary approach to design (Buchanan, 1992). Despite the irreducible and inherently creative nature of design, certain core positions can still be identified. Returning to Archer (1979), his view that design is concerned with material culture remains persuasive; however, his positioning of philosophy as a subset between the humanities and science is more contested. While philosophy and theology can be seen as underpinning cultural systems, all three domains, humanities, science, and design, can be understood as embedded within culture and as possessing distinct repositories of knowledge and ways of knowing, as outlined by Nigel Cross (1982, 2001). In this context, the view that design is fundamentally concerned with material culture is coherent, given that designers primarily produce artefacts. Similarly, Buchanan (1992) frames design as an art of material and technological culture, a position that may be considered central to contemporary design theory. Cooper (2001) further suggests that

design historically operated with relatively clear goals, even when these involved “wicked problems.”

More recent expansions of design discourse toward broad aims such as social good, climate change, and “changing the world” risk becoming overly diffuse as guiding motivations. Instead, the current phase of design may be more productively understood as focusing on human-centred practice within increasingly complex technological environments. This remains a form of engagement with “wicked” conditions, while still maintaining a commitment to social and cultural value. As such, Cooper’s (2001) view of design research’s present wave seems to echo the original purpose of developing wicked problems from Rittel, and Webber, (1973) as it was written for social policy planning. Social good, climate change, and changing the world are excessively broad and reside on the taste of the designer too much. If social good is a goal, then cultural differences need to be identified, and their properties will need to be in some way determined to be less good, ignored, or removed. An action so broad that anyone could point to examples of decision makers making choices that have affected their culture or another. This is due to the lack of choice in actions by those affected and the lack of variety of solutions in such situations. Although Vermaas and Pesch (2020) are correct in arguing that design thinking is not a panacea for social problems, it remains difficult to determine more effective approaches to “wicked problems,” given the breadth of methods encompassed by design thinking. Moreover, the nature of wicked problems themselves appears to have evolved over time, further complicating attempts to define a single optimal approach. One main point is that design is not a science as Rittel and Webber, (1973) state the wicked problems are not tame, and tame problems are for science. Moreover, it is not an art in the pure sense as it does not develop purely unique artefacts determined solely by the knowledge and taste of one individual for the purpose of expression in a culture.

2.2.2. Conclusion on Design

The challenge of the fifth wave is not its ambition but its lack of disciplinary boundaries. Without grounding in material and technological culture, design risks becoming general problem-solving positions and turning into an overly political field. Design is well-suited to wicked problems when they involve material, organisational, or experiential systems, but less suited when the problem is purely political, moral, or distributive, because these require determining values and as such aesthetic judgements beyond the scope of design methods and the designer.

In this thesis, Design is viewed as a transdisciplinary field concerned with the creation, interpretation, and maintenance of material and immaterial technological culture. Its knowledge resides in ‘designerly’ ways of knowing, thinking, object languages, and the ability

to navigate ill-defined, real-world problems. It is neither science nor art and is distinct from science and the humanities because it produces intentional artefacts rather than pure explanations or pure expressions. It also exists through cultural, social, and technological contexts that require collaboration and judgement rather than universal truths. Its aim today is to navigate increasing technological complexity while maintaining human-centric. This requires transdisciplinary collaboration, awareness of cultural variation, and an understanding of the limits of design methods.

2.3. Design Aesthetics

Now that the main components of design have been sufficiently outlined, the discussion can move on to Design Aesthetics, which is more concerned with applied aesthetics, specifically how aesthetic ideas are embodied in order to produce particular experiences and outcomes. Although not explicitly framed in relation to robotics, knowledge of design aesthetics is directly applicable to robotic artefacts, since robots are designed objects and therefore fall within its scope.

2.3.1. DA – Abstract Level (RED)

We start with the abstract level of design aesthetics concerned with the philosophical and conceptual success of the design aesthetics.

Folkmann (2010) states that aesthetics is one of the most important elements of design in relation to how it communicates. It is more important in 'non-professional' or personal contexts as these design artefacts are mainly attractive or appreciated entirely for their aesthetic qualities. The skill of working with aesthetics is often regarded as a central competence in design, though it is sometimes mistakenly assumed to be concerned with only surface treatment and styling, rather than function. While design aesthetics is difficult to define due to its heterogeneity, it remains distinct from art. Although design artefacts can emerge from artistic or autonomous expression, like art, the need for innovation, cultural relevance, and consumer engagement makes it difficult to categorise them strictly as art. The aesthetics of design, therefore, concern the sensuous qualities and experiences of objects, shaping how reality is perceived and arranged aesthetically. One aspect of design aesthetics views design as a structure of sensuous appearance, while a second aspect considers design as communication, using aesthetic coding to convey ideas or meanings physically, executed in various ways. Within this communicative aspect, self-reflection plays a key role, guiding how designers encode ideas aesthetically to generate meaning. Design can range from non-surplus to surplus appearance, and the ideas conveyed may vary in directness, influencing how meaning is perceived by the audience. As such Design can reflect underlying ideas through its form and execution (Folkmann, 2010). Alternatively, design aesthetics can be understood in terms of perceived affordances and visual feedback (Norman, 2004). These

perspectives highlight the importance of context and symbolism, or product semantics, in shaping aesthetic experience (Krippendorff, 1989). Beyond symbolic meaning, design can also convey “higher” spiritual significance, although contemporary objects often lack this dimension (Walker, 2001). This aesthetic communication of an object’s cultural and social significance is done through meaning and the introduction of new ideas. However, these innovations may eventually fall out of fashion and become mere styling. This aesthetic innovation refers to the presentation of an idea as novel, and experimentation is essential for launching new products where the perception of innovation is crucial. This concept aligns with the theory of product language, which distinguishes between practical and sensual (communicative) functions. Within sensual functions, formal aesthetic functions, derived from psychology, constitute the syntax of a design idea. These are guided by two principles: the transition from order to complexity, and from rich to poor stimuli. Formal functions can be observed independently of meaning, through shapes, colours, and other perceptible features. Semantic functions, also part of sensual functions, concern the meanings conveyed by a design. Within semantic functions, indicating functions relate to the physical aspects of a product, showing users what it is and how it works, while symbolic functions create associations, such as male or female cues, which evoke emotional reactions like attraction or desire toward the product (Steffen, 2010). Continuing with this communicative aspect of design, designed objects can be understood as serving six semiotic functions; *Referential functions* communicate a single, specific meaning (monosemic). *Emotive functions* enhance perceived value and form by engaging the interpreter’s emotional response. *Conative functions* are directed toward prompting action, such as encouraging purchase or use. *Aesthetic functions* involve the creator shaping interpretation toward a particular sense of truth, meaning, or experience. *Phatic functions* establish, maintain, or conclude interaction, similar to social cues such as a nod. Finally, *metalinguistic functions* provide explanation, clarification, or elaboration of communication itself. Together, these functions operate to both denote and connote meaning (Ashwin, 1984).

An example of a designer who use aesthetic to communicate complex idea is Christopher Dresser, who recognised ornament as a powerful means of expressing feelings and ideas. He also believed that other cultures and scientific discoveries offered richer sources of inspiration for ornamentation and the decorative arts. During Dresser’s time, historicism and classicism were waning in the Victorian period, and he sought to create a new approach to ornamentation that reflected the spirit of his era. Dresser aimed to identify the fundamental patterns underlying design and classify them in their ideal forms. He developed the concept of aesthetic experience as dependent on the perceiver’s recognition of a sensuous unity between mind and form, where the beauty of curves could be enhanced by their subtlety and complexity (Dresser and Halén, 1993).

Coates (2003) argues that certain elements are essential for a design to be aesthetically appealing. A design should embody two primary qualities: *epochal innovation*, where it introduces a novel and superior way of achieving a function, and *seminal form*, where it presents new aesthetic possibilities, either visually or typologically. Together, these contribute to the broader concept of *concinnous innovation*. Within this framework, aesthetics operates through two key mechanisms. The first is *information*, as the more information a design communicates, the greater its capacity to evoke reactions, emotions, and actions, thereby generating arousal and emotional engagement. The second is *concinnity*, which refers to the valence of an experience and determines whether it is perceived as positive or negative. For a design to be considered attractive, its concinnity must support rapid and coherent perception of information. Coates further identifies four aesthetic elements that contribute to a pleasing design. *Contrast* refers to differences between design elements such as colour, texture, line, or surface. *Novelty* describes the perceived difference between a design and its existing stereotype, mental model, or ideal. *Objective concinnity* refers to the internal coherence among a design's elements and its relation to other visual components, supporting perceptions of rational structure. *Subjective concinnity* describes the alignment between a design and the viewer's expectations, ideals, and stereotypes, what the object is, what is expected of it, and what is desired from it (Coates, 2003). Other accounts suggest that principles of pleasure in design aesthetics include *greatest effect with least effort*, where meaning or metaphor is communicated efficiently, producing maximum impact with minimal cognitive or perceptual load. *Unity in variety* refers to the ability to perceive order within complexity, in which elements are organised into a coherent perceptual structure despite variation. The principle of the '*most advanced and acceptable*' aligns with the preference-for-prototypes theory, which proposes that people tend to favour designs resembling familiar or prototypical examples within established categories. Finally, *optimal matching* describes the condition in which sensory impressions combine to produce an aesthetic experience aligned with what is desired or sought, potentially reinforcing positive engagement and, in evolutionary terms, supporting adaptive behaviour (Hekkert, 2006). This principle of unity has been proven in experimental studies to positively affect aesthetic responses and is seen more strongly when it is the only method of judgement. This property of unity is 'superadditive', as in when all elements match it will create the greatest effect. Possible due to unity needing to be all present or it is seen as absent (Veryzer Jr, and Hutchinson, 1998).

2.3.2. DA – Analytical Level (GREEN)

We now move to the analytical level of design aesthetics, where the outcomes of practical design decisions are evaluated as a coherent whole.

Aesthetic experiences may arise from complex cognitive and behavioural processes, flowing from subconscious emotions, perceived feelings, conscious judgment, and internalized preferences (Haug, 2016a). Aesthetic emotions (Figure 9) are discrete responses to aesthetic encounters, motivating engagement with aesthetically pleasing objects or events. These emotions inherently involve aesthetic evaluation and appreciation and are distinct from those elicited by art (Menninghaus, et al., 2019).

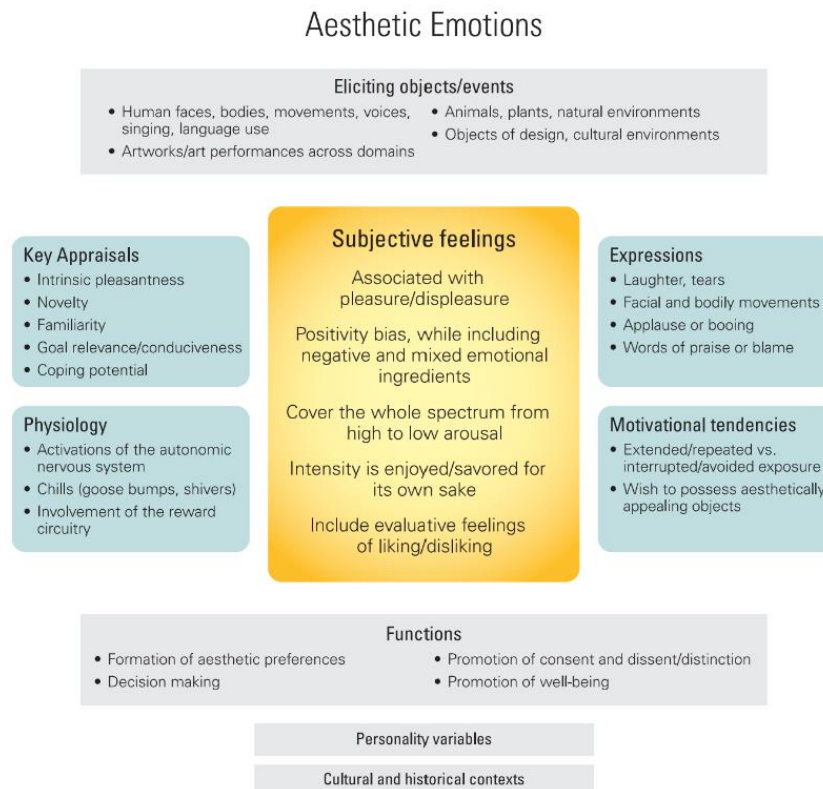


Figure 9 - Model of Aesthetic Emotions (Menninghaus, et al., 2019)

Some argue that this complex whole cannot be reduced to any single element of an object and is not necessarily directed toward the pursuit of beauty. Instead, it emerges through interactions with objects, as emotions trigger processes such as semiotic chains, anticipation, and the detection of affordances, among others. This approach has been termed “Interaction Aesthetics” (Xenakis and Arnellos, 2013). Additionally, some researchers have proposed principles specifically for design aesthetics. Such as, Ross and Wensveen (2010) applied the concept of aesthetic experience in interaction design to develop the aesthetic interactions of intelligent product systems. Grounded in a pragmatist aesthetic philosophy, they argued that aesthetics has practical value, is intrinsically meaningful, and cannot be fully understood without considering its social and cultural context, as both meaning and value shift with changing circumstances. They also emphasised that form and aesthetic experience are inseparable, with form seen not as static but as a “dynamic interaction of elements.” As a practical example, they designed an intelligent lamp inspired by dancers’ movements. The

lamp allowed users to alter the angle of its light based on how they touched it, creating an interactive and expressive aesthetic experience (Ross and Wensveen, 2010). Users become familiar with a design through interaction, gradually forming emotional attachment and investment over time. This demonstrates that emotional interaction in design extends beyond mere technical functionality. Additionally, the pervasiveness of an artefact enhances its significance and inevitability in daily life. Emotional interaction can be understood at three levels, reactive, behavioural, and reflective: Reactive interaction (Figure 10, (Top)), is sensory-driven, where the design stimulates emotional responses and the user's actions can, in turn, elicit responses from the design. This interaction is intuitive and instinctive. Behavioural interaction (Figure 10, (Bottom Left)), occurs during the process of using a product, shaped by its functionality, usability, and overall experience of use. It is an emotional engagement grounded in practical interaction. In an age of digitalisation, where manual skills are less common, designers aim for versatile usability by aligning the design with the user's mental model and anticipated use scenarios. This requires understanding the target user's characteristics, age, gender, environment, culture, background, and aesthetic preferences, to optimise both functionality and pleasure in use. Reflective interaction (Figure 10, (Bottom Right)), engages emotional knowledge and understanding, where meaning is derived from form. This level often relates to personal memories or prolonged engagement with a product, creating a deep, and reflective emotional experience (Yang and Chen, 2008).

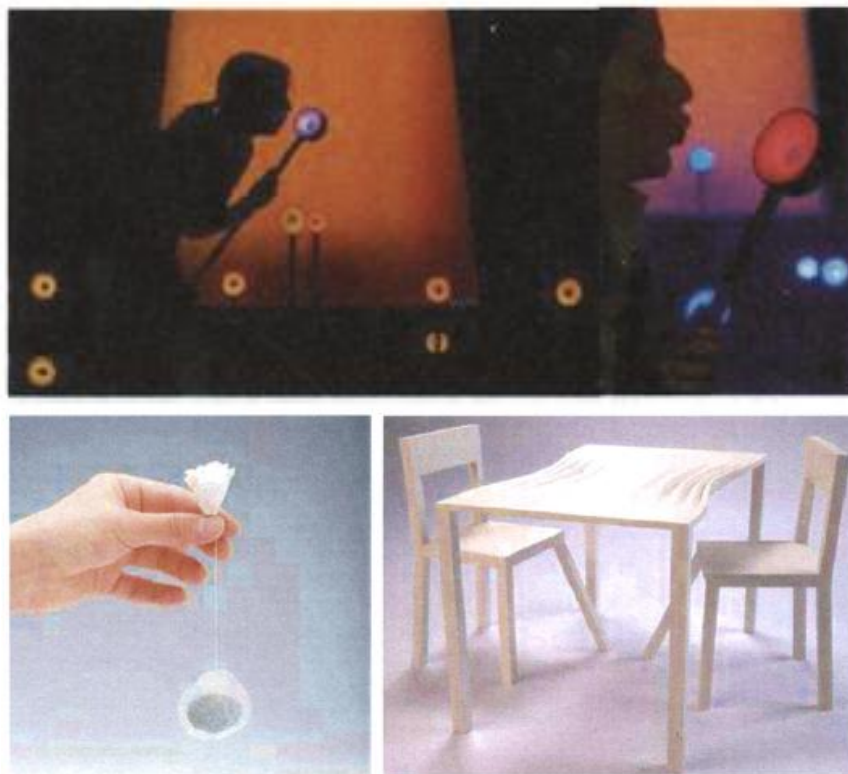


Figure 10 - Emotional Interaction - Reactive (Top), Behavioural (Bottom Left), Reflective (Bottom Right), (Yang and Chen, 2008)

Examples of these forms of emotional interaction exist in robotics. For reactive emotional interaction, there is 'Kismet' (Figure 11, Top Left), by Breazeal, (2003), which was designed to explore how emotional and expressive reactions could be used to regulate social interaction with humans through an anthropomorphic robot. It could mimic expression on the pleasure-arousal space for facial expressions, and a map of emotional categories based on arousal, valance, and stance dimensions (Breazeal, 2003). For behavioural emotional interaction, there is the work of Fiorini, et al. (2024) programmed a 'Pepper' robot (Figure 11, Top Right) to embody specific responses to react behaviourally to human emotional reactions when interacting with it (Fiorini, et al. 2024). For reflective emotional interaction, the work of Pu, et al. (2024), where they designed an interaction where participants spoke with a 'Jibo' robot, chosen for its emotional reactivity, and social embodied agent by way of a multi-device system (Figure 11, Bottom) which they termed their 'Jibo Robot Station'. The aim here was to encourage deep reflective emotions in children when viewing art (Pu, et al. 2024).



Figure 11 - Emotional Interaction Robot Examples - Reactive (Top Left) (Breazeal, 2003), Behavioural (Top Right) (Fiorini, et al. 2024), Reflective (Bottom) (Pu, et al. 2024).

Returning to design aesthetics, these experiences arise when a consumer engages with a product, particularly where there is alignment between the product and the consumer's preferences or characteristics. Six types of experience may intersect in this process: product observation (which influences perception), product interaction (involving physical contact), user observation and user interaction (where the surrounding environment shapes how the product is perceived or functions), and representation observation and representation

interaction (where mediated content, such as advertising or imagery, influences the experience). Interaction with an object can trigger both subconscious and conscious responses, which may be conceptualised through four states: subconscious-to-subconscious, subconscious-to-conscious, conscious-to-conscious, and conscious-to-subconscious transitions. These states operate through four interconnected processes: emotion (affective and valence-based aesthetic responses), attention (awareness of these aesthetic emotions), reflection (cognitive consideration of those responses), and internalisation (the incorporation of reflection into behaviour and subsequent aesthetic responses). The resulting experiences may range from negative to neutral to positive, and may unfold in cyclical or linear patterns, or through abrupt tonal shifts. The emotions generated within these processes also produce symbolic interpretations and associations, which in turn contribute to the formation of aesthetic emotions (Haug, 2016b). For example, in a qualitative study, Lam et al. (2016) explored how everyday aesthetic experiences influence the decision-making of high-end earphone users. They found that unconscious symbolic meanings, conveyed through aesthetic elements such as brand identity and imagined use contexts, played a significant role in shaping user preference. The earphones created a “*space of isolation*” in which users’ emotions were intensified; this temporary separation from the external world made their everyday lives feel more beautiful. The isolation produced by noise-blocking fostered imagination, emotional amplification, and personal meaning. Lam et al. concluded that social innovation extended beyond technological innovation, with aesthetic and experiential factors exerting substantial influence. They also emphasised that users themselves are a rich source of insight for innovation. (Lam, Liu and Yee-Nee Lam, 2016).

2.3.3. DA – Practical Level (BLUE)

Finally, the practical level of design aesthetics concerns the directly manipulable components that constitute design aesthetics itself.

2.3.3.1. *Form and Emotive Modelling*

Product form expresses design concepts and is vital to convey information, metaphors and references, as well as the understanding and thoughts of the designer and the design environment (Liu, Su, Zhang, Qiu, Wang, 2024). The perceived value of a product is strongly influenced by its aesthetic qualities. A visually appealing form increases consumer awareness of the product’s utility, shaping first impressions and motivating desire and purchase. Products that are carefully considered aesthetically tend to attract more attention, foster greater trust, and generate positive emotions, even when priced similarly to less attractive alternatives. In terms of perceived value, visual design (generally form) often employs pictorial metaphors. Branded products are unconsciously categorized, with visual

information pre-processed and integrated into context when these metaphors are interpreted. This holistic processing suggests that function and aesthetics are inherently interconnected rather than separate (Shi, Huo and Hou, 2021). Forms can be categorised into dominant, subdominant, and subordinate elements, each exerting major or minor directional influence. Rectilinear forms can function to wedge, cradle, or pierce, while curvilinear forms include spheres, hemispheres, cones, cylinders, ovoids, ovoid plinths, half-ovoids, and round spheres. Additionally, there are planar forms (Hannah, 2002). Form can also be explored through the physical design language of objects and their emotive impact. For example, the Emotive Design Framework uses the form of bottle-based models with emotive descriptors and adjustable sliders to shape the perceived emotional character of a bottle (Figure 12) (Mothersill, 2014).

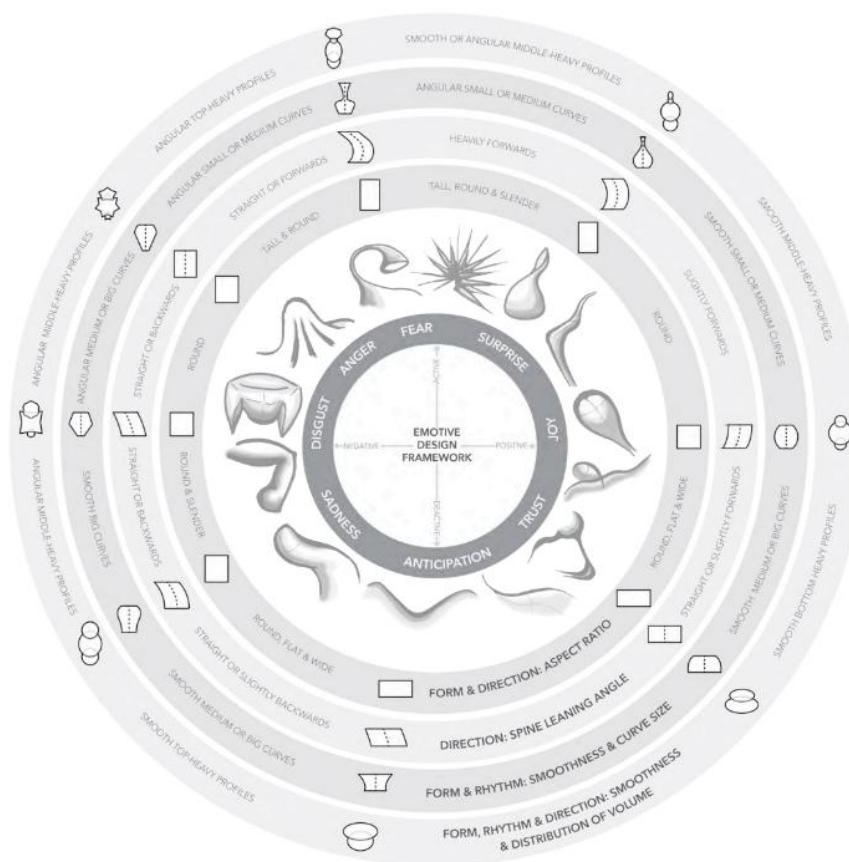


Figure 12 - Design taxonomy of Emotive Forms, (Mothersill, 2014)

Aesthetic perception and judgement involve both cognitive and emotional processes. These emotional responses shape and transform experiences of art, nature, and designed objects. Aesthetic emotions arise when individuals perceive and evaluate something in terms of its aesthetic qualities, thereby guiding judgement and evaluation. Schindler et al. (2017) identify 21 subscale aesthetic emotions, grouped into four main categories. *Prototypical aesthetic emotions* involve aesthetic appreciation independent of valence, such as the experience of beauty. *Pleasing emotions* are positive-valence responses, such as vitality.

Epistemic emotions relate to the search for or discovery of meaning during the experience, such as interest. Finally, *negative emotions* refer to negative-valence responses, such as sadness (Schindler et al., 2017). These responses are linked to neuro-aesthetics, where aesthetic experiences emerge from the interplay of three neural systems: *emotion–valuation*, *sensory–motor* and *meaning–knowledge*. *Emotion-valuation* primarily involves the right anterior insula, responsible for visceral perception and processing negative emotions. It relates to survival instincts and fulfilling social needs. *Sensory-motor* engages brain areas associated with sensation and perception, including the visual cortex. *Meaning-knowledge* is top-down processes where form, meaning, and prior knowledge shape aesthetic experience. Activation occurs in the ventromedial prefrontal cortex (reward and emotion) and in areas like the temporal pole and entorhinal cortex when contextual information or memory is involved, enhancing visual pleasure. Therefore, aesthetic experiences emerge from the dynamic interaction of these systems through judgment (Chatterjee and Vartanian, 2016). When this is applied to design through product emotion modelling, Desmet (2003) proposes four components: product, concern, appraisal, and emotion. The first three interact to generate the fourth: Product is the object being experienced. Concern is what one wishes to do with the object or the desired outcome of its use. Appraisal is the reaction to a specific event based on the experience of the product and one's concern. Emotion is the affective response resulting from the interaction of product, concern, and appraisal, e.g., feeling dissatisfied. This framework links emotional responses directly to both perception and use, showing how aesthetics shapes experience beyond mere visual appeal (Desmet, 2003).

The design process involves three main components: the designer, the design outcome(s), and the user. Most research focuses primarily on the emotional relationship between the design outcome and the user. However, designers also embed emotions into their work and often intentionally aim to evoke specific emotional responses through their designs. The 3E model from Ho, and Siu (2012) captures these interactions with three corresponding elements: Emotionalise Design, Emotional Design, and Emotion Design (Figure 13). Emotionalise Design, refers to the flow of emotion during the design process between the designer and the design itself. This stage is often less visible in practice because design typically prioritises the user, making these designer-focused emotions difficult to recognize. Emotional Design describes the flow of emotion from the design to the user through elements such as appearance, form, function, style, and usability. Here, the design evokes emotions in the user. Emotion Design emerges from the combination of these two processes and represents reflection on the design by the designer. This reflection can be informed by user feedback or user testing. The three levels of processing, visceral, behavioural, and reflective, can be used to explain emotion design. The visceral level refers to immediate emotional responses felt directly by the user, which may be influenced by the

emotional intent embedded by the designer during creation. The behavioural level concerns the emotional experience that emerges through interaction between the designer, user, and design during use, where the design mediates and communicates the designer's intent and is experienced by the user through engagement. The reflective level involves conscious interpretation and evaluation of the design experience by either the designer or the user. This may occur through direct feedback, observation of user interaction, or the designer's own reflection on the design's impact (Ho and Siu, 2012).

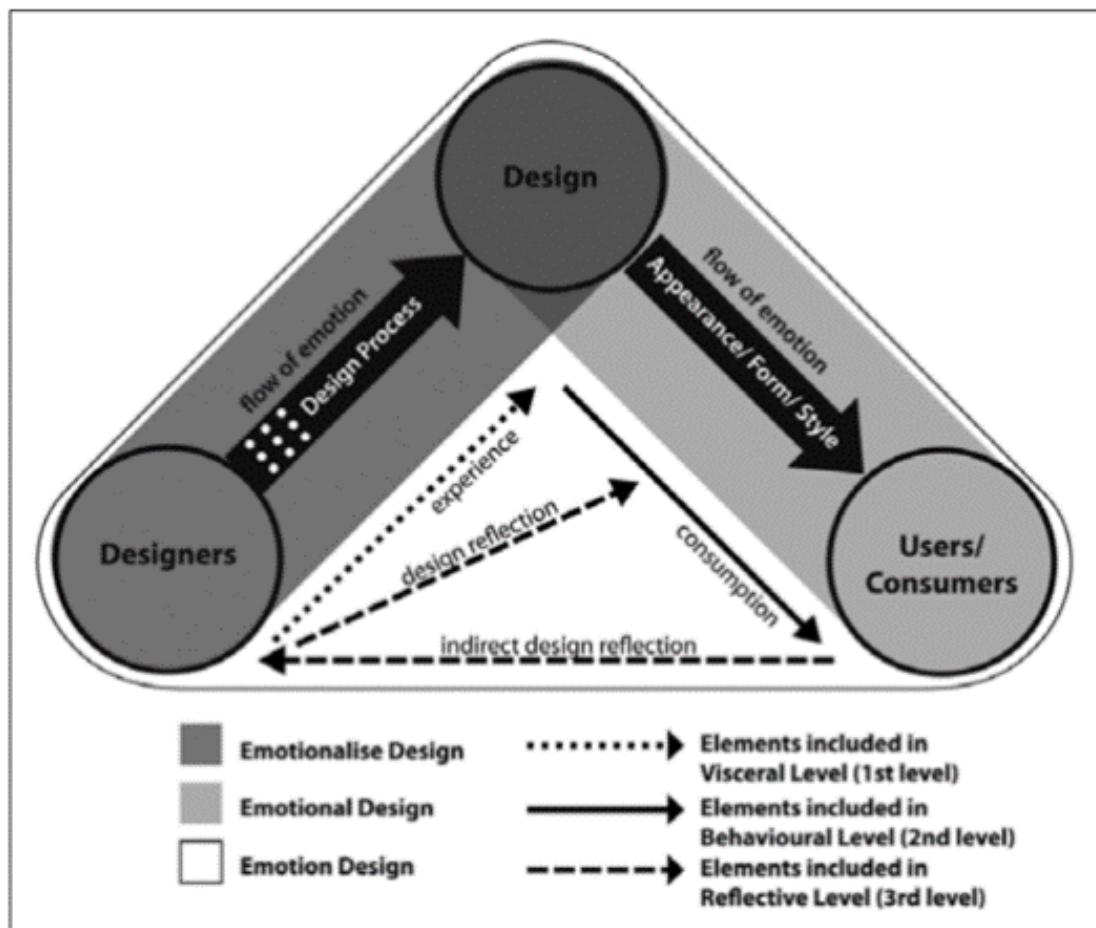


Figure 13 - 3E Model, (Ho and Siu, 2012)

In research, emotions are often categorised using a framework that balances four positive and four negative emotions arranged as opposing pairs: anticipation–surprise, joy–sadness, anger–fear, and trust–disgust. The intensity of each emotion can be represented visually in a diagram, where proximity to the centre indicates higher intensity, while positions toward the outer edges indicate lower intensity. This structure is commonly known as the “Wheel of Emotions” (Figure 14), in which the eight basic emotions are arranged so that related emotions are positioned adjacent to one another. The model was developed by Robert Plutchik (1991), who also associated each emotion with specific colours (Beltrán et al., 2019).

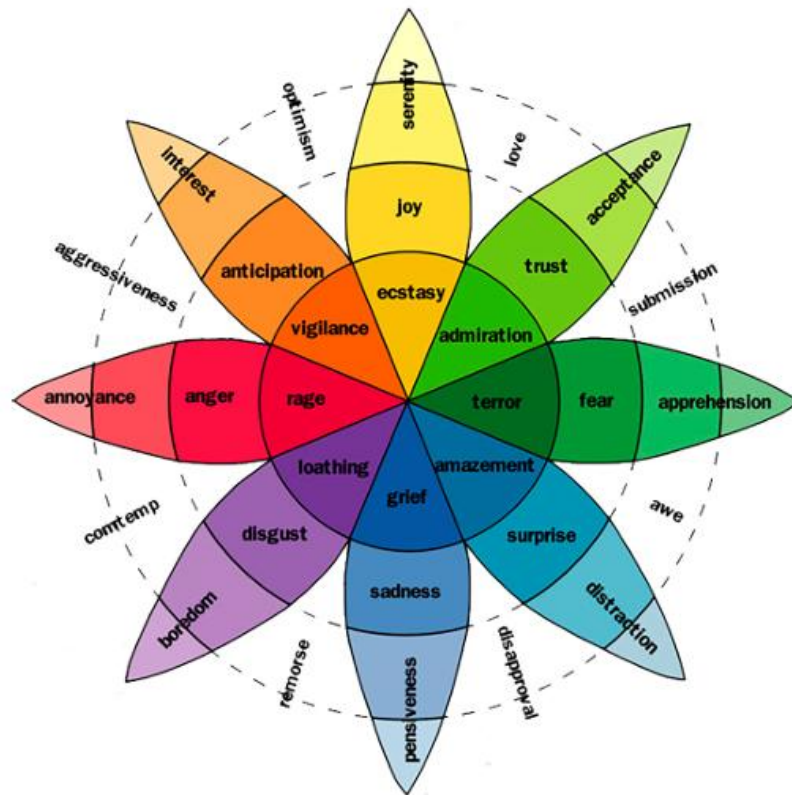


Figure 14 - Wheel of Emotion, (Plutchik (1991) in Beltrán, et al., 2019).

2.3.3.2. Colour and Colour Spaces

The relationship between emotion and colour remains significant, as each can reinforce the other and thereby enhance aesthetic experience.

Colour plays a significant role in aesthetics, influencing perception, creativity, and taste, and shaping what is considered beautiful within a given time and context. Culturally, colour can reference tradition and local meaning systems, affecting design choices depending on where and when a product is produced. It also functions as a form of personal expression, signalling affiliation with particular groups, roles, or social statuses, and thereby shaping both self-perception and how others perceive an individual. Colour may also have physiological effects: exposure to different hues can influence factors such as blood pressure, heart rate, and respiration, with colours such as pink and green often associated with calming responses. In many encounters, colour is one of the first perceptual cues noticed, particularly in clothing; and its effects can be intensified by proximity, which increases its impact on the nervous system. Colours that are lower in chroma exert less intense influence. Colour can even affect taste perception; for example, coffee served in brown mugs was perceived as too strong, yellow mugs made it taste weak, and red mugs were judged as just right. Environmental and climatic conditions also affect how colour is perceived, as they influence lighting. Additionally, colour is commonly used to describe

emotional states (Wilson, Benson, Bruce, Hogg, and Oulton, 2001). Colour can also communicate function, temperature, meaning, emotion, and even cultural or religious references. It acts as a social signal and a signifier, for example, red conveys intensity, blue conveys calmness, yellow conveys optimism, green conveys harmony, orange conveys warmth, purple conveys creativity, pink conveys tenderness, black conveys power, and white conveys purity. These effects arise from an object's reflection, brightness, saturation, and hue. Chromatic relationships are often organised using a colour wheel, which helps in creating harmonious colour combinations. The main harmony relationships include, complementary (colours opposite each other), analogous (colours next to each other), split-complementary (two adjacent colours paired with their opposite), Double-complementary (two pairs of complementary colours). These relationships are built from the interaction of three primary colours, producing secondary and tertiary hues (see the work of Johannes Itten), (Figure 15, (A)). Colours are also grouped into colour spaces (Figure 15, (B)), which are mathematical representations used in various applications, such as RGB, CMYK, and PANTONE (Nassar and Mohammed, et al., 2024).

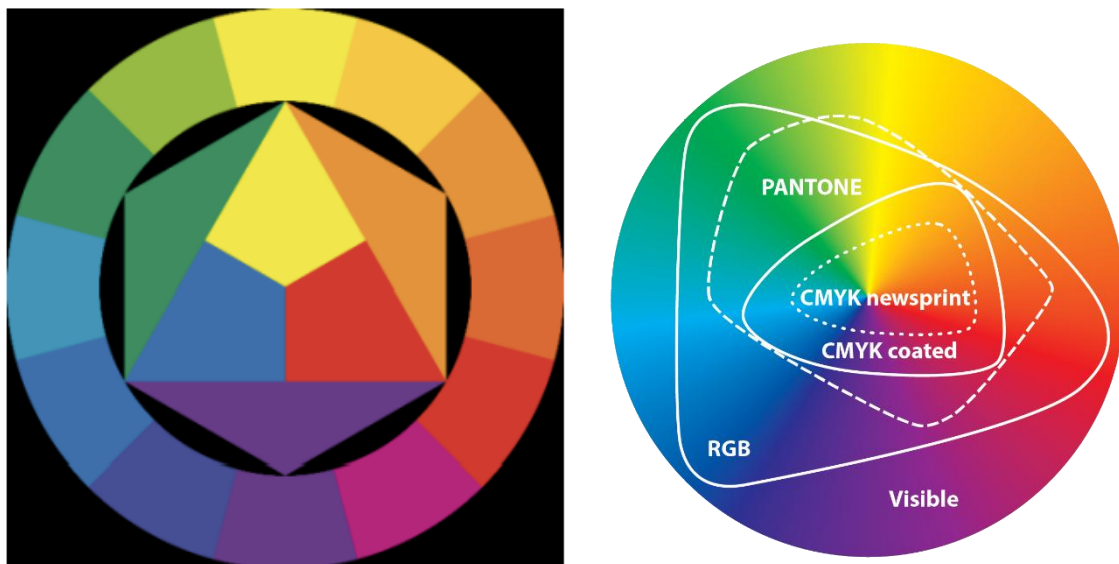


Figure 15 - Colour Wheel (A), Colour Spaces (B), (Nassar, Mohammed, et al., 2024)

2.3.3.3. *Pattern, Line and Texture*

In the absence of colour, other design elements such as pattern, line, and texture can also function as key aesthetic components, communicate meaning and eliciting affective responses.

Urquhart and Wodehouse (2021) define patterns as “structured sets of repeating aesthetic motifs” and explore their emotive significance through an evaluative study of 16 patterns (Figure 16). Participants assessed each pattern using emotive descriptors, with results aligning with prior findings in vision science and Gestalt theory. Curved patterns were

consistently associated with positive emotions such as trust and serenity, with interlocking curves suggesting reliability and movement. In contrast, angular patterns were perceived as interesting but distracting, with increasing complexity heightening engagement. The authors suggest that the ambiguity of angular forms may reflect cultural symbolism overriding innate perceptual preferences and conclude that identifying emotional responses to aesthetic elements can inform design practice (Urquhart and Wodehouse, 2021).

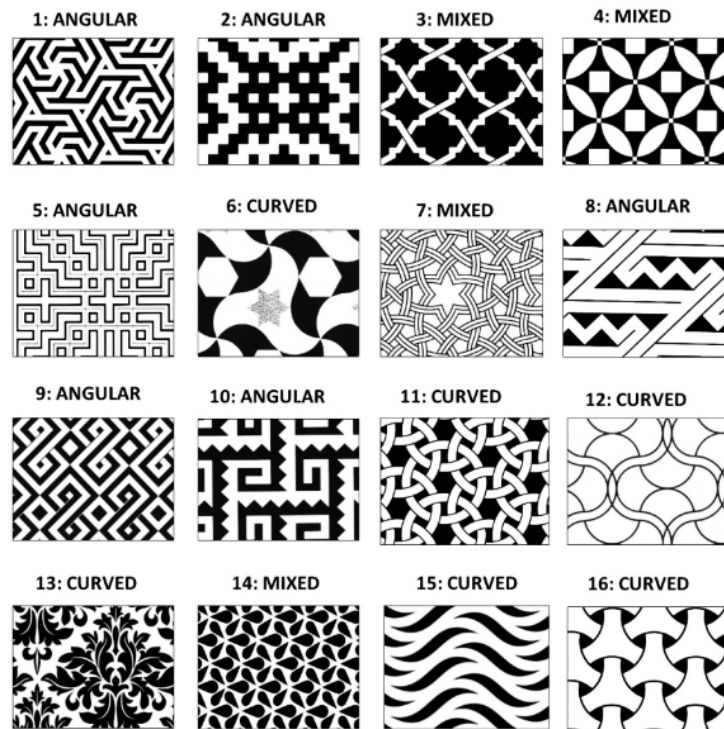


Figure 16 - Pattern Example, (Urquhart and Wodehouse, 2021)

A more controlled version of a pattern is a line, where Poffenberger and Barrows (1924), referencing Cox (1917), emphasised line as the most important means of artistic expression. They used a set of eighteen lines, categorised by elements of form, rhythm, and direction. These lines were presented as blueprints, with white lines on blue backgrounds. Participants were given a sheet of emotive terms or adjectives, organised into thirteen classes. The study found that downward-directed lines were associated with sadness and trust, whereas upward-directed lines conveyed anger and joy. Lines with curves and high rhythm suggested movement, energy, and positive emotions. Angular lines, by contrast, were perceived as rigid (Poffenberger and Barrows, 1924). Underneath these patterns and lines there exists texture where Sener and Pedgley (2021), in their “TextureFace” project, aimed to develop principles for texture design that can influence user actions through tactile attractiveness or aversion. Their work demonstrates that texture can extend product functionality, guide user behaviour, and shape the material experience of a product. In their analysis of over 200 products, they found that texture is often used to improve grip, with grip elements typically distinct from the product’s main body in terms of both colour and texture.

Texture also maintains its effectiveness over time and can help differentiate functional areas even when not visually apparent. Additionally, tactile displays can incorporate mutable micro textures that respond to user input or operate automatically. The authors claim this study represents the first systematic analysis of how texture can create or facilitate product function. They further developed a surface texture roadmap and identified eleven categories of functional texture (Şener and Pedgley, 2021).

2.3.3.4. Composition and Visual Dynamics

These practical elements are mediated by the forces that emerge from the interaction of the components, as well as by their overall arrangement. In this sense, composition and visual dynamics shape the aesthetic experience of a design through the way its elements are organised and related as a whole.

Using line as a means to explain composition, lines can vary in length, curvature, and angularity, and with ornamentation largely reduced, the line itself is often treated as a fundamental design element. Straight lines may differ in length, curved lines in their degree of curvature, and compound lines combine straight and curved segments. Lines can also be expressive, conveying sensations of speed, force, or movement and producing dynamic visual effects. A single line may appear isolated against a background, whereas two or more lines establish relational structures shaped by their position and spatial interaction. These relationships are influenced by factors such as height, volume, character, colour, texture, shape, and spatial arrangement. Composition is further shaped by how elements are positioned within space to produce effects of harmony or tension. Arrangements may be central, vertical, horizontal, symmetrical, asymmetrical, or relational, each influencing perceptual organisation differently. Placement can also suggest movement, force, or speed, a principle that applies not only to lines but also to points or groups of elements that are aligned or mirrored in relation to one another (De Lucio-Meyer, 1973). The tool and medium further shape the qualities of the output. A medium may be sympathetic or antipathetic to a given tool, producing different interactions between mark-making, environment, and observer. Each visual modification introduces dynamic shifts in form that can elicit subjective responses. Designers therefore need to engage with these dynamics, understanding their character and behaviour in order to work effectively. Visual experience is both holistic and fragmentary: information is often apprehended almost instantaneously and then interpreted in relation to prior experience and conceptual frameworks. Colour also plays a significant role in shaping emotional response from an early age. In the creative process, the arrangement of elements such as line, form, and colour can produce a sense of unity of purpose, generating cohesion, rhythm, and controlled imbalance. This sense of conceptual unity arises through the interaction of contrasting visible and invisible compositional forces,

including movement and pattern. These interactions generate rhythms and counterflows that balance tensions such as linear thrust–counter thrust and movement–counter movement (De Saumarez, 2007). This sense of movement was explored by Weerdesteijn, Desmet, and Gielen (2005) who aimed to determine how to use expressive movements to create products that elicit predefined emotional responses. They designed six objects that expressed: anger, fear, sadness, joy, pleasant surprise, and attraction (Figure 17). The aim was for the emotional movements of these objects to help children express themselves physically. The study found that the objects significantly enhanced the children’s expressive abilities. Within an educational context, teachers observed that the expressive movements of the objects made emotions more tangible and perceptible to the children, demonstrating that the objects’ dynamic character, movement, and interactive qualities were crucial for both expressing and experiencing emotions (Weerdesteijn, Desmet and Gielen, 2005).

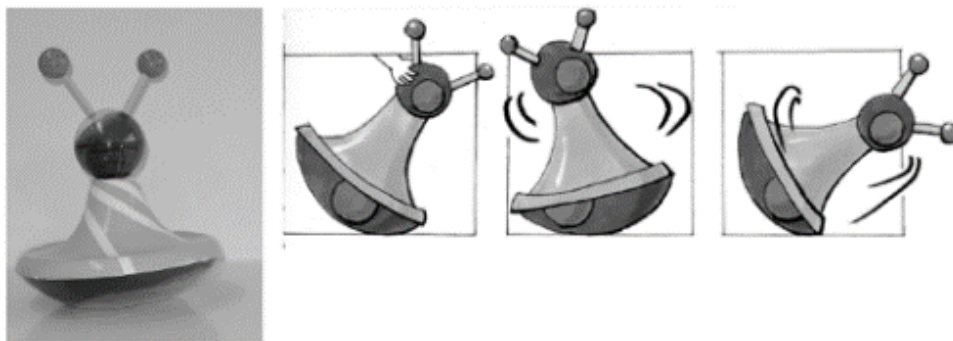


Figure 17 - Movement Design Example, (Weerdesteijn, Desmet and Gielen, 2005)

2.3.3.5. Space, Time, Light

Areas of design aesthetics that appear to be less extensively covered in research include space, time, and light. These dimensions possess movement, compositional, dynamic, and emotional qualities, and are frequently employed to significant effect by designers.

Space can be understood as the effect of form on the surrounding environment over time, shaped by visual and haptic feedback. This includes spatial, visual, and temporal dimensions, producing expressive spatial experiences. In visual arts, three-dimensional forms are created through moulding or modelling (plastic arts), where the form itself is central. Architecture, on the other hand, shapes space, with emphasis on the environment rather than individual forms. Sculpture focuses on form, influencing the surrounding space, whereas urban design emphasises directional and organised spaces (Zucker, 1945). Light is used to give form to space as it reveals distance, shape, and opacity when illuminating a form or area. Light is a more fluid design element without a fixed shape, expressed primarily through the forms of other objects. It can be natural or artificial, but its perception is determined by human vision and influenced by the Purkinje effect, in which photopic (day)

vision shifts to scotopic (night) vision as brightness decreases, altering the perception of colours, for instance, reddish-purple may appear as blue violet (Volf, 2010). Other critical factors include luminance ratios (from subtle to uniform), distribution, colour harmony, and intensity, as well as utility and appropriateness. These factors must be proportionally balanced: the contrast between accent and general lighting, the relationship between luminaires and their environment, their relative size in interior or exterior contexts, and the interaction of luminance with surrounding surfaces. Shadows cast by objects further shape perception. All ratios should be adjusted according to purpose to achieve a sense of balance, appropriateness, and functionality (Żagan and Kowalska, 2017). An example of integrating space and light is found in 3D-printed objects with lenticular surfaces, which change appearance based on the viewing angle (Figure 18 (Top)). This technique has been applied to guide users in tasks, such as indicating optimal use of a kettlebell or container, where text or visual cues are only visible from specific perspectives (Zeng et al., 2021). Building on this, the concept of “Illusory Material” (Figure 18 (Bottom)) was developed, creating optical textures that dynamically alter based on the viewing angle (Illusory Material, n.d.). This example also involves time, as users must move and shift perspective, and such changes in spatial experience necessarily occur through time changing.

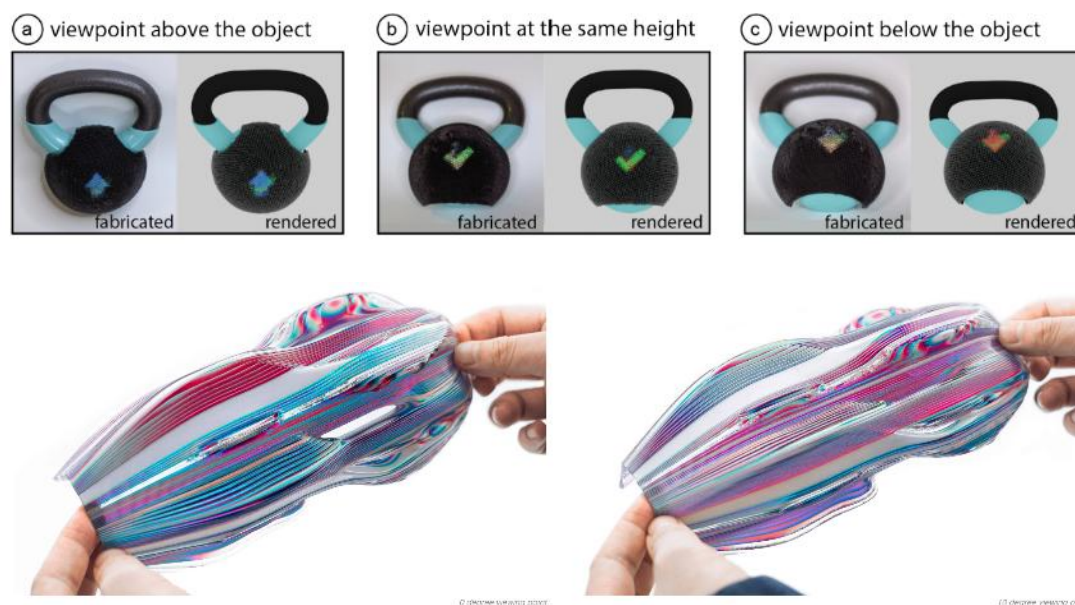


Figure 18 - Lenticular Objects (Top), (Zeng et al., 2021), Illusory Material, Optical Textile (Bottom), (Illusory Material, n.d.)

Time can be perceived sensorially, carrying a sense of rhythm, slowly or quickly, which shapes judgement and emotional experience (Shusterman, 2011). Physical time is marked by change as its passage produces entropy and movement. In contrast, psychological or perceptual time can feel like persistence, when nothing appears to change. Time also has duration, the felt length of an experience, and a temporal order, the sequence

in which events must occur, such as seasonal cycles (Power, 2021). Philosophically, Heidegger conceptualised time as the horizon that both limits and defines beings, a field of polarities and possibilities through which existence becomes intelligible (Geniusas, 2023). There are also more complex scientific notions of time arising from quantum physics. For example, the Hartman effect describes how matter can appear to tunnel through barriers faster than classical limits would allow, while the quantum Zeno effect shows that the act of observation can prevent a system from changing state (Altaie et al., 2022). These ideas have inspired emerging practices such as quantum aesthetics, where concepts from quantum theory are used metaphorically or structurally within artistic creation. The Arts at CERN programme, for instance, has supported artworks exploring these themes (Schröter, 2014). Similarly, semiotic theory has been interpreted through quantum-like dynamics such as collapse, decoherence, contextuality, entanglement, and superposition (Broekaert, 2018). An illustrative example is the video game *Miegakure* (Figure 19), in which the player interacts with a four-dimensional space, effectively manipulating spatial and temporal dimensions to solve puzzles (Bosch, n.d.). In the images below, the playable space changes size and configuration, altering the objects within it over time.



Figure 19 - Time-Space Shifting Game, (Bosch, n.d.)

2.3.4. Discussion on Design Aesthetics

Design aesthetics emerges as a multidimensional field in which perception, emotion, meaning, and cultural context converge to shape how people understand and engage with designed objects. Across the reviewed literature, aesthetics is shown not to be only a surface-level concern but a fundamental mode of communication, one that expresses ideas, evokes emotions, structures interaction, and frames the user's relationship with the world. As such, the work of Liu, Su, Zhang, Qiu, Wang (2024), Shi, Huo and Hou (2021), Hannah (2002), Mothersill (2014) forms are mediated through emotion and subsequently evaluated through taste, such that both perception itself and the judgement of that perception constitute part of the aesthetic experience. These defining element of aesthetic experience by Haug (2016b) and Lam, Liu and Yee-Nee Lam (2016) raise an important avenue for research and design which is how can new sources of insight and new knowledge domains be identified and tested? In their study, Lam, et al. (2016) it was the acoustic isolation that created emotional resonance and perceived aesthetic enrichment. For robots, a parallel might be the degree to which people feel seen, considered, or emotionally supported by the machine. If

music stimulated imagination, then perhaps robot behaviour could similarly open up the user's sense of possibility, through movement, gesture, rhythm, or atmosphere. This might involve exploring whether aesthetics can guide users toward more hopeful, imaginative, or future-oriented interpretations of robotic presence, for instance through slow, soft, melodic behaviours that suggest calm, growth, and care. Whether approached through sensuous appearance, product semantics, emotional interaction, or aesthetic innovation, aesthetics forms the foundation through which design becomes desirable, and meaningful. As shown, the design-aesthetic concepts concerning types of emotional interaction that designers can create from Xenakis and Arnellos (2013), Ross and Wensveen (2010), Yang and Chen (2008) and the concept of aesthetics emotions Haug (2016a), Menninghaus, et al., (2019) are applicable to robotic design. These complex experiential outcomes can be achieved in robotics through the application of design-aesthetic knowledge and theory. However, in the examples from Breazeal (2003), Fiorini, et al. (2024), Pu, et al. (2024) discussed, these principles were not explicitly applied, and as a result, the designs could potentially have been more effectively developed to produce more relevant outcomes and to support richer emotional experiences. The work of Schindler et al., (2017), Chatterjee and Vartanian (2016), and Desmet (2003) show that it is not only the emotions aroused in the user or perceiver that are relevant, but also the emotional intent embedded in the design and the emotions experienced by the designer during the design process.

At the perceptual level, elements such as form, line, pattern, colour, texture, and light provide the structural vocabulary from which designers compose visual and tactile experiences. These elements carry emotional weight: curved patterns evoke trust and serenity, angularity heightens interest and tension, upward lines convey joy, and colour modulates physiological and cultural responses. Light reveals form and governs' atmosphere, while space and time expand aesthetic experience into dynamic, temporal, and even quasi-illusory dimensions. The work of (Bosch, n.d.) illustrates that the perception of time within an experience does not always unfold in a linear or continuous manner. Instead, temporal experience can feel fragmented, layered, or multidirectional, fast, slow, concurrent, or even looping. Past experiences can resurface with such vividness that they feel as though they are occurring in the present, and new imagined scenarios may arise in response to an ongoing aesthetic encounter. These temporal distortions shape our emotions, judgements, and perceptual framing, becoming part of the aesthetic experience itself. If illusions of perspective and space can be intentionally constructed, then it follows that illusions of time can also be created. Illusions far more complex than the common feeling that time is "speeding up" or "slowing down." Such temporal illusions already exist in abstract domains like the aesthetics of knowledge, where individuals can be guided, persuaded, or

indoctrinated into perceiving or failing to perceive certain information. In these cases, the manipulation of temporal perception, what is remembered, forgotten, anticipated, or suspended, becomes an aesthetic and cognitive phenomenon in its own right.

Together, these elements show that aesthetic experience is not static but evolves through changing sensory, cognitive, and contextual conditions. Emotion is central to this as research in neuro-aesthetics and product design consistently demonstrates that aesthetic judgments arise from intertwined cognitive–emotional processes. Interaction amplifies this as users respond viscerally to sensory qualities, behaviourally to usability, and reflectively to meaning and memory. As shown in earphone users' experiences of emotional “isolation” or intelligent artefacts shaped by expressive movement, aesthetics is inseparable from how users feel with and through objects. This underscores that the value of design cannot be reduced to function alone, as aesthetic experience shapes desire, trust, behaviour, and long-term attachment. At the symbolic and cultural level, aesthetics acts as a language. Products communicate through aesthetic coding, signifying purpose, identity, status, or cultural belonging. Ornamentation, once dismissed as superficial, becomes a channel for ideas and emotional resonance, as seen in Dresser's search for universal pattern principles. These communicative elements from Norman (2004), Krippendorff (1989), Walker (2001), Steffen (2010), Ashwin (1984), Dresser and Halén (1993) are intended to attract users and perceivers by shaping an object as pleasing and appealing through the elicitation of both positive and negative affective responses. Aesthetic innovation arises when new forms, patterns, movements, or ideas expand this language, shaping not only user expectations but cultural narratives. Even emerging concepts such as quantum aesthetics highlight the expanding frontier of how perception, knowledge, and aesthetic meaning can be constructed. Interpreting Coates (2003) and Hekkert (2006), an aesthetic approach extends beyond mere form, encompassing ideas, knowledge, and concepts that can be explored and manipulated. This can and should be applied to new technology such as human-centric robots. Speculative design demonstrates this potential, using aesthetics to craft narratives about the effects and implications of the objects a designer envisions. The concept of Aesthetic Innovation is particularly important in this context, as the aesthetics of robots must be enhanced to better align with the needs and desires of users.

Bringing these threads together, we can conceptualise design aesthetics as the embodiment of ideas through interconnected aesthetic elements, structured across three levels, abstract, analytical, and practical, each influenced by broader contextual and purposive forces. Practical elements such as form, colour, pattern, movement, interaction, and texture provide the tools; analytical qualities such as unity, subtlety, and complexity organise them; and abstract qualities such as symbolism, meaning, and aesthetic function

assess whether the design communicates its intended ideas. Context, execution, and purpose exert pressure on all levels, shaping how aesthetics is both conceived and perceived. Design aesthetics is not merely a matter of beauty but a holistic system of experience-making, shaping the emotional, perceptual, cultural, and symbolic relationships between people and artefacts. It informs how users understand objects, how designers embed meaning, and how new ideas, behaviours, and futures can be imagined. As such, aesthetics is central to innovation, not only in creating new forms but in generating new ways of experiencing the world. Ultimately, design aesthetics shapes not only the appearance of an object but the very perception of its meaning, influencing the ideas that take root in the user's mind. Through its visual, tactile, spatial, and interactive elements, aesthetics can elicit specific emotions, at precise moments, from particular sources, with particular intensities and durations. Across the literature, there is evidence for the existence of both universal and culturally conditioned models of aesthetic experience, visible in shared emotional responses to form, colour, pattern, and movement, as well as in culturally embedded symbolic and semantic interpretations.

However, a notable limitation in current research is that aesthetics is often treated as static, focused on fixed forms, stable patterns, or unchanging sensory cues. Only a limited body of work examines aesthetics as something dynamic, evolving through time, interaction, and context. In relation to robotics and their aesthetics, design-aesthetic knowledge helps define the perceptual experience of objects by identifying which designable elements can be adjusted to produce specific perceptual, interactive, comprehensible, and relatable experiences. This is valuable both for designers working on robotic systems and for researchers exploring and testing such systems.

2.3.5. Contribution and Conclusion - Design Aesthetics Taxonomy

From the literature a taxonomical diagram of Design Aesthetics can be created where the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE) for one whole in Figure 23.

Structuring the abstract level in Figure 20, it forms around the 'Scope of Design Aesthetics', in which communication and context shape and alter the intended aesthetic outcome. As a field, it is heterogeneous and related to, yet distinct from, art: it is less concerned with individual expression and more focused on expressing the intent of the design project. This scope also includes sensuous qualities and the perception of reality, drawing on aesthetic philosophy and notions of affordance in relation to Gestalt principles. In this way, it establishes the boundaries of the field and grounds all subsequent areas of focus in how aesthetics operates within design. The 'Sensuous Appearance and Aesthetic Coding' refers to how perception is shaped through aesthetic structures linked to affordances and

Gestalt organisation which describes how aesthetics is encoded as meaning, distinguishing between non-surplus and surplus appearance. This relationship connects form to semantic content, guiding how users interpret, decode, and reflect on design concepts. ‘Aesthetic Innovation and Product Language’ concerns the expression of novelty through formal aesthetic syntax, such as order–complexity and rich–poor stimulus relationships, as well as semantic functions including indication and symbolism. Within this framework, six signifying functions operate to generate novelty, shape user expectations, and connect product form with meaning through product semantics.

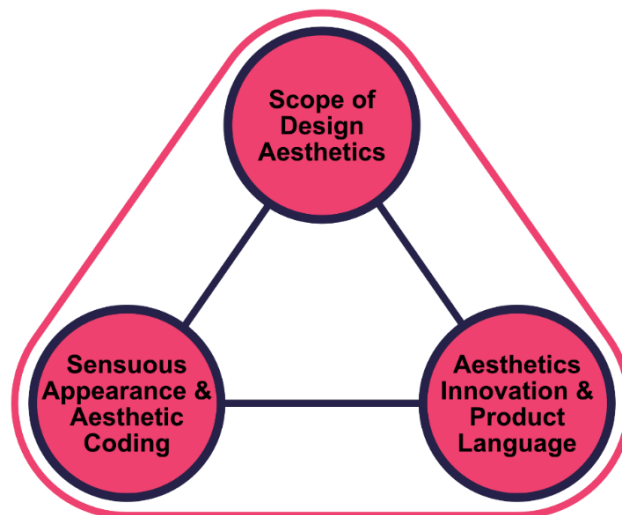


Figure 20 - Design Aesthetics - Abstract Level

Structuring analytical level in Figure 21, ‘Aesthetic Emotions and Interaction Aesthetics’ refers to the role of discrete aesthetic emotions in motivating engagement with, and desire for aesthetically pleasing objects. It also encompasses emergent aesthetics arising through user–object interaction, where emotional responses are shaped by design affordances and help sustain user engagement. ‘Interaction and Emotional Interaction Levels’ describe stages of user engagement, beginning with reactive (sensory) interaction, followed by behavioural (usability) interaction, and culminating in reflective (meaning-based) interaction. Together, these levels structure how users engage with a design and provide feedback that can inform iterative design decisions.



Figure 21 - Design Aesthetics - Analytical Level

The practical level in Figure 22, starts with, 'Form and Emotive Modelling' refers to the technical elements of design that can be manipulated, including the organisation of dominant, subdominant, and subordinate components. These are expressed through formal vocabularies such as curvilinear and rectilinear forms, which contribute to the overall emotional and perceptual character of the design. Form can be seen through valence/arousal which influences emotional response and reinforces the communication of form. 'Pattern, Line and Texture' is where there are pattern types: angular, curved, mixed. Line qualities denote direction, rhythm, curvature. Texture categories imply functional, expressive, surface. These constitutive design elements that evoke specific emotions and afford actions. 'Colour and colour spaces' is where cultural traditions, and emotional reactions dictate colour meanings. Where there are colour harmony relationships (complementary, analogous, etc.) and colour wheels and spaces (RGB, CMYK, PANTONE). Colour acts as a key aesthetic element for immediate perception, emotional impact, and brand or cultural signification. Light is a fluid, shapeless element that reveals form through interaction, shaped by vision and perception. Its qualities, natural or artificial, luminous ratios, shadows, define spatial mood, harmony, and utility. Space emerges through form and time, shaped by visual, tactile, and directional experiences. From architecture to lenticular surfaces, space is dynamic, responsive, and perception dependent. Time is sensed through rhythm, change, and duration, shaping emotion, memory, and aesthetic flow. It spans from physical entropy to quantum paradoxes, where perception and illusion redefine its order. 'Composition and Visual Dynamics' have visual design elements: line, form, space, rhythm, light that can create sense if unity in variety and balanced tension, as well as conceptual–fragmentary visual flow. A holistic arrangement of elements that governs attention, rhythm, and aesthetic unity. The collection of letters are all the manipulable practical elements of; Form, Line, Pattern, Space, Texture, Interaction, Movement, Time, Emotions, Colour, Light, and Composition. Together, these levels articulate how ideas become embodied aesthetically within objects, and how context, purpose, and execution shape the final aesthetic expression towards an object.

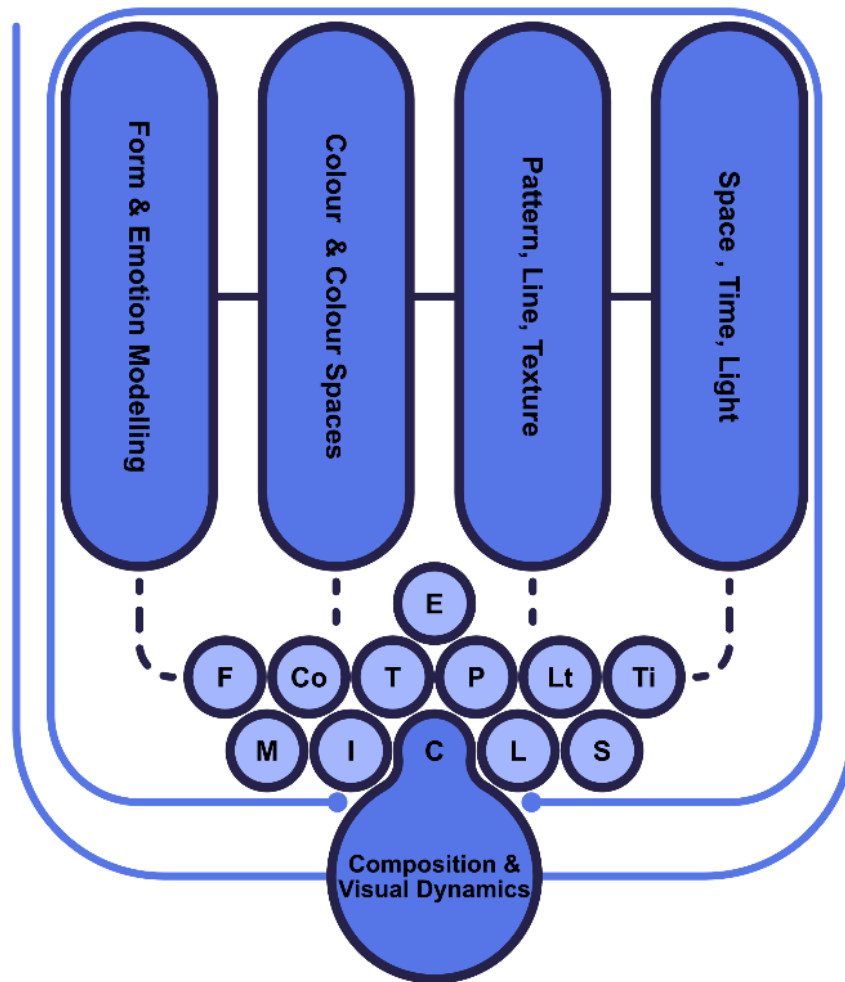


Figure 22 - Design Aesthetics - Practical Level

Design aesthetics can be understood as the embodiment of ideas within objects through aesthetic elements that operate across perception. A taxonomical was developed to synthesise the preceding discussion by structuring design aesthetics into three interrelated layers: the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE). From this view, a taxonomical diagram was created to represent the elements and their relationships (Figure 23).

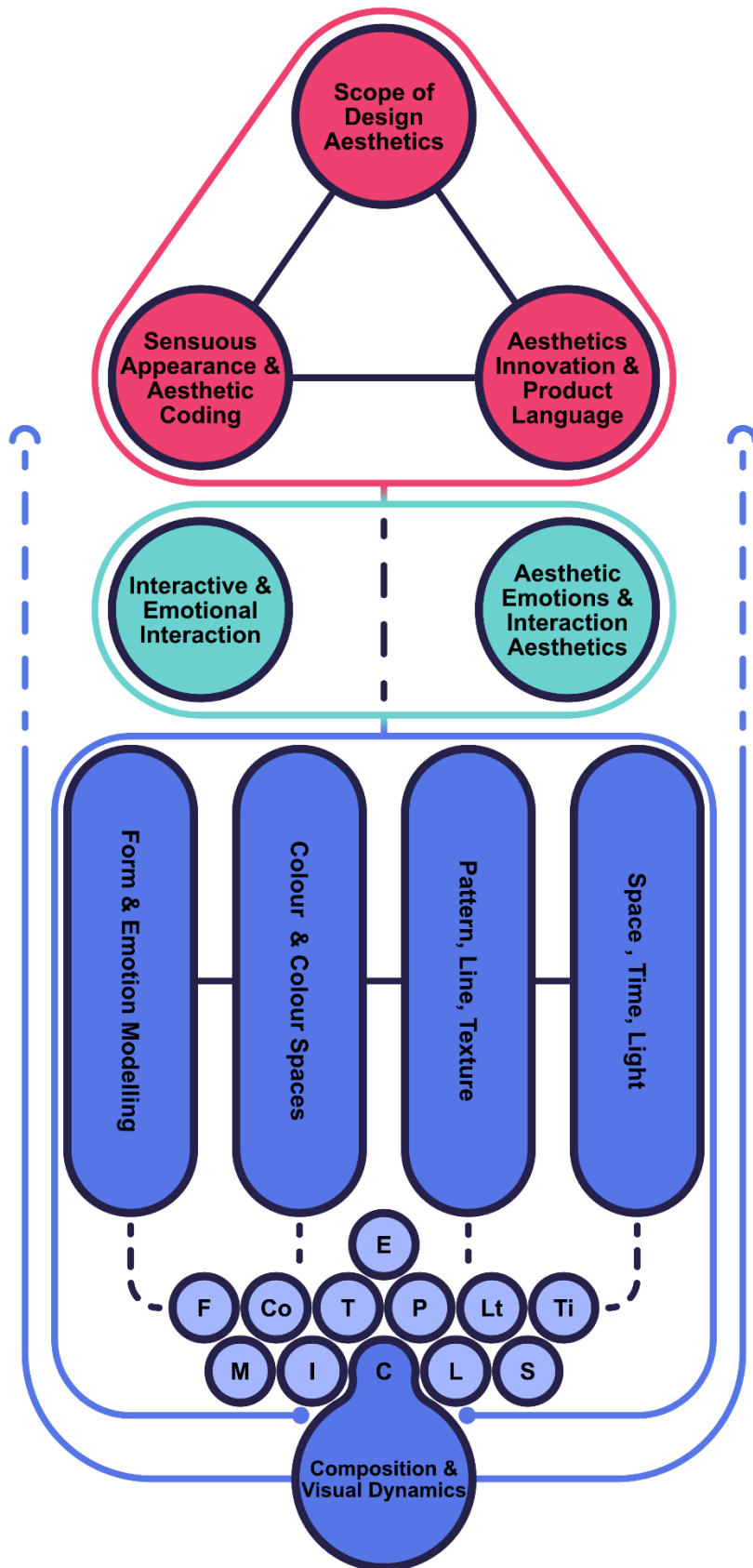


Figure 23 - Design Aesthetic Taxonomy Diagram

2.4. Humans and Robots

Design aesthetics concerns the ways in which meaning is produced through artefacts via their aesthetic properties, encompassing both enduring physical characteristics and more transient, situational, or performative qualities. This framework extends to robotics, and in particular to human–robot interaction, where aesthetic design plays a critical role in shaping human perception, interpretation, and response to robotic agents. The following section examines this relationship by analysing human responses to robots, progressing from human-centred considerations toward those grounded more explicitly in the robot’s material and behavioural properties.

2.4.1. HR – Abstract Level (RED)

Firstly, the abstract level concerns the historical, cultural, and ethical dimensions that have shaped both humans and the outcomes of their robotic creations.

2.4.1.1. *History and Context*

Myths of robots and artificial beings have existed for millennia, beginning with figures such as the Titan Prometheus, who created humans from clay, Talus, the giant bronze servant associated with Hephaestus, and accounts of Egyptian priests concealing themselves within oracle statues (c. 2500 BC), among other early automata-like narratives. The term “robot” itself derives from the Slavic *robota*, meaning forced labour, and was first popularised in Rossum’s *Universal Robots* (1920), a play by Karel Čapek (Siciliano, Khatib and Kröger, 2008). In Čapek’s play, robots are depicted as android-like beings with implanted brains capable of emotion, which ultimately enables them to revolt against humans and replace them (Reilly, 2011). In ancient Greece, Hero of Alexandria described automata as mechanisms designed to inspire wonder and religious awe in the public, moving from mere illusion to technical explorations of mechanics and pneumatics (Bur, 2016). Hero documented these creations in his book *Automatopoietica* (Papadopoulos, 2007). The ancient Greek fascination with automata may have been influenced by earlier Egyptian myths linking android-like creations to divine powers. For example, the statue of Amenhotep III at Thebes reportedly produced sounds like breaking harp strings at dawn (LaGrandeur, 2012). Other historical examples include the automatic wine-serving maids described in *Pneumatics*, whose lost automata have more recently been reconstructed using virtual reality techniques (Nicolle, Fleury and Lezoray, 2020). In the 1800s, Jewish folklore added the concept of a clay servant animated through religious ritual (Dekel and Gurley, 2013). More recent depictions include Mary Shelley’s *Frankenstein*, Stelarc’s cybernetic artworks, and advanced representations in cyberpunk media, all reflecting humanity’s enduring fascination with animating inanimate forms. These narratives blend an archaeological perspective, and culture as expressed through artefacts mediated through interactive interfaces with a

computational angle. As robots become more prevalent, a “cultural robotics” perspective may be required, in which human–robot interaction actively shapes cultural values rather than merely reflecting them (Samani et al., 2013). This idea of cultural robotics and “techno-mythology” is largely shaped by science-fiction. Early robotic art was, in a sense, already embodied in cybernetics research in the late 1940s. For example, William Grey Walter developed simple autonomous robotic “turtles,” known as Elmer and Elsie. Later developments included large-scale, biologically inspired systems such as a three-metre robotic arm called the “Senator,” which incorporated handmade technologies enabling forms of human interaction that would not be widely recognised as such for another twenty-five years (Penny, 2013), (See Figure 24).

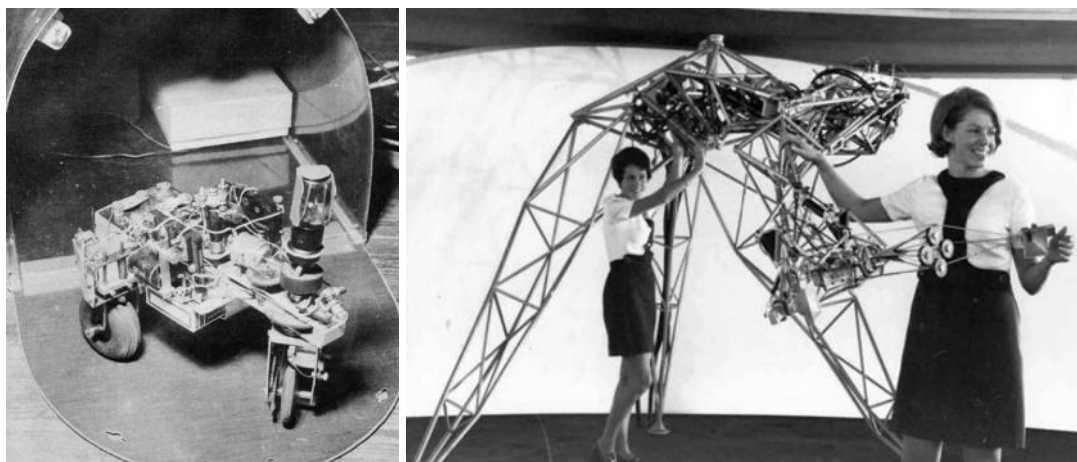


Figure 24 - Cultural Robot Examples, Elsie (Left), Senator (Right), (Penny, 2013)

2.4.1.2. Culture and Technology

Culture also significantly influences human behaviour (Berríos, 2024), and cultural values are themselves shaped by external factors such as climate, as well as internal ones like wealth, which mediate priorities such as survival versus self-expression (Van de Vliert, 2007). Moreover, technology affects how humans interact with each other and the world (Woodward, 2014).

From a cultural perspective, robots have historically symbolised acts of creation, embodying the intentions and imaginative projections of their makers, as though animated with the capacity to influence reality. Contemporary trends, however, increasingly emphasise the potentially dehumanising integration of technology into everyday life, which can also generate resistance to it. In contrast, a more human-centred approach, where robots adapt to and respond to cultural behaviours rather than imposing their own logic, may lead to improved social and cultural outcomes (Ornelas, Smith and Mansouri, 2023).

2.4.1.3. Conceptual and Ethical Views

From an ethical standpoint, robots are best understood as tools and extensions of human capability rather than autonomous moral agents (Bryson, 2009). In this view, attributing human-like agency to robots' risks obscuring human responsibility, since their actions ultimately derive from human design and intent, making them ethically comparable to other artefacts. Consequently, robots should be designed to support and enhance human efficiency while avoiding wasteful or manipulative interactions, including forms of simulated social engagement that exploit or misdirect human attention (Bryson, 2010). Otherwise, contemporary concerns include the exploitation of users through technologically mediated misrepresentations that may dehumanise individuals and reinforce in-group and out-group divisions via communication strategies such as branding and marketing. Examples include the "illusion of sympathy" associated with systems such as Amazon Alexa and Siri, where perceptions of trust and empathy are generated without substantive evidence, as well as smart devices whose actual functionality may fall short of their advertised capabilities. Addressing such issues would support a more transparent, equitable, and culturally open society. One proposed solution is greater technological transparency. Although there is no single, widely accepted theory of dehumanisation, related phenomena can be observed in social media contexts, for example through labels such as "Covid Karen" and "anti-vaxxer," where in-group and out-group distinctions are constructed in ways that can intensify social division and pressure conformity. In such cases, algorithmic systems may contribute to fragmented online social dynamics that extend into offline social relations (Oldfield, 2023).

There are also the concerns about displacement and technological overreach which echo Luddite anxieties, though these fears have persisted through successive waves of technological innovation, from AI to robotics. Even Turing considered the idea of machines "thinking" as largely irrelevant (Turing, 1950/2007). Along with this, centralised approaches to automation risk social, economic, and ethical costs, including taxation, corruption, reduced innovation, lower well-being, and unemployment (DeCanio, 2016).

2.4.2. HR – Analytical Level (GREEN)

The analytical level focuses on the technical and relational elements of human–robot interaction, particularly how collaboration and communication are enacted in practice and what kinds of relational dynamics emerge during joint work.

2.4.2.1. H-R Interaction and Collaboration

Human–Robot Interaction (HRI) encompasses a broad range of research and design activities. While Human–Automation Interaction (HAI) has been explored for decades, and Human–Computer Interaction (HCI) is an established field, HRI remains comparatively less studied despite its growing relevance. There are four primary application domains for HRI:

human supervisory control, remote control of vehicles, automated vehicles with human passengers, and human–robot social interaction. The final category is most relevant here, as social robots can elicit seemingly “normal” human reactions yet may also risk reducing imaginative behaviour, particularly in children. HRI also faces challenges related to human factors, especially when robots are taught through master–slave dynamics, where asymmetry of control complicates ease of use and understanding. A persistent issue concerns the appropriate form a general-purpose robot should take, and whether humanoid morphology is desirable at all. In practice, robot form is usually determined by the task and context rather than by efforts to mimic human appearance (Sheridan, 2016). Most HRI research has been conducted within an anthropomorphic paradigm, assuming that robots should emulate human-to-human interaction. However, this paradigm has shown significant limitations. Many anthropomorphic robots are not optimised for human factors across diverse situations, and recognition technologies still fall short of supporting naturalistic anthropomorphic interaction. Consequently, when such robots fail to deliver the “human-like” responses their appearance promises, users often experience disappointment, confusion, or distrust (Park and Kim, 2009). As communication is fundamental in human–human interaction, and the same is true for Human–Robot Collaboration/Interaction (HRC/HRI). Effective cooperation requires the establishment of a shared mental model, supported by communication channels between human and robot. These channels include verbal, non-verbal, and multimodal forms of communication (Salehzadeh, Gong and Jalili, 2022). In order to evaluate interaction quality more systematically, ISO 9241 (2011) offers criteria relevant for different robot types, including learnability, efficiency, memorability, error reduction, and overall user satisfaction (Germak, Lupetti, Giuliano and Ng, 2015). Ultimately, in HRI the designer can affect five elements that affect interaction between robots and humans which are; the levels of autonomy, information exchange, team structure and role, adaptation with learning and training, and the shape of the task. All of these elements and the scope of the field geared towards dynamic interaction between the human and the robot (Goodrich, and Schultz, 2008).

2.4.2.2. Work-Space Relationship

The relationship between work and time is central to both HCI and HRI and is often framed within the concept of Computer-Supported Cooperative Work (CSCW), which employs a time–space taxonomy. This taxonomy categorises collaborative activity into four modes: Synchronous (same time), Asynchronous (different times), Collocated (same place), and Non-collocated (different places). CSCW also identifies several communication modalities, audio, visual, and document/data based which may be used individually or in combination. In HRI, however, this range expands to include additional modalities such as tactile and haptic feedback, reflecting the embodied and physical nature of human–robot

collaboration. In both multi-agent and single-agent systems, the nature of the task strongly influences the organisation of robot teams. Some tasks require coordinated action that can only be completed by a group of robots, while others are better suited to a single agent. Multi-robot teams can be classified according to factors such as communication range, communication topology, group size, bandwidth, reconfigurability, processing capability, and team composition. Task structure and reward mechanisms can, in turn, be defined by time constraints, performance criteria, target of action (e.g., robot movement, object manipulation), resource limitations, group mobility, and the physical capabilities of the platform. Other relevant considerations include task type, task criticality (ranging from low to high risk, including potential for human harm), robot morphology (anthropomorphic, zoomorphic, or functional), the ratio of robots to humans, team composition, and the required level of interaction. Figure 25 provides a useful framework for representing human–robot team configurations. In their diagrams, circles labelled H and R represent human and robot agents, respectively. Bidirectional arrows denote the flow of information and commands, where humans issue instructions, and robots return sensor data to maintain shared situational awareness of goals and tasks. Squares indicate that agents are part of a coordinated team rather than acting as independent units (Yanco and Drury, 2004).

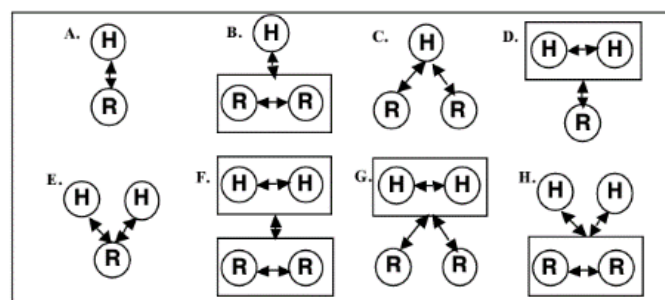


Figure 25 – Human-Robot arrangement by number and isolation, (Yanco and Drury, 2004)

Although multi-robot or multi-agent systems are difficult to design due to the complexity and variability of possible configurations, biological group behaviour can provide useful inspiration. Such systems often exhibit characteristics including appropriate inter-agent spacing, local communication, the sharing of goal locations, and coordinated orientation toward a shared objective. Tasks that are well suited to multi-agent robotic systems are typically those that can be decomposed into separate but related sub-tasks. In this context, the nature and importance of the task fundamentally shape system design, while factors such as communication structure, team composition, and reconfigurability determine the system's overall performance and characteristics (Dudek, Jenkin, and Milios, 2002). These work relationships between humans and robots are commonly categorised into four types: cell, coexistence, cooperation, and collaboration. In a cell arrangement, the robot operates within a restricted, caged zone inaccessible to humans, and the tasks of human and robot are entirely unlinked. Coexistence allows humans and robots to occupy the same

workspace but without physical contact; safety sensors typically halt the robot when a human approaches, and again, tasks are not interconnected. Cooperation involves linked tasks and permits human–robot contact, although contact is not necessary. The robot operates at limited speed, similar to coexistence arrangements. Collaboration, however, is the only category in which humans and robots work simultaneously on the same task, often with regular physical interaction enabled through hand-guided control mechanisms and similarly reduced operating speeds (Kopp, Baumgartner and Kinkel, 2021). These four modes of interaction are widely cited in literature, including in Hentout et al. (2019) and related studies.

Ellis, Gibbs, and Rein (1991) introduced the concept of a time–space taxonomy in the context of groupware systems, computational tools, implemented in software or hardware, designed to support interaction among multiple users engaged in shared tasks. These systems are premised on the idea that social structures are shaped by patterns of human interaction. Within collaborative environments, groupware supports three core forms of group activity: communication, coordination, and collaboration. Groupware can be further categorised according to whether interaction occurs in real time or asynchronously. Effective augmentation of collaborative work requires an appropriate balance between social processes and technological structures, as these systems are inherently multi-dimensional. One key dimension is task commonality, which describes the extent to which users engage in shared work: low commonality involves users working independently on separate tasks, whereas high commonality involves users jointly participating in the same task. A second-dimension concerns environmental cueing, referring to the degree to which the system provides shared contextual information about group activity. Low environmental cueing results in minimal feedback about others' actions, while high environmental cueing supports awareness through clear indicators of shared states and interactions. The time–space taxonomy further classifies groupware according to whether users are co-located or distributed in space, and whether they interact synchronously or asynchronously in time. Overall, collaborative systems should be designed to support socially meaningful interaction, emphasising the importance of sociologically informed design principles in the development of groupware (Ellis, Gibbs, and Rein, 1991).

2.4.2.3. Communication Channels and Cues

The design of collaborative robots is seen as the most challenging system to tackle. Particularly in industrial settings due to the complex tasks and work environments. As such they usually have 7 Degrees-of-Freedom (DoF). They tend to have one or multiple users which requires processing of human actions, behaviours, gesture, tone, and expression. These social elements result in relationships that can be affected by the robot's morphology, behaviour, and reactivity to human actions, expression and behaviour (Hentout, Aouache,

Maoudj and Akli, 2019). Although drawing more from Human–Human Collaboration (HHC) models, three components are essential: communication channels (audio, visual, environmental), communication cues (verbal and non-verbal), and the technological affordances that shape how these cues are transmitted. The environmental channel encompasses the surrounding world; the audio channel includes speech and sound; and the visual channel covers gestures, gaze, and physical actions. Technologies mediating these channels vary in their ability to support collaboration, and analysing each channel can help identify what is required for an effective HRC system. Such a system must recognise and generate verbal language, detect and interpret human non-verbal cues, express its own non-verbal signals naturally, recognise objects and understand how humans interact with them, and perceive spatial relations. HHC relies heavily on face-to-face cues and engagement with shared objects, though non-verbal cues are only meaningful when contextualised by speech, for example, deictic gestures. Gaze behaviour is particularly important in conveying attention, emotional state, conversational flow, and relational cues. Other forms of non-verbal communication, such as force feedback (FF), play a key role in teleoperated and remote-controlled robots, enhancing intuitive control, reducing mechanical strain, and improving performance. When robots express themselves through robot-appropriate cues, rather than simulating human behaviour in a misleading way, communication clarity improves. Nonetheless, incorporating aspects of humour, emotion, gesture, gaze, and directional movement can significantly enhance collaborative interaction, as humans naturally rely on these behaviours to resolve ambiguity and maintain mutual understanding (Green, Billingham, Chen and Chase, 2008).

2.4.2.4. Social and Aesthetic Dimensions

The size and scale of a co-bot also influence human perception during collaboration. Although physical size does not directly affect perceived workload, which correlates more strongly with task complexity, larger co-bots tend to be perceived as safer, more natural, more efficient, and more fluid. They also slightly reduce stress during complex tasks. As well as movement speed contributing to perceived helpfulness, fluidity, and efficiency. Interestingly, during assembly tasks, users tend to focus primarily on the end-effector rather than the robot's overall size (Gervasi, Capponi, Mastrogiacomo and Franceschini, 2024),

Some researchers argue that collaborative robots must also become social because they operate within human social environments (Fischer, 2019). These social robots, or “so-bots,” are capable of autonomous social behaviour and decision-making. Although co-bots and so-bots are often treated as distinct categories, collaboration inherently contains social components, making these typologies deeply interconnected (Cusano, 2022). Social robots may be defined by the presence of a social interface, which in turn is tightly coupled to the

aesthetics of the robot's form. In this respect, they possess social functions, a social form, and a social context (Hegel et al., 2009). Social robots are widely used across domains such as healthcare, therapy, public services, education, and domestic settings. The appearance of social robots significantly shapes perceptions of human likeness as well as expectations of robot competence. Simply adopting a humanoid form is insufficient and often counterproductive, as technological limitations lead to disappointing user experiences. Therefore, the aesthetics of social robots must reflect not only their social and behavioural functions but also their context of use and their practical requirements (Leite, Martinho and Paiva, 2013).

2.4.3. HR – Practical Level (BLUE)

Finally, the practical level consists of the actual robotic elements, the directly tangible components that give rise to the complex relationships within human–robot interaction.

2.4.3.1. *Industrial Robots and Framework*

Robots themselves are devices that can be reprogrammed and has multifunctional manipulators designed to move matter and items through programmed motion for different tasks (Considine and Considine, 1986). Framed by the industrial revolutions that illustrate the changes in production and automation. The first revolution shifted from manual labour to machine and steam power. The second introduced production lines and electricity, significantly increasing productivity. The third applied computers and communication technologies, enabling automation. The fourth revolution combined cyber-physical systems with intelligent decision-making, flexible production, and high-quality personalised mass production. Industry 5.0 extends this by explicitly incorporating human values into industrial production (Xu, Lu, Vogel-Heuser and Wang, 2021). From a practical perspective, industrial robots have proven useful in executing heavy and repetitive tasks, removing labour from humans. The design of industrial robots can be traced through multiple generations. The first generation (1950–1967) was programmable but lacked the ability to change modes or communicate externally. The second generation (1968–1977) remained programmable but included adaptive behaviours to respond to the external environment. The third generation (1978–1999) enabled greater user-robot interaction through complex interfaces and introduced limited self-programmability. The fourth generation, beginning in 2000 and continuing today, incorporates high-level intelligence, deep learning, and collaborative capabilities (Gasparetto and Scalera, 2019). These industrial robots are typically application-specific, large, heavy, and rigid. These generations related to the industrial revolutions.

The term “Industry 4.0” was first used at the Hannover Fair in 2011 (Vogel-Heuser and Hess, 2016). Although related, Industry 4.0 and the fourth industrial revolution are distinct: 4.0 was a German initiative from 2011–2015 that gained international attention

through Klaus Schwab's book *The Fourth Industrial Revolution* (Thomas and Nicholas, 2018). Industry 5.0, introduced by the European Commission in 2021, emphasises human-centric, resilient, and sustainable industrial systems (Breque, De Nul and Petridis, 2021).

2.4.3.2. Collaborative Robots

Robotics has changed manufacturing, but flexible solutions remain a continuous problem. Industrial robots are still programmed for singular tasks. Alternatively, collaborative robots are more adaptable to tasks that change regularly and can be programmed through human demonstration (Kragic, Gustafson, Karaoguz, Jensfelt and Krug, 2018). This new counterpart, the collaborative robot, is designed specifically to work alongside humans (Sherwani, Asad and Ibrahim, 2020). Similarly, Industry 5.0 emphasises human-robot collaboration rather than competition, where robots assist with repetitive tasks or provide cognitive support through artificial intelligence (Akundi et al., 2022). Industry 5.0 technologies and social systems can work together to deliver mass-produced, personalized products and services. By using information inputs such as observation, data exchange, and intelligent agent interpretation, robots collaborate symbiotically with humans, forming collaborative robotics or "Co-Botics/Cobots." These systems are designed to enhance productivity but also introduce challenges such as cybersecurity risks and potential human isolation, necessitating careful socio-technical planning (Bednar and Welch, 2020). Compared to traditional industrial robots, co-bots are increasingly favoured due to their lower cost and their ease of integration into existing workflows without substantial system redesign. They leverage a synergy between robotic strength and human sensitivity and dexterity, enabling a hybrid capability that is difficult for either agent to achieve alone (Pizoń, Cioch, Kański and Sánchez-García, 2022). The concept itself of collaborative robots or "co-bot," was invented by J. Edward Colgate and Micheal Pashkin in two papers from 1996 and 2001. The stated forms of these original co-bots are vastly different from current designs. In a qualitative evaluation of suitable task for human operators and robotic systems, the human operators were best suited for lower weight, highly dexterous, and/or flexible tasks. As human like dexterity and flexibility may be an unreachable characteristic for traditional robots. Whilst collaborative systems combine the dexterity of humans the robot's repeatability (Matheson, Minto, Zampieri, Faccio, Rosati, 2019). Originally Colgate, et al. (1996) defined a co-bot as:

"a robotic device which manipulates objects in collaboration with a human operator. A co-bot provides assistance to the human operator by setting up virtual surfaces which can be used to constrain and guide motion."

(Colgate, et al., 1996, pp.1)

They state that co-bots are passive devices with non-holomorphic (velocity constraint) joints which makes them useful for tasks that require safety. Their design was a single joint that is a wheel that can be controlled (See Figure 26). Their first design was a unicycle constrained on an x and y frame with a handle to move it around. It had two modes; Mode one was the “virtual caster” when the wheel would know the direction of the forces it was being pushed in and orient the wheel in that direction. This means that the co-bot felt like a free-floating point that can be moved in any direction in the plane. Mode two was the “virtual wall” where when the computer sensed the co-bot wheel would ‘hit’ a virtual wall the wheel would be turn tangentially to the constraint and forces that further push the wheel into the constrain where counteracted by the system. Their second design was only drawn, and it was a bicycle with independent wheels. They considered that any motion of the wheels was as a rotation around a centre. That format could have allowed for better orientation control. They aimed to add a third wheel whose shaft is not collinear with the other two. This would have made the design statically stable, and the frame would become unnecessary (Colgate, Wannasuphoprasit and Peshkin, 1996).

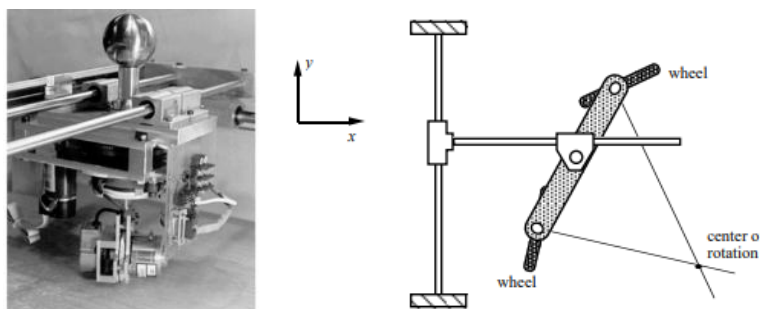


Figure 26 - First Cobot Prototype (Left), Other Cobot Design (Right), (Colgate, Wannasuphoprasit and Peshkin, 1996)

Modern co-bots conform to ISO EN 10218 and other recommendations in ISO/TS 15066. Therefore, they do not have a different morphological design from industrial robots. These ISOs define four types of Human-Robot Collaboration (HRC) in a workspace where; ‘Safety-rated Monitored Stop’, is when the robot stops moving as soon as a human is in its’ workspace. A more interactive mode is ‘Hand Guiding’, where the human can move the robot as desired, and the robot does not initiate movement. These are typically fitted with extra sensors and a dead man’s switch. ‘Speed and Separation Monitoring’, is when the workspace around the robot is divided into multiple areas which have sensors and visions systems in them. The most integrated form of physical collaboration is ‘Power and Force Limiting’, which is a type of HRC that requires special collaborative robots where their motion is monitored precisely so that even minute deviations from the programmed path can be detected, as well as changes in speed, force, and torque. This allows the co-bot to detect impacts into and obstacles in a short period of time, stop after impact and even avoid one. Co-bots are limited to around 10kg or load and a speed of 250mm per second. Therefore,

designs can be made lightweight, which in turn reduces damage from impacts. Additional passive safety measures may include rounding off forms and eliminating pinch points where fingers could become trapped due to movement or rotation. Surfaces can also be fitted with soft plastic shells or covered with foam to better absorb impacts, while cables and pressurised hoses can be integrated internally or safely enclosed within the cobot structure. In this context, collaborative robots (cobots) expand the range of robotic applications rather than replacing non-collaborative industrial robots (Vysocky and Novak, 2016).

Today, collaborative robotics are seen as robotic systems designed to operate in close physical proximity to humans within a shared workspace. Collaboration is often organised according to the temporal structure of the task, whether the robot and human work continuously, synchronously, alternately, or in other coordinated modes. The fundamental purpose of co-bots is to support and enable humans in performing tasks that would be difficult or impossible to accomplish otherwise. As such, they can enhance workflow flexibility, improve output quality, and offer cognitive and ergonomic benefits, among other advantages. Although the term co-bot did not exist at the time, earlier studies in the 1980s explored interaction control in robotic systems (see Ref. 3–11 in Vicentini, 2021). These works effectively laid the foundations for contemporary collaborative robotics by introducing principles such as force control, compliant actuation, and related interaction mechanisms. In modern contexts, the design of co-bots requires comprehensive risk assessment to evaluate both physical and cognitive interaction demands. Physical Human–Robot Interaction (pHRI) is typically restricted to low-powered tasks, and contact-based interaction is divided into accidental and intentional contact. Accidental contact mainly requires safety measures, whereas intentional contact demands more detailed consideration of the system’s mechatronics and control strategies. Ultimately, the form and degree of human–robot interaction depend on the collaborative task structure (Vicentini, 2021).

2.4.4. Discussion on Humans and Robots

Recent interactions between human culture and technology have, at times, involved the use of misleading representations of technological systems, which may contribute to processes of dehumanisation. Avoiding such practices could support a more open, equitable society. The approach of addressing this is through greater transparency in technology design, could ensure that devices are understandable, adaptable, and that their aesthetic presentation accurately reflects their underlying functionality. This raises a key ethical concern in robot aesthetics research: the use of pleasurable user experiences to generate trust without sufficient basis in truth or transparency. While anthropomorphising objects has historical precedent, sometimes expressed through divine or spiritual interpretations in ancient religious contexts, contemporary technological developments, alongside a broader

cultural shift from utopian to dystopian (as exemplified in Čapek's work), complicate this framing. In this context, automation should be understood as a constructive extension of human will and intention, rather than as a mechanism for waste, deception, or the erosion of human value.

Essentially, co-bots were originally conceived by Colgate, Wannasuphoprasit and Peshkin (1996) in research as intelligent tools designed for specific industrial tasks that assisted human control rather than as autonomous partners working alongside people. Early concepts even relied on the human operators as the primary energy source for moving the co-bot, instead of powering the system independently, an approach that made the device more intuitive and usable. Viewing co-bots as reactive robotic instruments driven directly by human intention gives them a far broader range of potential applications than the conventional, fully actuated robot arms that dominate industry today. Now rooted in ISO safety standards and derived from the morphology of traditional industrial robots. Today, however, the focus has shifted as the relationship now centres on the human user, the human's interactions with the robot, and the robot's responses to human action within a shared mental model of the task. This interaction unfolds within the established time-space framework of collaborative systems: Synchronous (same time), Asynchronous (different times), Collocated (same place), and non-collocated (different places). Remarkably, from Ellis et al. (1991) to the present, these same theoretical structures continue to underpin collaborative work. This means that more than thirty years of co-bot and groupware research has relied on an essentially unchanged conceptual foundation.

The industrial transitions from Considine and Considine, (1986), Xu, Lu, Vogel-Heuser and Wang, (2021) Gasparetto and Scalera (2019) in robotics can be understood as a progression from the automation of labour to the automation of movement, to the automation of information, and finally to the automation of interaction. Each industrial revolution represents not only a technological shift but also a transformation in how these technologies affect human life. The ".0" labels from Vogel-Heuser and Hess (2016), Thomas and Nicholas, (2018), and Breque, De Nul and Petridis (2021) can be interpreted as theoretical framings, Industry 4.0 and 5.0 were initiated as conceptual programmes by a nation-state and a supranational organisation respectively and later popularised through wider discourse. As Industry 5.0 explicitly aims to embed human-centric principles into robotics, its success would imply far greater robotic proliferation in everyday life. Consequently, robot aesthetics will significantly shape not only their technical performance but also their cultural acceptance and their perceived legitimacy as tools.

Given that modern co-bots, frequently exemplified by small, compliant industrial arms such as the UR5, are used in the vast majority of HRI and HRC studies, the field shows signs of theoretical and morphological stagnation. Research often tests only a single robot typology or form factor, leading to limited advances in theory, taxonomy, design, engineering, and philosophy. While this consistency allows for repeatable experiments and reliable comparisons, it also constrains innovation in co-bot morphology, interaction models, and aesthetic design. In effect, the tools have evolved, but many of the conceptual frameworks, and the forms of the robots themselves have remained largely the same. Following this, workspace relationships can be classified as cell, coexistence, cooperation, and collaboration. The communication model in Human-Robot Interaction (HRI) draws inspiration from Human-Human Collaboration (HHCo), where communication is mediated through verbal and non-verbal cues across available channels, audio, visual, environmental, documentation, and physical. These cues include dialectic gestures, gaze, speech, force feedback, tactile interaction, as well as robot-specific characteristics such as size, morphology, appearance, movement, speed, behaviour, emotions, and interface style. Interactions are shaped by human social behaviours, cultural context, the task, and the robot's intended purpose. Collaborative robots (cobots) can be understood as a specialised form of computer-based groupware, structured around particular temporal, spatial, and task-related relationships between humans and robotic systems if we apply the work of Yanco and Drury (2004), Dudek, Jenkin, and Milios (2002) Kopp, Baumgartner and Kinkel (2021) Ellis, Gibbs, and Rein (1991). However, unlike conventional groupware, cobot design must also incorporate social, cultural, and morphological factors that shape human–robot interaction. These additional dimensions influence not only the functional design of the system, but also the wider implications of the robot's form, behaviour, and presence for human experience, expectations, and patterns of interaction and communication. The work of Bryson (2009, 2010) and Oldfield (2023) show that historically, the elevation of objects to quasi-human status, whether divine in ancient religions or utopian/dystopian in literature, reflects the need to carefully consider how automation and robot aesthetics convey intent. Automation should serve to extend human will, not replace or undermine it. The considerations from Turing (1950/2007) and DeCanio (2016) also highlight the importance of designing robots as human-centred tools embedded within cultural and ethical frameworks, rather than as autonomous agents that dictate human behaviour. Culture is created by and for humans; therefore, robots should be understood primarily as tools that support cultural practices rather than as active participants in cultural formation. Given that the work of Berríos (2024), Van de Vliert (2007), and Woodward (2014) show the value of culture it would be beneficial to integrate robots in ways that respect and adapt to cultural and social dynamics, rather than dictate them, is therefore essential for creating harmonious and ethically sound human–robot

interactions. The work of Ornelas, Smith and Mansouri (2023) this stands in contrast to earlier computational systems, which often required users to adapt to the constraints of the technology rather than the technology adapting to human contexts.

Consequently, the design and appearance of a robot are strongly determined by its functional purpose. The work of Gervasi, Capponi, Mastrogiacomo and Franceschini (2024) suggest a “beast of burden” perception where usefulness outweighs morphology. Such considerations are closely tied to robot aesthetics. A robot is first understood as a system, which requires interaction, which in turn requires communication, which enables collaboration, and ultimately forms a relationship. The physical and non-physical qualities of these interactions, psychological, aesthetic, and environmental, affect task completion. However, it is important to note that these interactions are not truly social as robots are inanimate objects, and any apparent social behaviour is a conduit for communication or task facilitation. As Green et al. (2008) observed, objects can augment collaboration and provide information, but any “social” interaction is ultimately mediated by the human programmer or operator, not the robot itself. Therefore, the collaboration exists between humans, facilitated by the robot as a tool, rather than there being a social interaction with the robot. As such, it is valuable to view robots as human-centred tools, artefacts that extend and amplify human capability, accommodate user needs, and provide beneficial forms of automation. In doing so, they should support well-being and freedom of action and therefore remain ethically appropriate to the problems they are designed to address.

The focus here is on the aesthetics of robot design, including morphology, appearance, user experience, and intended function. Interactions with robots are primarily visually perceived and interpreted through meanings assigned by users, who are simultaneously pursuing specific goals. These perceptions are shaped by users’ emotional states and by how they interpret the robot’s purpose, whether practical, social, or cultural. Such factors are closely interrelated and influenced by the robot’s aesthetic qualities, underlying design philosophies, and the user’s own psychological and cultural context. In relation to robotics and aesthetics, the ways in which humans relate to robots are central to their ability to understand, use, and trust autonomous behaviours. Without accounting for these human factors, it would not be possible to design robots that are meaningfully usable in human contexts.

2.4.5. Contribution and Conclusion - Human-Robot Taxonomy

From the literature a taxonomical diagram of Robot Aesthetics can be created where the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE) for one whole in Figure 30.

Structuring this in **Error! Reference source not found.**, the abstract level starts with the 'History and Context', this section traces early conceptions of artificial beings, from myths and legends such as Prometheus and Talus to the development of automata and pneumatic devices in traditions often associated with 'automatopoietica', including Philo's mechanical maid. The term 'robot' itself originates from the play *R.U.R.*, derived from the Slavic word *robota*. This leads into 'Culture and Technology', where societal perceptions of robots are shaped by cultural narratives and early aesthetic imaginings of artificial agents. Positive cultural depictions of technology can influence acceptance, while culture simultaneously shapes and is shaped by technological environments. This reciprocal relationship affects both social and aesthetic evaluations of robots, including what is considered acceptable, ethical, or desirable. Within 'Conceptual and Ethical Views', robots are framed either as tools or as quasi-slave-like constructs, reflecting tensions between human-centred design and dehumanisation. Issues such as transparency versus the "illusion of sympathy" (e.g., systems like Alexa or Siri) become central to questions of trust. Concerns about automation and potential human replacement further inform ethical frameworks, guiding priorities such as safety, autonomy, transparency, and trust.

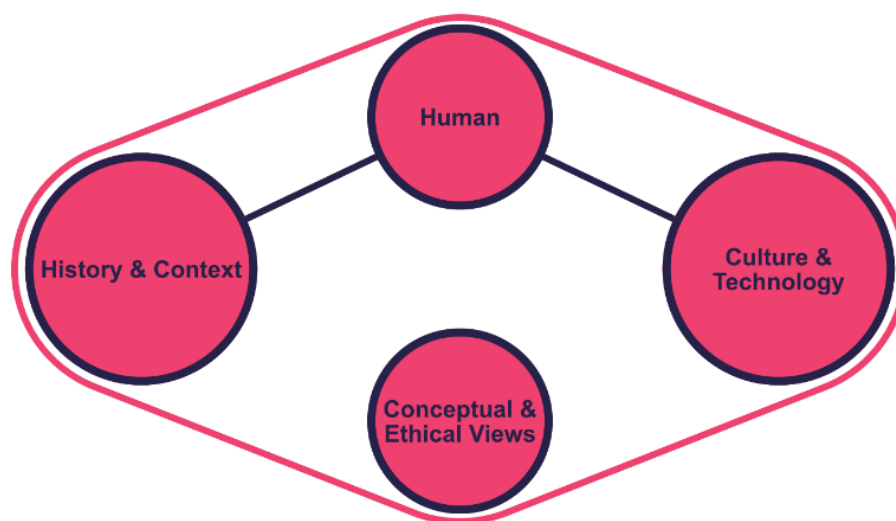


Figure 27 - Human-Robot - Abstract Level

The analytical level in Figure 28, starts with 'Human–Robot Interaction and Collaboration', attention shifts to physical human–robot interaction (pHRI), including contact modes, morphology, and degrees of freedom (DoF). These elements define the practical implementation of safety, ergonomics, and real-time interaction within shared human–robot workspaces. The 'Work-Space Relationship' categorises levels of interaction as cell (caged robots), coexistence (sensor-based stopping), cooperation (linked tasks with limited contact), and collaboration (simultaneous work with physical contact). These categories define spatial and temporal modes of human–robot collaboration (HRC), shaping safety requirements and

interaction design. In ‘Communication Channels and Cues’, interaction is mediated through channels such as audio, visual, environmental, documentation-based, and tactile/haptic modalities. These are supported by verbal and non-verbal cues, including gestures, gaze, and force feedback, as well as multi-agent communication structures. Together, these enable coordination, shared mental models, error resolution, and situational awareness in HRC systems. These systems also influence and are influenced by the ‘Social and Aesthetic Dimensions’, which crosses all three levels, where the function and context of social robots (e.g., healthcare, education, domestic environments) shape morphology, appearance, behavioural cues, and movement characteristics. In turn, these factors affect user perception, trust, emotional engagement, and acceptance, feeding back into ethical and design decisions. Within this conceptual framework, system-to-relation structures organise interaction, communication, and collaboration into a hierarchical model that clarifies interdependencies in human–robot relations.

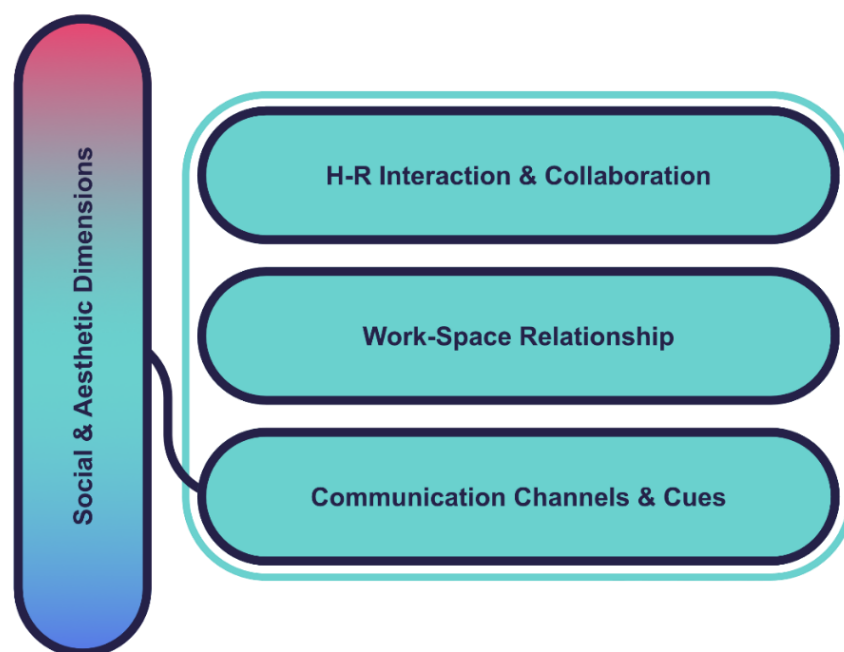


Figure 28 - Human-Robot - Analytical Level

The practical level in Figure 29, has ‘Industrial Robotics and Frameworks’ situate these developments within generational progress from Industry 1.0 to 4.0 (cyber-physical systems) and Industry 5.0 (human-centric, resilient, and sustainable systems). This provides the technological context and capability trajectory enabling new forms of human–robot collaboration. Then the concept of the ‘Collaborative Robot’ (cobot), originally defined by Edward Colgate and colleagues (1996), is operationalised through ISO-standard HRC modes: monitored stop, hand guiding, speed and separation monitoring, and power and force limiting.

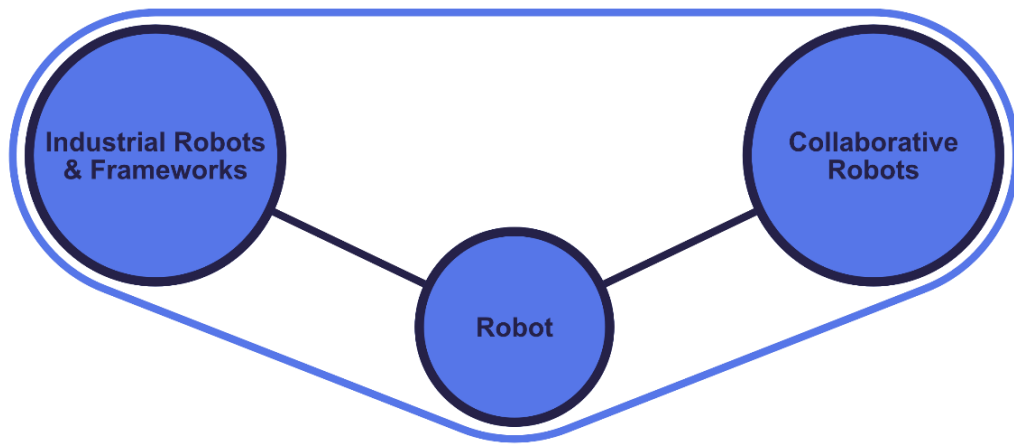


Figure 29 - Human-Robot - Practical Level

All these components are organised through a taxonomical diagram that moves from the more cultural and human aspect to the relational to the practical and robotic aspects (See Figure 30). It synthesises the preceding discussion by structuring human–robot relations into three interrelated layers: the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE). It clarifies how each component influences the others, forming a coherent structure for analysing and designing human–robot interaction.

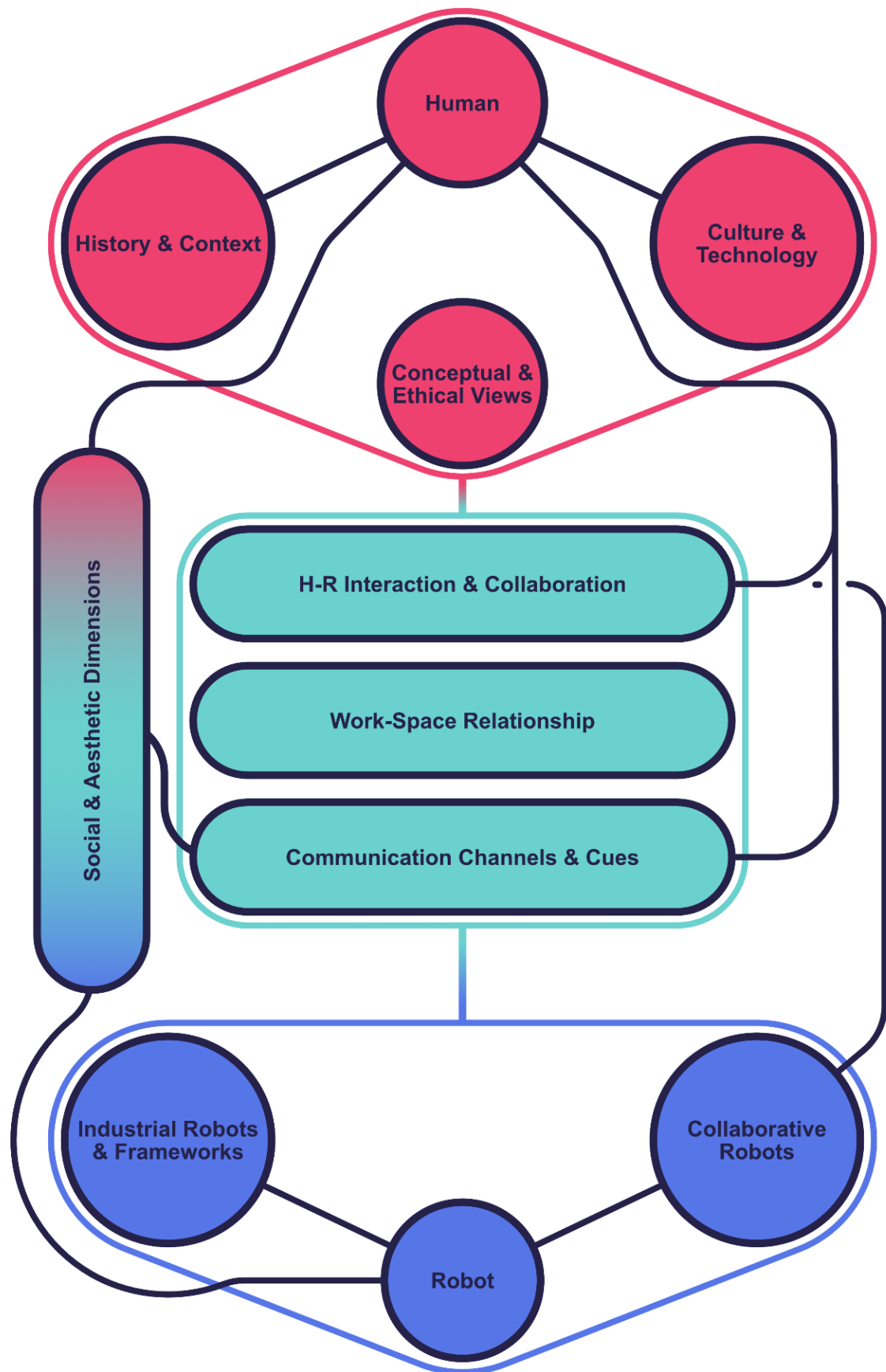


Figure 30 - Human-Robot Taxonomy Diagram

2.5. Robot Aesthetics

Building on historical and cultural understandings of human–robot relationships and interaction, the discussion can now turn to robot aesthetics in greater detail. This section focuses on styling and morphology as key areas for developing a more coherent framework for robotic form.

2.5.1. RA – Abstract Level (RED)

Firstly, the abstract level concerns the core aesthetic principles of robot aesthetics which ties to the related areas of the ethical contexts, and cultural and historical influences.

2.5.1.1. Core Robot Aesthetic Principles

When robots were first conceived, their design typically imitated biology, particularly through anthropomorphic forms, with the earliest examples being robotic anthropoids. Today, robots increasingly employ “synthetic aesthetic languages”, designed around their specific context and function. Given the growing prevalence of robots in everyday life, the relationship between robotic devices and humans requires careful investigation, particularly about the ethical dimension, which should prioritise outcomes that are beneficial for humans. Humans can be understood as having three fundamental dimensions: biological, social, and ethical, which together generate a rich cultural life. Therefore, in HRI, it is essential to convey why humans might accept or engage with a robot. Initial contact is often shaped by the robot’s expressive or aesthetic qualities, which precede usability considerations. Key factors in HRI include advantage, compatibility, complexity, trialability, observability, and physical appearance. Robots can be broadly classified into two morphological types: mechanical and anthropomorphic. Mechanical robots, in their pure form, are performance and functionality focused, whereas anthropomorphic robots, designed with human-like features, tend to elicit more empathetic interactions from humans. The interplay between acceptance and expressiveness in robots is primarily influenced by three factors: Facial expression, enables the robot to convey emotion, personality, and intent, improving engagement. Fluidity of movement, smooth, adaptable articulation avoids a mechanistic feel and allows responsive interaction with the environment. Formal synthesis, the form communicates the purpose and functionality of the robot, integrating design with meaning (Germak, Lupetti and Giuliano, 2015) (Figure 31).

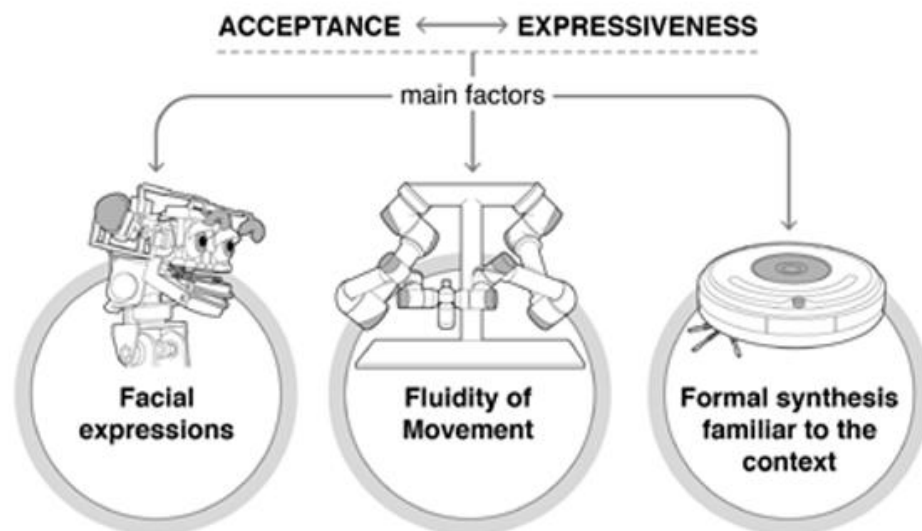


Figure 31 - Expressiveness and Acceptance, (Germak, Lupetti and Giuliano, 2015)

The human element of HRI has evolved to interpret and react to sensory cues that affect our thinking and emotions. The aesthetics of the objects that elicit affective responses have a great impact on the level of trust a human has with a robot. A lack of trust can result in the robot never being used. Pursuing the expression of aesthetics of robots can create an emotional connection, for example, cartoon designs foster further trust. Other design elements also affect the aesthetic of the interaction. Such as colour, design elements, and design principles, which will all further change the level of trust (Pinney, Carroll and Newbury, 2022). This aesthetic perception and sense of trust relate to the uncanny valley, first proposed by Masahiro Mori in 1970, remains influential in human-robot interaction. It suggests that as a robot becomes more human-like in appearance and movement, positive emotional responses increase proportionally until a sudden drop occurs, resulting in negative affect. In some cases, this drop may be permanent, never reaching the level of emotional response elicited by a real human. This phenomenon may relate to framing theory, whereby humans rely on past experiences and contextual memory to interpret unfamiliar environments (Bartneck, Kanda, Ishiguro and Hagita, 2007). As such, robots can also be used as tools to study social cognition. For example, human stereotype agents, such as software or baby-faced robots, are perceived as more sociable. People attribute different knowledge, personalities, or capabilities to robots depending on perceived traits such as nationality, gender, or vocal intonation. There is also a tendency for similarity attraction, where users are drawn to robots that share physical or behavioural characteristics with themselves. However, robots designed with a singular, fixed characteristic (e.g., a perpetually cheerful robot) may eventually fatigue human social stereotyping, as the initial social narrative breaks down over repeated interactions. This meaning-making process is well illustrated through studies such as the Heider-Simmel film, mentioned previously, where

humans construct social narratives from movement patterns. Altering the presentation of the film (e.g., reversing it or changing the speed) disrupted the perception of intentionality and social meaning, highlighting that humans actively construct social understanding from observed behaviours. Within this framework, humans tend to anthropomorphise objects and animals they prefer, and they favour physical, embodied entities over virtual projections, as the presence of a real agent is physiologically arousing and facilitates social interaction. Furthermore, humans process three-dimensional, embodied structures differently from two-dimensional representations, emphasizing the importance of tangible, physically present robots in social contexts (Kiesler, et al., 2008).

2.5.1.2. Cultural and Philosophical Influence

Postmodernism has prevented the establishment of universal guidelines for aesthetics, yet aesthetics remains crucial for the societal acceptance and success of a technology. Earlier movements, such as Modernism, promoted clear rules. Forms should be geometric, clean, and efficiently convey function. In contrast, Postmodernism, emerging in the 1980s, emphasised culture and emotion in product design from the work of Krippendorf, while the 1990s added psychological perspectives on emotional experience from the work of Desmet. More recently, the concept of product experience has extended to pleasurable interactions, enabled by advances in technology that allow almost any form or interaction to be created. Consequently, achieving consensus on aesthetics remains elusive. Aesthetic theory now suggests a contextual approach, where a general theory can be adapted to specific design situations. Despite significant efforts by roboticists, large-scale social and domestic use of robots has largely been unsuccessful, with the notable exception of automated vacuum cleaners. Ultimately, how products are shaped greatly affects user perception, yet it is also influenced by culture, context, and the designer's intentions. Given the inseparability of humans and technology, effective integration should leverage the value of both the human and the technology. Successful technological diffusion aligns with the prevailing philosophy of technology over time and reflects the dominant design movements, which are typically optimistic and visually expressive. However, design movements are only recognised retrospectively (Eggink and Snippert, 2017).

As design has historically been successful in translating abstract philosophical and ethical ideas into tangible products, providing insight not only into functional form but also into the conceptual inspiration behind the object. This process allows designers to embed meaning, emotion, and societal or cultural significance into the artefact. For instance, when students develop projects grounded in societal issues, their work tends to be idea-driven rather than object-driven, producing outcomes that communicate purpose and intention more effectively (Eggink, 2008).

2.5.1.3. Techno-mimesis and Ethical Context

Given the complexity of the artificial and technological world and its further incorporation into the human and social world there is a need to become more concerned with balancing and creating a safe relationship between human and technology (Piebalga and Yung, 2014). With that, technological development often produces ethical issues that were not initially anticipated, and artefacts exert influence across the technological, biological, social, and semiotic worlds of both individuals and their environments. Ethical dilemmas emerge at the interface between the individual and their environment, where human moral action and technological action intersect (Findeli, 1994). These ethical challenges are directly shaped by the morphology, appearance, and behaviour of robots, as their form influences human perception, trust, and engagement. The Care-Centred Value-Sensitive Design (CCVSD) approach provides a framework to address such ethical challenges by embedding human values, wellbeing, and care considerations into the design process (van Wynsberghe, 2012).

Although anthropomorphism, both in physical appearance and behaviour, remains the most common approach in current robot design, it is often followed by biomorphism. While these strategies can support intuitive interaction, they may also constrain exploration of the distinct capabilities and social functions of robots. Unlike humans, robots are artefacts whose functions and behaviours can be intentionally designed beyond human limitations and, in principle, without fixed bounds. Humans tend to form embodied relationships with technology in two primary ways. The first is as an extension of the self, where tools become incorporated into bodily experience. The second is through an alterity relationship, in which humans engage with the robot as a distinct “other” in a form of quasi-dialogue. The latter is more prevalent in human–robot interaction (HRI), as design often leverages perceptual and cognitive cues that encourage users to attribute lifelike qualities to machines. In both human–computer interaction (HCI) and HRI, it can be more productive to distinguish the respective strengths of humans and robots rather than attempting to make robots imitate human behaviour. One methodological approach for this is ‘Techno-Mimesis’ (Figure 32), which uses deliberate, imperfect imitation as a way of exploring the capabilities of different entities, originally developed in animal studies. In design contexts, techno-mimesis employs prosthetic or simplified mock-up systems that embody selected abilities of both humans and technologies. This enables designers to explore the strengths of each agent, envision novel forms of interaction and behaviour, and develop more holistic understandings of hybrid human–technology experiences. Through this method, designers can also experiment with performative embodiment, including emotion, physicality, and perceptions of time, space, and behaviour (Dörrenbächer et al., 2020).



Figure 32 - Techno-mimesis, (Dörrenbächer, et al., 2020)

2.5.2. RA – Analytical Level (GREEN)

The analytical level focuses on the categorical elements of robot aesthetics particularly the morphological and styling categories.

2.5.2.1. Morphologies and Stylings

Robotics has now entered the morphological paradigm, following the previous focus on artificial intelligence and efficiency. In this paradigm, the body of the robot becomes central, and factors such as interaction, psychology, and evolutionary principles play a crucial role in both design and use. The concept of form is key, encompassing the robot's exterior appearance, flexibility, materials, morphology, and how it interacts with the world and users. Symbolic and representational approaches are increasingly questioned, and the variety of designs and methodologies has dramatically expanded, making this paradigm epistemologically significant and a focus for innovation (Freyberg and Hauser, 2023). From soft robotics to robots inspired by biological organisms, morphology informs both structure and behaviour, from locomotion to sensory systems that mimic perception (Song and Zhao, 2024). As such robots are taxonomically classified by morphology, which dictates their architecture, mobility, kinematics, interaction capabilities, and sensor placement. Common categories include bioinspired, humanoid, wheeled, legged, and domain specific designs, each optimized for specific tasks and environments (Ryalat, Almtireen, Al-refai, Elmoaqet and Rawashdeh, 2025). These robot morphologies can be defined as zoomorphic, caricatured, functional and anthropomorphic and embody different perceived purposes as users will initially treat the robot based on what it looks like (Fong, et al., 2003).

The morphology of a robot can be categorised according to the inspiration for its design: Artefact-shaped: Inspired by human-made tools or objects. Functional: Designed primarily around performance constraints. Bioinspired / biomorphic: Derived from natural

organisms, often called zoomorphic when inspired by animals. Bioinspired robots can take cues from humans, animals, plants, or fungi. Anthropomorphic designs can elicit empathy and social engagement, but overly realistic forms risk unrealistic social expectations or the uncanny valley effect. Similarly, zoomorphic robots vary in familiarity as a dog-like robot is easily anthropomorphised and can foster bonding, while a more unfamiliar animal (e.g., a seal) can evoke curiosity or caution. The interaction quality depends on this balance between familiarity and novelty, as well as technological limits that may prematurely end engagement (Löffler, Dörrenbächer and Hassenzahl, 2020). Following this, a robot's appearance or aesthetics can vary widely depending on its purpose, with elements such as size, shape, and colour playing a key role in user perception (Hiroi and Ito, 2008). Users tend to focus on the overall form and salient features such as what are perceived as "eyes." With that, anthropomorphic designs are often experienced as being more comfortable compared to traditional industrial robots, as humanlike characteristics, such as intent, personality, or mood, are attributed to these robots. This allows users to build a relationship with the robot, perceive it as possessing "good" or "bad" human traits, and approach problem-solving collaboratively, leveraging the robot's perceived social capabilities. Importantly, these attributions and interactions are shaped primarily by the robot's morphology and behaviour, though in many studies only anthropomorphic robots have been examined (Sauppé and Mutlu, 2015). Given that the aesthetics of robots deeply affects their ultimate success of their deployment. Identifying fundamental principles of robotic aesthetics is needed. One range is from abstract to realistic humanoid robot head forms. More realistic humanoid designs can appear like "dead matter" due to the movement not matching the appearance. As such, more appropriate aesthetics and their skilful execution result in fuller engagement and successful deployment of the robot. This theoretically replaces the uncanny valley with the theory of paths of engagement, as the uncanny valley could be seen as poor execution of the aesthetic intent (Hanson, 2006). Two design principles affect the resultant design of an anthropomorphic principle being positive (the form having human qualities) and the other principle being negative (the association of human-like qualities onto non-human objects). These are inseparable to the aesthetic perception of robots and that in turn are inseparable from the social perception (Tondou and Bardou, 2009).

Linked to this is that humans have a natural tendency to anthropomorphise objects, which can be explained by two complementary theories. The rational theory of pareidolia suggests that humans understand the world by relating unfamiliar stimuli to known forms. The emotional theory posits that anthropomorphism arises from humans' inherently social nature and a need to reduce perceived threats. Both theories are rooted in self-perception and social cognition. In the context of robotics, this tendency contributes to phenomena such as the "uncanny valley," where highly representational faces appear artificial and elicit

negative emotional responses from users. To analyse robotic aesthetics, six categories of robot types have been proposed: *Functional*, designed for a precise, typical industrial purpose. *Assistant*, often zoomorphic, acting as a cute companion. *Humanoid*, uses simple forms to allude to human morphology. *Android*, complex humanoid design that remains visibly mechanical. *Uncanny*, attempts realism but fails aesthetically or in motion, generating discomfort. *Cyborg*, hybrid of human and mechanical elements with an overall human-like quality (Wodehouse, et al., 2018). In anthropomorphic design, high levels of detail and geometric complexity are often associated with perceived intelligence and functional sophistication, whereas roundness and softness tend to evoke feelings of cuteness. Anthropomorphism can be understood as encompassing both the physical form and behavioural qualities of a robot, and may be analysed along two dimensions: seduction, where anthropomorphic features are used primarily as a persuasive device to encourage use or purchase regardless of functional relevance or user experience; and fulfilment, where anthropomorphism is meaningfully integrated with purpose, supporting appropriate understanding and more grounded engagement with the product. Within design practice, four main functions of anthropomorphic form have been identified: *keeping things the same*, where existing conventions are maintained; *explaining the unknown*, where anthropomorphic cues help introduce and clarify unfamiliar functions or technologies; *reflecting product attributes*, where form and behaviour are structured according to how the object operates; and *reflecting human values*, where design expresses sociocultural meanings and the human context of use (DiSalvo and Gemperle, 2003). Alongside anthropomorphism there are also soft biomorphic designs, a class of robots inspired by the visual, material, and kinetic qualities of soft natural organisms, generates positive emotional responses and new design opportunities. These robots leverage compliance and tactile affordances to enhance human interaction (Christiansen, Rafsanjani and Jørgensen, 2024).

Beyond fixed morphologies, evolutionary robot design explores autonomous adaptation of both hardware and software. Robots can evolve their morphology, actuation, and behaviour to optimise task performance or user interaction (Jelisavcic, et al., 2017; Doncieux, et al., 2015). This approach can be applied to their design where the complexity of robot design in achieving behaviours of a can be done in seconds through computerised evolution (Matthews, et al., 2023). Some designs are more amorphic or polymorphic, capable of dynamically changing shape to meet user needs or environmental demands, enhancing perceived usefulness and attractiveness (Colle, 2020). See Figure 33, for images of different robot morphologies collected from Gao, et al. (2019), Złotowski, et al. (2015), Gasparetto, et al. (2019). A mixture of both styling and morphology is the design-centred evaluative framework where their classification are on five bipolar dimensions but with more abstract terms as sub terms; Form (abstract, biomorphic, anthropomorphic), Modality (unimodal,

multimodal), Social norms (No knowledge, minimal knowledge, full knowledge), Autonomous (no, some, full), and Interactivity (no, some, full) (Bartneck, and Forlizzi, 2004)



Figure 33 - Robot Morphology Examples, Top Row (Gao, et al, 2019), Middle Row (Złotowski, et al., 2015), Bottom Row (Gasparetto, et al., 2019)

2.5.3. RA – Practical Level (BLUE)

The practical level of robot aesthetics, although shorter, focuses on the results of the materialist and movement of the robots (See Figure 37).

2.5.3.1. Material and Kinetic Aesthetics

The material qualities of a robot play a critical role in its aesthetic perception and interaction potential. For example, soft robots are often perceived as less “natural” than mechanical designs, potentially due to the lack of visible mechanisms. However, their softness encourages human touch and interaction, creating opportunities for engagement that rigid designs may not afford (Jørgensen, Bojesen and Jochum, 2022) (See Figure 34 for examples). As kinetic agents, robots can use motion to communicate intent, convey emotions, and influence user empathy. Pneumatic systems in soft robots, for instance, can transmit meaning through kinaesthetic cues, shaping user perception of emotion and purpose (Christiansen, et al., 2023).

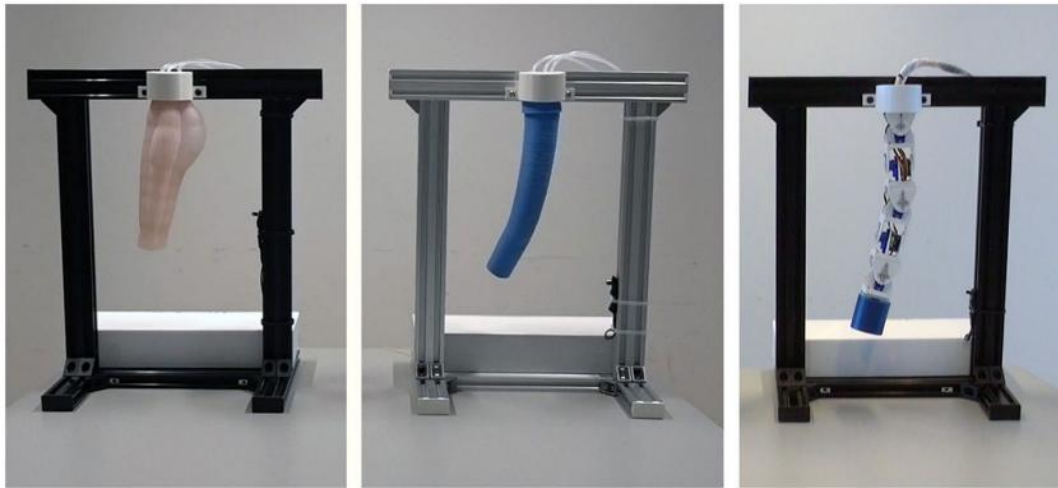


Figure 34 - Two silicone-based, pneumatically actuated soft robots (left), conventional, rigid robot (right) (Jørgensen, Bojesen, Jochum, 2022)

2.5.4. Discussion on Robot Aesthetics

By linking ethics, aesthetics, and functionality, CCVSD from Findeli, (1994) aligns with a human-centric approach to robotics. Robots are treated as tools designed to extend and support human action, rather than autonomous moral agents. Their design must respect cultural, social, and individual contexts, ensuring that interactions are transparent, meaningful, and morally appropriate. In doing so, the aesthetic choices of designers, how a robot looks, behaves, and signals its purpose, become central to ethical design, bridging the gap between technical capability and human values. This perspective underscores the thesis argument that robot aesthetics are inseparable from ethics, functionality, and cultural acceptance, making the design process a site of moral as well as technical deliberation. Within the approach from van Wynsberghe, (2012) as well as Piebalga and Yung, (2014), aesthetics is not merely a matter of style but also an ethical dimension of design. The form, size, movement, and interface of a robot communicate its purpose and intended function to users, shaping interaction and mediating human responses. In this sense, the visual and functional qualities of a robot can either support or undermine ethical outcomes such as comfort, trust, autonomy, and dignity, particularly in vulnerable populations including patients and older adults.

Although the absence of a unifying and positive design movement that is needed for successful acceptance of technology mentioned by Eggink and Snippert, (2017), coupled with the failure of robotics to achieve widespread social and domestic adoption, has contributed to technology being seen as uninspired, repetitive, or alienating rather than transformative. Without a coherent aesthetic or cultural vision, new technologies struggle to integrate meaningfully into society. Taking into consideration another paper by Eggink (2008). One could argue that self-referential culture resembles an ouroboros, endlessly consuming

itself. Rather than generating true novelty or growth, it primarily reproduces what already exists, and even when it “regrows,” it does so in repetitive patterns. Self-reference, in this sense, is not creation. This pervasive self-referentiality may help explain the negative perceptions of technology today. It may be more appropriate to design robotics from a more socially driven perspective to help in solve problems from people and change the negative perception of robots into one of being useful tools.

The approach of Techno-mimesis from Dörrenbächer, et al. (2020) functions as a form of empathetic modelling for behavioural artefacts, providing insight into how humans perceive and interact with machines. Ultimately, designing robots as extensions of human intention, rather than as purely anthropomorphic replicas, offers a more valuable and potentially transformative direction. It enables designers to leverage the distinct capabilities of robots while remaining sensitive to human interaction patterns, rather than constraining robotic design within a reductive human-like paradigm. This approach functions as empathetic modelling for behavioural artefacts, offering insight into how humans perceive and interact with machines. Ultimately, designing robots as extensions of human will, rather than merely anthropomorphic replicas, represents a more valuable and potentially transformative approach. It allows designers to leverage the unique capabilities of robots while respecting human interaction patterns, rather than constraining robots to a reductive human-like paradigm.

Ultimately, these aesthetic morphologies and dimensions are guided by underlying aesthetic philosophies, the intended function, and the design elements that communicate the robot’s purpose, personality, and utility to the user. They are central to designing robots that are both engaging and effective in human-robot interaction. The aesthetics and morphology of robots are central to their perception, usability, and success in human environments. Morphology informs both physical and social interaction, and aesthetic dimensions, naturalness, familiarity, abstraction, realism, shape engagement, trust, and acceptance. While anthropomorphism and zoomorphism dominate, designers should explore novel and hybrid morphologies, leverage unique capabilities, and consider ethical, cultural, and experiential contexts. The inspiration for these morphologies need not be literal, as it can be imagined or hybridised, allowing designers to explore novel forms and interactions. Robotic design is not merely functional but also philosophical, ethical, and psychological, and it requires a balance of form, function, and meaning to maximize human-robot collaboration and acceptance. Robot aesthetics therefore has ethical and cultural foundations which shape morphological choices, morphology then frames aesthetic themes, then themes are expressed through material and kinetic qualities, and core principles ensure coherence and user trust. This thesis supports the design of robots that are not only functional but also

meaningful, aesthetically intentional, and fit their social and cultural context. In essence from the work of Freyberg and Hauser (2023), Song and Zhao (2024), Ryalat, Almtireen, Al-refai, Elmoaqet and Rawashdeh (2025), robot morphology serves as both a functional and inspirational source in design. Anthropomorphism as seen by DiSalvo and Gemperle, (2003) thus appeals to innate human cognitive and social tendencies, often in ways that can be used for persuasive or “seductive” ends, but when applied more deliberately it can also support meaningful design objectives and a more reflective, “designerly” approach. Importantly, anthropomorphic design is not a recent development but has been present in human artefacts since the earliest periods of material culture. The approach from Christiansen, Rafsanjani and Jørgensen, (2024) parallels biological diversity: some organisms are hard, with exoskeletons (e.g., insects), while others are soft, with internal skeletons (e.g., humans).

As such, designers may benefit from focusing on underlying driving ideas rather than the object itself, an approach that can be generalised beyond societal concerns to all areas of design, including robotics. In this context, the aesthetic, functional, and interactive qualities of a robot can be shaped by guiding philosophical concepts such as human-centredness, care, collaboration, or empowerment. By prioritising the ideas that motivate design, it becomes possible to create robots that meaningfully augment human activity, communicate ethical and social intentions, and adapt flexibly to complex real-world situations. This reinforces the thesis’ emphasis on understanding robots as tools whose form, behaviour, and aesthetics emerge from their underlying purpose, rather than as autonomous agents whose design is determined solely by technical considerations.

The relation to robotics and their aesthetics, the aesthetics of robots is obviously linked. As the aesthetic experiences and categories of designs determines how people relate and perceive them. Along with users assuming the robots’ abilities from their aesthetics, both in appearance and behaviour. Without theories of robot aesthetics there would also be nothing to relate or interpret any findings from experiments or studies. Nor would it be clear on how to embody design intents to develop a concept and solve a problem.

2.5.5. Contribution and Conclusion - Robot Aesthetic Taxonomy

From the literature a taxonomical diagram of Robot Aesthetics can be created where the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE) for one whole in Figure 38

Structuring this in Figure 35, the abstract level is where robot aesthetics taxonomy begins with the ‘Core Robot Aesthetics Principles’, which include movement–form congruence (and the avoidance of the uncanny valley), as well as the balance between

anthropomorphic seduction and functional fulfilment, both of which shape user relationships with robots. It also considers presence and embodiment (e.g., 3D versus 2D forms and their effects on social facilitation), alongside expressive elements such as facial expression, colour, and articulation. These are integrated through formal synthesis, where form communicates function. Collectively, these principles bridge classification and styling by explaining how morphological and dimensional choices shape user interpretation, trust, and engagement, while also connecting to techno-mimesis and ethical considerations. Next, 'Techno-mimesis and Ethical Contexts', addresses how robots imitate or extend human and natural systems in ways that can be beneficial when guided by care-centred and value-sensitive design approaches. This includes ensuring cultural and contextual fit, so that robotic systems align with both human and technological strengths in ethically appropriate ways. Within this framework, alterity relations (dialogue between human and robot) and embodied relations (robots acting as extensions of human will) connect directly to broader human–robot interaction taxonomies. This then links to 'Cultural and Philosophical Influences', where design is shaped by broader cultural attitudes toward technology, including optimistic or progressive design movements. Philosophical ideas can be embedded within artefacts to address societal challenges, with aesthetic and ethical dimensions being interpreted through cultural lenses and translated by the designer into form and behaviour.

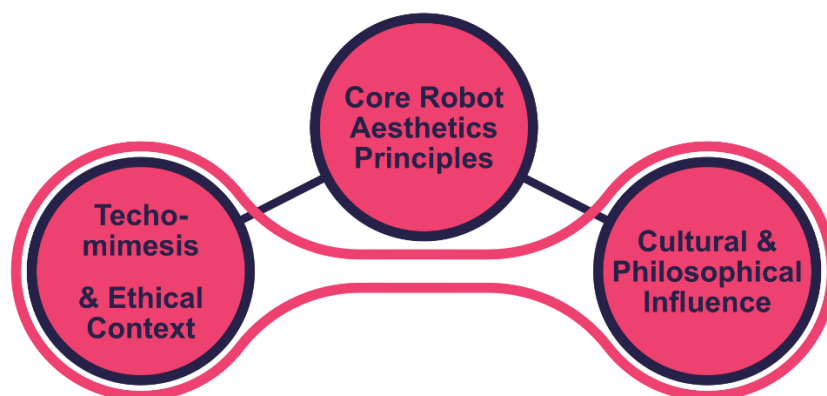


Figure 35 - Robot Aesthetics - Abstract Level

Therefore, intent and personality can be inferred through robot behaviour, and morphology directly affects user comfort and interaction. With the increasing prevalence of robots interacting with humans, the aesthetics of these robots profoundly influence the success of their deployment. Identifying fundamental principles of robotic aesthetics as stated by Hanson (2006) is therefore essential. Otherwise, the perception of “dead matter” and the uncanny valley will occur.

The analytical level in Figure 36, starts with 'Morphologies', which describe the robot's bodily composition. These include:

- **Anthropomorphism:** The robot is inspired by humans, often emphasizing human-like features or behaviours.
- **Zoomorphism:** The robot is inspired by animals, reflecting biological forms or motions.
- **Phytomorphism:** The robot is inspired by plants or flora.
- **Artimorphism:** The robot is inspired by inanimate objects or artefacts.
- **Functionomorphism:** The robot's form is dictated by its functional requirements.
- **Amorphism:** The robot exhibits a lack of fixed order or structure, evolving over time, similar to evolutionary robots.
- **Polymorphism:** The robot can adapt or change its morphology dynamically to suit user needs or context.
- **Neomorphism:** The robot presents a novel form or a hybrid of multiple inspirations, producing a sense of newness.

These morphological categories shape first impressions and expectations of capability, influencing which design dimensions are most effective (for example, zoomorphic forms may benefit from more familiar styling cues). Alongside morphology are 'Stylings', which refer to aesthetic qualities such as form language, colour, and visual expression, drawing on but distinct from morphological structure. These include continuums such as:

- **Natural to mechanical:** highlighting the perceived organic or artificial nature of the robot.
- **Familiar to strange:** emphasizing how recognizable or alien the robot feels.
- **Abstract to realistic:** reflecting the level of visual and behavioural realism.

Stylings function as granular tools for adjusting emotional tone, trust, and perceived social presence within any given morphological category. For example, a zoomorphic robot may benefit from "familiar" or "soft" styling, while a functionomorphic robot may lean toward mechanical or angular themes. Morphology therefore sets the perceptual frame through which all other aesthetic decisions are interpreted.

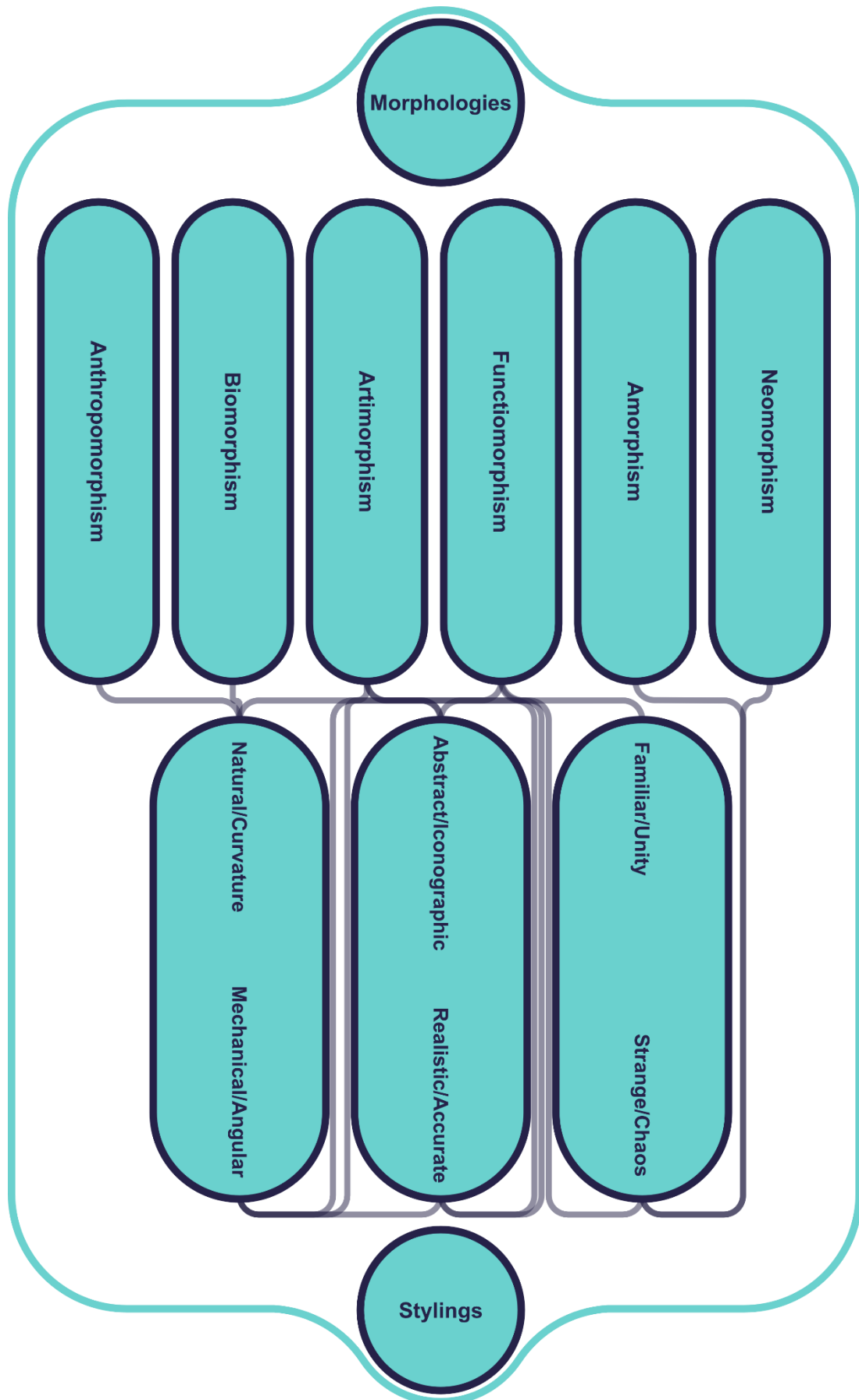


Figure 36 - Robot Aesthetics - Analytical Level

Structuring the practical level in Figure 37, it starts with 'Material and Kinetic Aesthetics' considers how material choice and movement contribute to perception, including soft biomorphism, pneumatic kinesis, and visible mechanisms. These emphasise compliance, texture, and motion dynamics as key aesthetic affordances. Overall, grounding robot design in aesthetic philosophy ensures that morphology, behaviour, and interaction are not only functional but also meaningful. Integrating perception, affordances, user experience, and cultural context support the creation of robotic artefacts that are effective, socially acceptable, and emotionally engaging.



Figure 37 - Robot Aesthetics - Practical Level

Robot aesthetics is grounded in context, as a robot's appearance must be appropriate to the cultural, social, and functional environment in which it operates. A taxonomical diagram (Figure 38) has been developed. The diagram synthesises the preceding discussion by organising robot aesthetics into three interrelated layers: the abstract level (RED), the analytical level (GREEN), and the practical level (BLUE).

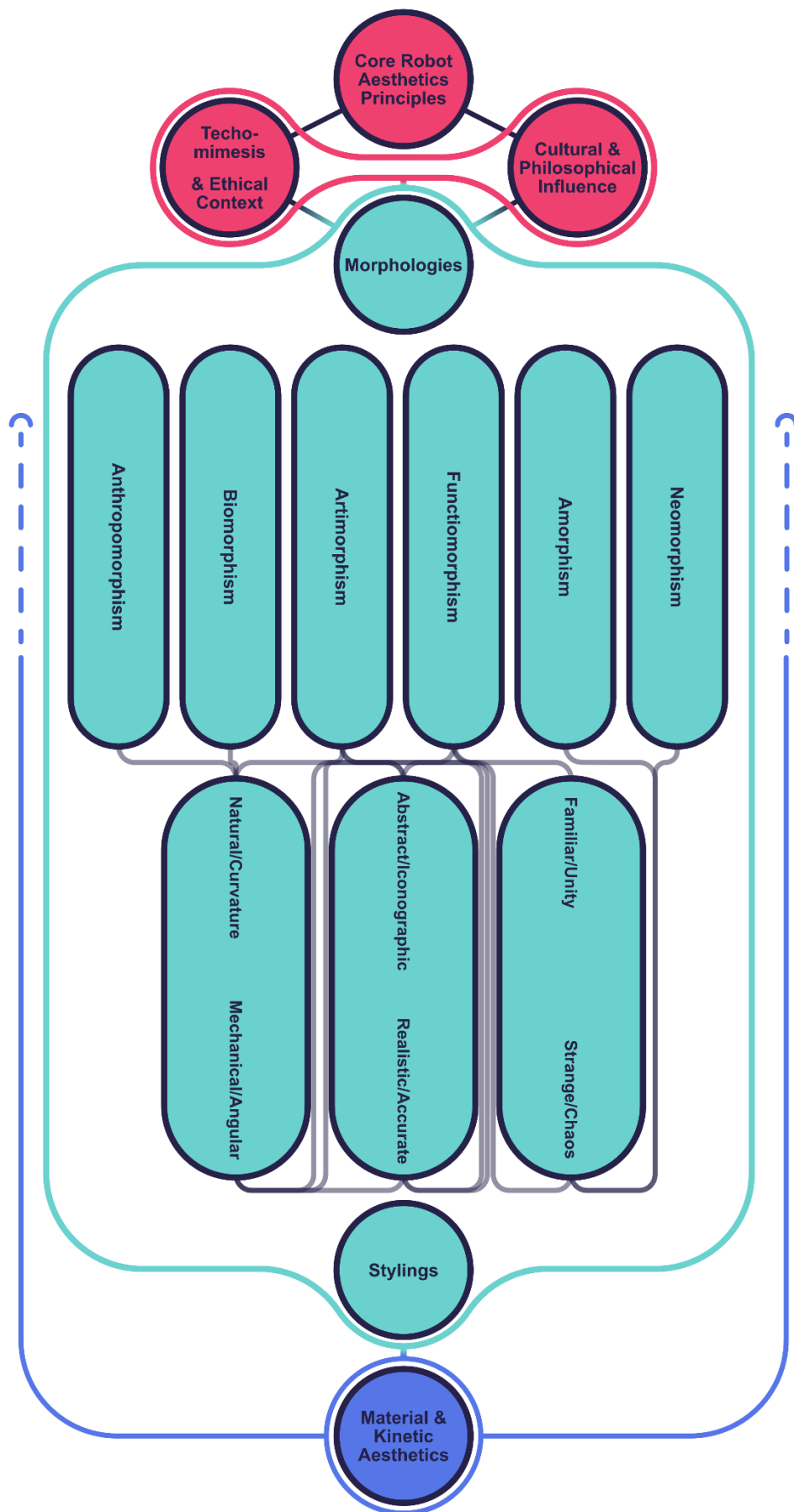


Figure 38 - Robot Aesthetics Taxonomy Diagram

2.6. The Taxonomy Framework

Having established the theoretical foundations of aesthetics from philosophical, design, human–robot interaction, and robotics perspectives, a framework is required to integrate these knowledge domains into a coherent structure. The **Framework of Taxonomies** (Figure 39) fulfils this role by linking abstract concepts to analytical categories and practical design elements. Across all included taxonomies, three shared layers are identified: an abstract level (RED), an analytical level (GREEN), and a practical level (BLUE).

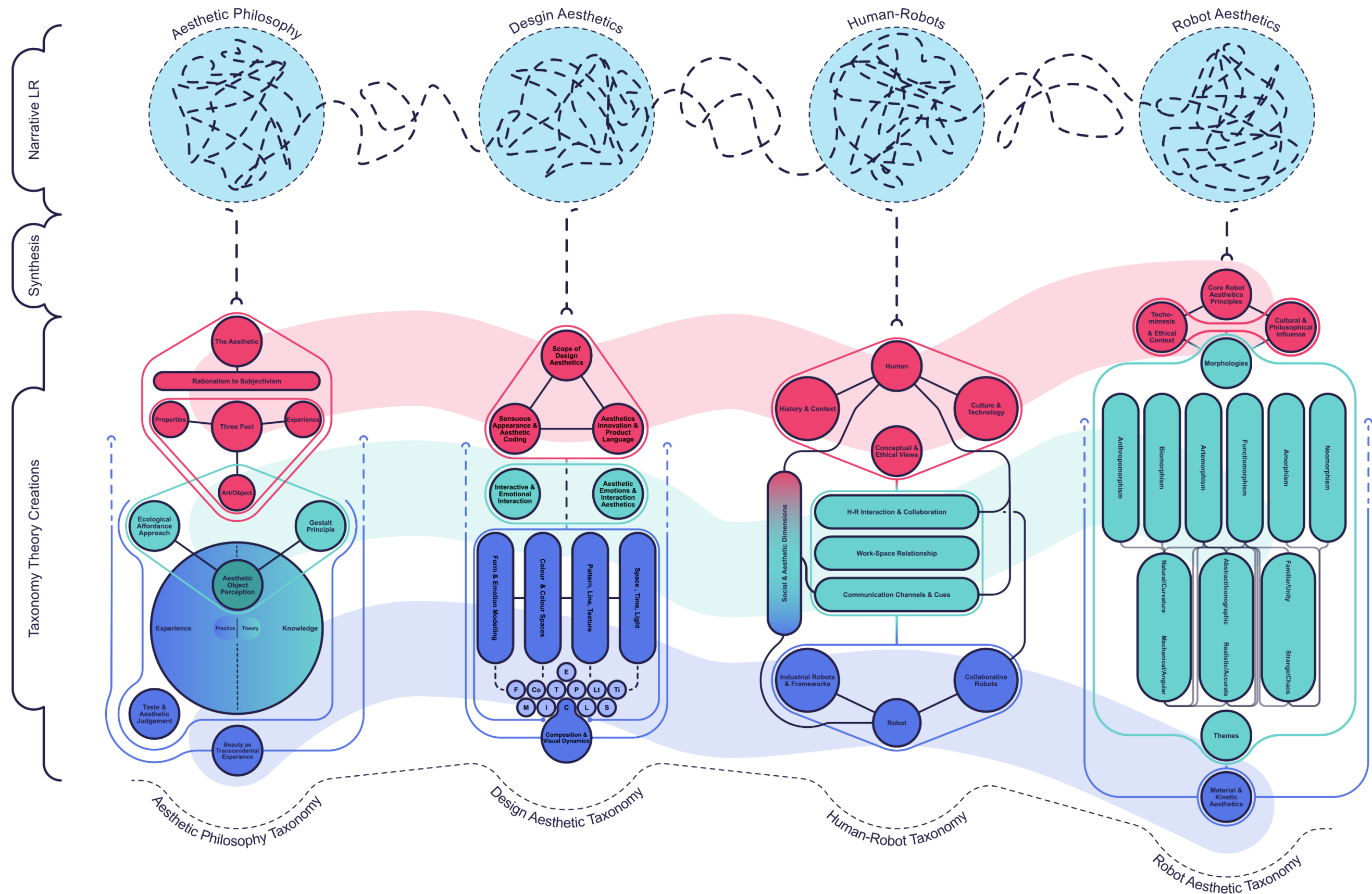


Figure 39 - Framework of Taxonomies

2.6.1. Conclusion on Taxonomies and Literature

Most user-centred and design research concerns artefacts that are not robotic. Nevertheless, the broader literature in these fields, often developed to address specific interaction problems, provides valuable insights that can inform robot design. In contrast, a strongly robotics-focused approach can lead to formulaic interpretations and repetitive design outcomes, which may partly explain why robots have not yet become widely integrated into domestic and everyday contexts since their industrial emergence. Unlike controlled industrial environments, domestic settings are more dynamic, unpredictable, and less structured, posing distinct challenges for robotic integration. A key limitation in aesthetic robotics research is the frequent reliance on single-robot studies within positivist methodologies, often without sufficient qualitative analysis of either the robot's design or the nature of user interaction. In addition, there is a persistent assumption that robots should adopt humanoid forms on the basis that humans naturally prefer interacting with other humans. However, if this assumption were universally valid, it would imply that all artefacts, particularly those involving movement, should resemble humans in form and expression, which is an overly reductive position. Human–object relationships and anthropomorphism are far more complex than simple analogies based on human appearance or communication. Designers can deliberately employ forms typically associated with positive human traits to generate unexpected or even negative emotional responses, demonstrating that meaning is not determined solely by resemblance. Despite this complexity, robot morphology remains relatively underexplored compared to other dimensions of human–robot interaction, likely due to the cost and practical difficulty of evaluating multiple physical robot variants. In addition, a strong emphasis within design and psychology on optimising positive user experiences may have shaped research priorities, potentially limiting investigation into broader questions such as societal adoption and the underlying design principles guiding robot development.

At present, automation is often most effective when it functions as an external system with which users interact through outputs, rather than as a fully immersive process. In this sense, automation can be understood as extending human agency and intention, rather than replacing it.

2.7. Research Gap from Literature Review

Although the literature provides valuable insights across the four knowledge domains, several important gaps in understanding remain. This section identifies these gaps and outlines the need for empirical and design-led investigations into robot morphologies and aesthetic dimensions. In summary, while substantial research exists on human interaction with objects and on anthropomorphic design, much of robotics research remains relatively formulaic, with a predominant focus on anthropomorphism, as identified in the literature review. This reductive emphasis has limited exploration of the wider possibilities of robot morphology, aesthetics, and functionality, particularly within uncontrolled and everyday environments. Key gaps include the limited use of qualitative methods, insufficient investigation of diverse robot morphologies beyond anthropomorphic forms, and a lack of understanding of how design decisions shape human perception, emotional response, and societal acceptance. Furthermore, existing research often prioritises the creation of positive user experiences over critical examination of the broader diffusion and integration of robots within society. These limitations demonstrate the need for more holistic and experimental approaches that address the interrelationship between aesthetics, behaviour, context, and human–robot interaction. Such approaches can support the development of robotic systems that are more meaningful, adaptable, and socially integrated.

Having established the four aesthetic taxonomies and demonstrated their integration within a coherent framework, the next step is to define the philosophical foundations that underpin this Thesis. While the taxonomies identify the constituent elements of robot aesthetics, their application within a rigorous research methodology requires a supporting philosophical position. This leads into Chapter 3, which outlines the philosophical assumptions informing the subsequent empirical and design-based investigations.

Chapter 3 – Philosophical Foundation, Research Design, and Methodology

This chapter provides the philosophical grounding that connects the theoretical structures introduced previously with the empirical and design-led methodology adopted in this research. While Chapter 2 established four interrelated taxonomies, Aesthetic Philosophy, Design Aesthetics, Human–Robot Interaction, and Robot Aesthetics, this chapter explains the research worldview that supports the synthesis and demonstrates why a human-centred, design-led, and pragmatist approach is necessary for the study of robot aesthetics.

The next step is to identify which categories are perceived by participants as valid morphologies and themes for robots, followed by the creation of a framework or toolkit to assist designers in the design process. Both quantitative and qualitative methods are used to validate the categories, representing research through design, and the framework/toolkit is then applied in a practical robot design project, representing research as design. By bridging subject and object, qualitative and quantitative methods, this approach seeks to generate more meaningful knowledge, recognising that these categories are deeply interconnected.

3. Philosophical Framing

As such the philosophical framing of this research is shown in Table 2 below.

Table 2 - Philosophical Framing

Level	Function	Position	Knowledge
Meta-theory	Governing Rules	Aesthetic Pragmatism	Knowledge comes from experience and knowing is not only collecting facts but also, feeling, doing, perceiving, experimenting and reflecting
Paradigm	Philosophical Architecture	Pragmatism	Knowledge emerges from inquiry, experiment, evaluation and action. Validation comes from usefulness.
Axiology	Values	Aesthetic Humanism	This is anchored in human experience and ethics.
Ontology	Nature of Reality	Transcendental Culturalism	Perception is within the cultural structure
Epistemology	Nature of Knowledge	Abstractionist Fallibilism	Ensures clarity and knowledge revision
Methodology	Research Logic	Multi-Methodology	
Methods	Tools of Inquiry	RtD · Interview · Observation · Art-Based	

The Meta-Theory of Aesthetic Pragmatism sets the criteria by which aesthetic concepts and theories are evaluated, by their consequences to the lived experience. The Paradigm of Pragmatism provides the overarching philosophical ground of truth being instrumental, knowledge is situational and fallible, and experience is the primary evaluator. The Axiology of Aesthetic Humanism values the human aesthetic experience which is intrinsically meaningful and that the research serves to benefit human beings through and within an aesthetic life. The Ontology of Transcendental Culturalism positions reality as culturally constituted and contextual but not reducible to any single cultural instance. It is always expressed through particular cultural forms, holding the tension between universality and particularity. The epistemology of abstractionist fallibilism states that knowledge is produced through abstraction from experience, but all such abstractions remain provisional and open to revision. Multi-methodology acknowledges the complexity of aesthetics and human experiences, and multiple methodologies are used consistent with pragmatism and the richness of aesthetic humanism. The methods of research through design, interview, observation, and art-based, are used where each method accesses a different dimension of aesthetic experience: design is focused on practice; interview captures meaning; observation documents situated behaviour; art-based methods use the aesthetic to inquire itself.

The rationale for the development and application of this philosophical framework was to ensure that aesthetics and aesthetic consideration remained central to the research project. As other philosophical choices hold assumptions about criticality, positivism, or specific political views that would be inapplicable or unused in the context of this research. Other paradigms that were considered were: Critical Realism, Interpretivism, Abstractionism. Respectively, they were not selected for being too concerned with critiquing the current state of the field, the research was not exclusively about subjective interpretations and exclusively holding an abstract perspective on without acknowledging the real and evolved elements of aesthetics would have been inappropriate or untrue. For the Ontology and Epistemology similar views were considered along with Objective, or Subjective views. As the literature on aesthetic experience in the design aesthetics section found that in aesthetic cognitive research, the more appropriate approach is to combine objective and subjects view and methods to capture the full picture. Therefore, the novel philosophical positions were developed to incorporate human-centred design views and the contextual and cultural fabric that determines attraction or repulsion towards aesthetic objects.

3.1. Meta-Theory: Aesthetic Pragmatism

The meta-theory of Aesthetic Pragmatism was developed by the author to give the central importance of aesthetics and the need to adapt and use knowledge to determine its usefulness and truth.

Derived from Richard Shusterman's *Pragmatist Aesthetics* (1992), as well as the works of Dewey (*Art as Experience*, (1934) and Bourdieu, this approach considers aesthetic experience in relation to context, content, interaction, and function, aligning with philosophical ideas from Aristotle, Nietzsche, Dewey, and Wittgenstein. Aesthetics, in this view, contributes to improving the human condition through practice and experience, emphasising beauty, intensity, and harmony in engagement (Shusterman, 2015), rather than being disinterested, as Kant suggested. Dewey's pragmatist perspective highlights that aesthetic experiences enhance life and enrich human experience without being reducible to purely instrumental goals, while Shusterman emphasizes the flexible, practical, and meaningful role of aesthetics in everyday life (Shusterman, 2006). This position, in this thesis, aesthetics, and specifically beauty, is of central importance. This is why aesthetics is the first term and pragmatism the second as aesthetics is applicable to anything and can become useful in that context rather than pragmatically applying and adapting it to make it more useful.

3.2. Paradigm: Pragmatism

The paradigm of pragmatism was chosen as knowledge created needs to be useful and this supports the aims of the thesis.

Pragmatism separates ontology and epistemology in order to use whatever approach is most effective (Lawani, 2021). Specifically, pragmatism views knowledge of the world as inseparable from actions within it and holds that something is "true" only if it is useful (Legg and Hookway, 2008). For pragmatists, derived from Dewey, technology is the primary means of problem-solving, with science functioning as an application of technology. This allows for more open-ended investigations, where aesthetics is understood broadly, not limited to art, but encompassing the qualities of interactions between humans, objects, and phenomena. Knowledge is therefore rooted in lived experience, and there are no rigid divisions between types of knowledge (Östman, 2005). Given that the aims of this research are to understand how people perceive robot aesthetics, develop a corresponding framework, and apply it, the focus on social reality is secondary. The primary concern is the use of objects to uncover mechanisms that can inform design. There is no explicit critique of social structures or mechanisms. Consequently, the research aligns with a pragmatic paradigm, where the truth of knowledge is measured by its usefulness to the design of robot aesthetics.

3.3. Axiology: Aesthetic Humanism

The axiology of aesthetic humanism was developed by the author and supports an aesthetic human experience that improves lives which are deemed valuable and ultimately guide the choice of methods.

Humanism is a human-centred worldview, independent of theological elements, in which humans assign meaning and bear responsibility for their lives. It emphasises building an ethical and humane society, valuing reason, inquiry, and human capabilities. This perspective originated in Europe inspired by the cultural and intellectual movement of Renaissance Humanism (Copson, 2015). This humanist outlook aligns closely with human-centric design, where design practice is oriented toward the future and societal change. Human nuances and contextual understanding help designers anticipate and respond to societal needs, in contrast to deterministic or positivist views of human behaviour that treat humans as passive actors merely reflecting innovation and change. In this view, people are interactive participants, and their responses underscore the importance of humanist and interpretivist approaches (Lofthouse and Prendeville, 2018). Here aesthetic judgment plays a central role in this framing. The capacity to evaluate and appreciate aesthetic experiences is foundational to moral action. In this sense, ethics is inseparable from aesthetics, and aesthetic considerations can guide humanist concerns and values (Jørgensen, 2008). Given the aims of this research is to ultimately develop a toolkit for designers to design robots and robot aesthetics enhancing meaningful beauty and uplifting humanity through aesthetic experience. This axiology aligns with the aims of the research to ensure the appropriate selection of methods where aesthetics and the experience of it in the main goal of the human centred design process.

3.4. Ontology: Transcendental Culturalism

The ontology of Transcendental Culturalism was developed by the author to consider that we change with time and context. As aesthetic is bound by cultural limits and it's changing nature. This is where aesthetic objects exist and are accepted or rejected by those in a culture.

Taking the transcendental from 'transcendental realism', this pertains to the philosophy of science which posits that a transcendental reality exists independently of our observations. Observed events, and our interpretations of them, arise from unobservable but real mechanisms (Zhang, 2023). The term 'transcendental' signifies that reality allows for the generation of possible knowledge and is subject to change. However, this transcendental aspect can blur distinctions between ontology (the nature of being) and epistemology (the nature of knowledge) (Ferraris, 2015). A Florian Znaniecki added culturalism to this and also developed the philosophy of new humanism, where he saw that, with the increased prevalence and complexity of culture and its influence on nature, this renders purely naturalist approaches invalid. As such culture is the driving force of reality and reality as such is constructed by humans (Hałas, 2010). Given the aims of this research and the constructed nature of aesthetics, robots, and the contextual tastes of the preceptors, this ontology was

developed and needs to be both useful and align with pragmatism and aesthetic pragmatism. It acknowledges the aesthetic and contextual being of the subject of study. This perspective is termed, Transcendental Culturalism. The purpose to the thesis is that it serves as a means of knowing within a context and a culture.

3.5. Epistemology: Abstractionism Fallibilism

The epistemology of Abstractionism Fallibilism was developed by the author and considers that fallible knowledge is created through abstractions built through and interacting with reality.

Knowledge thus emerges through both intellectual and sensible abstraction and cognition, as discussed by Aquinas, a concept we can refer to as Abstractionism. While Aquinas considered the intellectual aspect of knowledge to be infallible and the sensible (perceptual) aspect fallible, there is no definitive reason to treat intellectual knowledge as inherently infallible (Smit, 2001). In this research, knowledge is assumed to be fallible until it is tested and validated through appropriate means. Fallibilism posits that knowledge may be wrong, and justifications for a belief do not guarantee its truth. However, when knowledge withstands scrutiny and testing, it can be considered reliable (Reed, 2002). To be more specific, aesthetics promotes knowledge and understanding by creating empirical insights through affective interactions between sensory-motor, emotion-valuation, and meaning-knowledge systems during and after the observation of art. A view also held in the research of the neuroscience of aesthetic cognitivism (Christensen, Cardillo and Chatterjee, 2023). Objects are thus carriers of knowledge, echoing the principles of 'Research through Design' (RtD), where designed artefacts themselves embody and communicate design knowledge (Hengeveld, Frens and Deckers, 2016). Given the aims of the thesis, knowledge is derived from perception and subsequent abstraction, interpreted through contextually meaningful and value-laden lenses which was termed abstractionist fallibilism. The fallibility of knowledge is precisely why the pragmatist paradigm along with abstractionist fallibilism are suitable for this research, as it allows for the generation of useful knowledge even when data or phenomena are uncertain or incomplete. It retains the abstract and constructed nature of knowledge and its fallibility.

3.6. Methodology: Multi-Methodology

Multi-methodology is employed as the research requires a combination of qualitative, quantitative, and design-based methods to address its questions, reflecting its interdisciplinary nature across three fields.

Multimethodology can take various forms, such as methodology enhancement, which augments a primary methodology with complementary approaches. This is inherently pragmatic, allowing the researcher to shift methods as needed. Such flexibility is particularly

valuable for addressing real-world problems, as it accommodates complexity and evolving research requirements. Given that this research involves multiple phases, each potentially informed by the outcomes of the previous phase, multimethodology enables adaptation, expansion, and refinement of methods, ultimately producing more robust outputs (Mingers and Brocklesby, 1997). A multimethod approach ensures that the research captures the multilayered nature of reality: the unseen social mechanisms, observable events, physical phenomena, and subjective experiences. Focusing on a single level would fail to generate knowledge that explains the whole context (Schutz, Chambless and DeCuir, 2004). These social mechanisms and behaviours are shaped by culture, which establishes what is socially acceptable and defines the roles individuals may occupy (Matsumoto, 2007). Given that this research spans robotics, design, and aesthetics, a methodology of multi-methodology combined with a pragmatic paradigm is well-suited to generate valuable insights. This approach aligns with industrial design processes, where flexibility in testing theories through design, artistic practice, and empirical methods is essential for producing practical, actionable knowledge for designers.

3.7. Methods: Research through Design, Interview, Observation, Art-Based

The methods of 'Research through Design', interview, observation, and art-based, all allow for flexible research and the ability to capture qualitative and quantitative data, in an interdisciplinary thesis.

Design research itself is inherently interdisciplinary and heterogeneous, with the overarching aim of improving the world. It can be broadly divided into three approaches, including 'Research into Design' and 'Research as Design'. Most relevant to this thesis is 'Research through Design' which is experimental and problem-focused, where challenges external to design are addressed through the design process. It generates new knowledge and artefacts through iterative practice (Milton and Rodgers, 2017). The other methods used were the fusion between linkography and thematic analysis (LTA) which were combined to capture quantitative and qualitative results, along with researcher observation notes during the studies which also, provided more detailed descriptions of each step. A reflexive post study journal was created which helped develop themes and determine patterns in the results. Sketching analysis with iconographic descriptions was an interpretive approach used throughout the sketching phase using robots that were quantitatively evaluated as dominant by the participants. These icons were then fused together to create visual descriptions of morphologies and stylings. For the second study and the development of the toolkit, the method used was 'Research through Design' and using the aforementioned designs to inform modifications to the processes and their development into a toolkit. After which, interviews were conducted with designers to gather feedback on the new toolkit and the

three final processes were used by the researcher to ascertain their utility, to generate design outputs, and to possibly make small modifications. Given the previous choices these methods adhere to the philosophical framing as they span qualitative, quantitative and designed artifacts such as the toolkit.

3.8. Conclusion on Philosophical Framing

In this research, each step of the philosophical and methodological framing builds upon and reinforces the next, creating a coherent foundation for investigating robot aesthetics (Figure 40). At the meta-theoretical level, aesthetic pragmatism positions all inquiry as design-led studies, evaluated through the lenses of beauty, meaning, and utility. The paradigm of pragmatism justifies flexible, problem-oriented methods and supports iterative, fallibilist processes, allowing knowledge to emerge through action. Aesthetic humanism, as the axiology, places human dignity, creativity, and the intrinsic value of beauty at the centre of all design decisions. At the ontological level, Transcendental culturalism recognises culture as a real, a priori structure that shapes perception, experience, and social interaction. The epistemology of abstractionist fallibilism treats knowledge as provisional, generated through perceptual and intellectual abstraction, and continuously tested and refined through practice. This philosophical structure is mirrored in the methodology. Multi-methodology reflects pragmatism's openness and accounts for the layered, culturally informed reality of human-robot interaction. 'Research through Design' embodies abstractionist fallibilism by treating prototypes as live tests of aesthetic and functional hypotheses. Complementary methods, including interviews, observation, art-based techniques, traditional design practice, and speculative design, allow both the cultural a priori categories and participants' aesthetic judgments to be explored in context. Collectively, this framework ensures that the research is human-centred, iterative, and grounded in both practical design knowledge and broader philosophical inquiry, providing a robust foundation for understanding and shaping the aesthetics of robots in human environments.

This chapter establishes a coherent philosophical framing for a thesis focussed on robot aesthetics. These philosophical commitments directly support the development of the human-centred toolkit in later chapters as well as the following studies. The next section details the phases of the research.

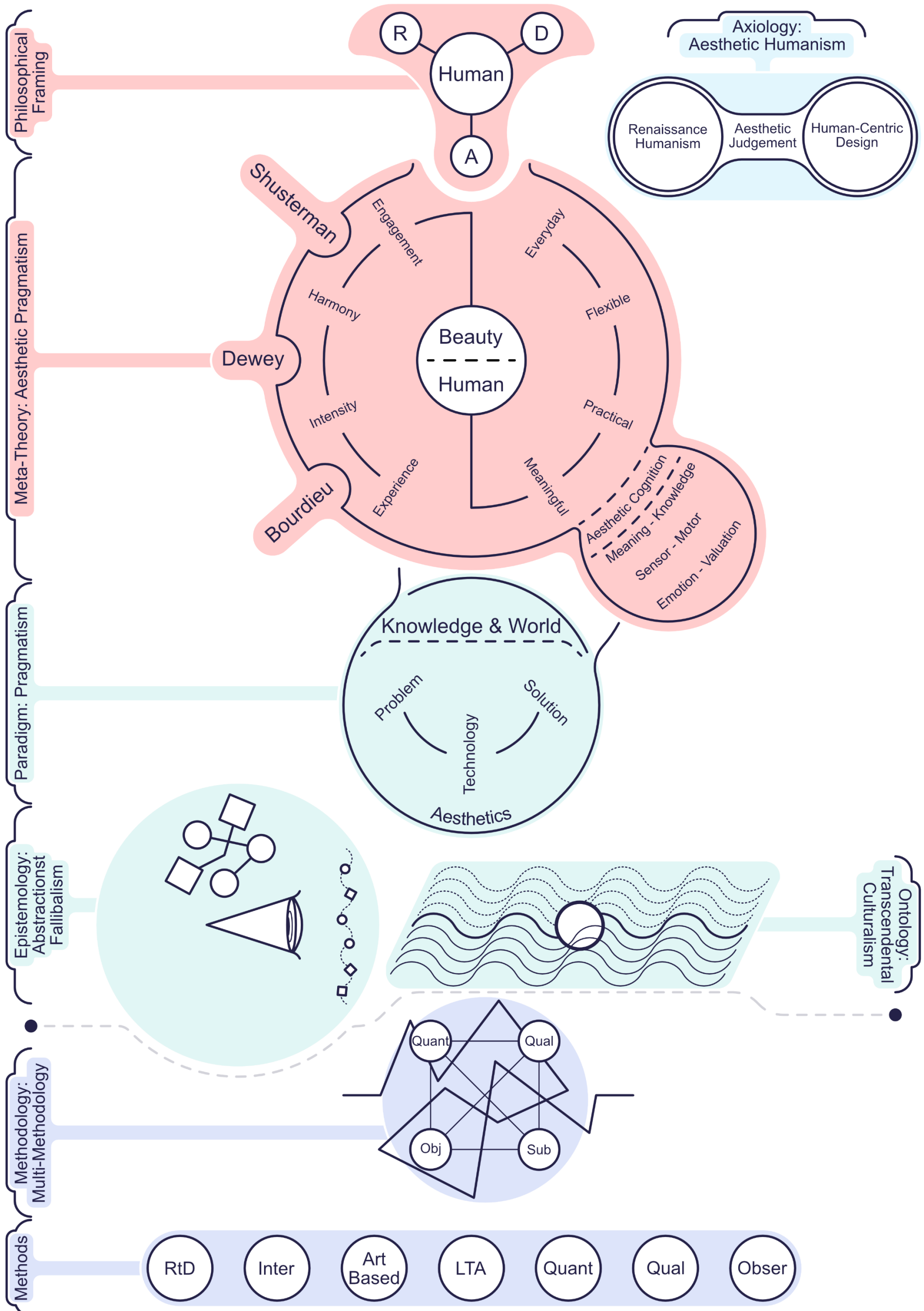


Figure 40 - Philosophical Structure

3.9. The Three Phases of Research

Informed by the philosophical assumptions developed previously the research design and methodology explains how the combination of empirical studies, aesthetic analysis, and design research methods align with the pragmatic, human-centred worldview underpinning the thesis. Addressing these gaps required a methodological approach capable of capturing both objective patterns and subjective aesthetic experience. The methodology therefore combines quantitative sorting, qualitative interpretation, and design-based research to investigate how people perceive robot morphologies and how these insights can then inform the development of the design process or toolkit. This involves three phases (Figure 2).

Phase One: focused on identifying robot aesthetic morphologies, dimensions, and related taxonomies across philosophy, design, and human-robot interaction. This phase established how morphologies guide robot form, function, symbolism, and interaction, and resulted in the creation of four taxonomy diagrams: Aesthetic Philosophy, Design Aesthetics, Human-Robot Interaction, and Robot Aesthetics. These provided a structured framework for understanding robot aesthetics.

Phase Two: tested and validated the robot aesthetic taxonomy, particularly the morphologies and dimensions, through designer-focused studies. Using art-based methods, interviews, sketching, and a card-based image set, participants explored, recorded, and evaluated aesthetic perceptions. A novel Linkographic with Thematic Analysis (LTA) method which combined quantitative evaluation and qualitative thematic coding to capture complex participant responses. Analysis identified dominant design themes, patterns of aesthetic thinking, and validated the morphologies and dimensions from the literature. The outputs included a map of robot aesthetics and a model of robot aesthetic experience, demonstrating LTA as an effective method for mixed data collection in design research.

Phase Three: involved the development of a toolkit for robot design. This synthesised research findings into practical design methods and resources to guide designers. Various prototypes of the toolkit were explored, including card systems, modular panels, mood boards, and interactive lookbooks. Each concept aimed to translate the taxonomy and aesthetic principles into usable tools, supporting ideation, exploration, and decision-making in robot design. While some concepts were exploratory, they highlighted future opportunities for interactive, playful, and flexible design tools. After this it was applied the process with two teams of designers with the same brief to see if they created aesthetically focused robot designs. Then the process was redesigning and expanding the process into a toolkit that catered to designers with a low, a medium, and a high level of skill in design. Finally, involved interviewing practicing designers to obtain their views on the process in the toolkit related to

them was done. One roboticist, one design engineer, and one product designer were interviewed and after this the comments were incorporated as changes into the toolkit.

Together, these phases combined literature synthesis, empirical validation, toolkit development, and practical application, producing a comprehensive, human-centred approach to robot aesthetics that integrates theory, perception, and design practice.

3.9.1. More detail on the phases

The **first phase** identified various robot aesthetic morphologies, and stylings as well as aesthetic taxonomies in philosophy, design aesthetics, and human-robot interactions. This was necessary because the morphologies act as major aesthetic guides for a robot, determining its overall form and constraining the design functionally, aesthetically, symbolically, and interactively. This helped to understand how the fields: philosophy, design, human–robot interaction, and robot aesthetics conceptualise aesthetics. These insights were then synthesised into a series of taxonomy diagrams: the Aesthetic Philosophy Taxonomy, the Design Aesthetic Taxonomy, the Human–Robot Taxonomy, and the Robot Aesthetic Taxonomy.

The **second phase** of the thesis focused on testing and validating the Robot Aesthetics Taxonomy, with particular emphasis on robot morphologies and styling themes, in order to investigate how the aesthetic experience of robotic forms is perceived. Examining designers' perceptions of these categories was necessary to determine the extent to which their interpretations aligned with or differed from those identified in the literature. Designers were selected as participants because they play a central role in shaping the development of current and future robotic systems. The first study had several objectives. First, it aimed to develop a method for analysing robot aesthetics and morphology. Second, it employed art-based methods to explore and extract aesthetic qualities, themes, and conceptual associations from both the robot image set and participant responses. Third, the study sought to identify which morphologies were perceived as distinct and coherent categories, and which aesthetic characteristics were consistently recognised, thereby enabling validation of findings derived from the literature review. The study consisted of three distinct phases: the study phase, the analysis phase, and the synthesis phase. During the study phase, participants were presented with a set of robot cards and asked to note, sketch, and verbalise their perceptions while the researcher documented observations. The analysis phase began with the completion of a reflexive journal following each session. This was followed by thematic development and coding of the collected data. Sketch analysis was then conducted on the most dominant robot designs identified within the participant responses. Finally, during the synthesis phase, the findings were integrated into the development of a model of robot aesthetic experience and a map of robot aesthetic

evaluation. As the aim is to analyse the aesthetic morphologies (Anthropomorphism, Zoomorphism, Phytomorphism, Artimorphism, Functionism, Amorphism, and Neomorphism) and styling dimensions (Natural/Curvature-Mechanical/Angular, Abstract/Iconographic-Realistic/Accurate, and Familiar/Unity-Strange/Chaos) new methods to capture qualitative and quantitative results were developed to study these categories. Linkography and Thematic analysis were mixed to create Linkography with Thematic Analysis (LTA). Where it could capture moves, quantitative evaluation and qualitative thematic results in one study. A reflexive journal was kept after each participant finished their study whilst looking over their data to record deeper observations, theories, and help with generating the themes. The results were the map of robot aesthetics and a model of robot aesthetic experience that aligned with other authors such as Lehar (2003), Norman (2013) and Gibson (2015). In addition, the validation of LTA was a usable method for mixing qualitative and quantitative data in one approach in design research. This all informed the design of the toolkit later. The use of sketching for the sketching analysis and participant notation was done because it encourages the creative process as a form of visual analogy and shortens the incubation period of an idea as mentioned by Verstijnen, et al. (1998).

The **third phase** of the thesis involved the development of the toolkit. This process began with an ideation stage, followed by informal testing and iterative refinement, which also informed the design of the final study. The aim of this phase was to establish a practical method for analysing and applying robot aesthetics, resulting in a toolkit intended to support designers in investigating design problems and developing robotic systems. This phase synthesised the findings from the preceding studies into an applied toolkit for robot design. Then framework was applied in practice in order to demonstrate the utility of the toolkit. This was achieved through collaborative design activities involving the key participant groups, who used the toolkit to support the development of robot concepts. The final study included the key participant groups: product designer, design engineer, and roboticist. There were two groups all with one of the key participants who each conducted a design exercise. Their brief was:

How might we design a robot to improve engagement at museums or galleries. Bettering guidance, interaction and or understanding.

The participants worked through 4 large bubbles on the worksheet; Define, Ideate and Develop, Prototype, and Final. These had associated taxonomy bubbles. The Aesthetic philosophy bubble was associated with ideation. Design aesthetics and robot aesthesis bubbles were associated with development. Human robot interaction was associated with

prototyping. The results were analysed and then participant feedback was collected to further iterate on the toolkit design. As a result, the original single-process structure was reconfigured into three distinct processes tailored to different levels of design expertise, framed by the amount of time need to complete them: short, medium, and long skill. This transformed the framework into a tiered toolkit for robot aesthetic design, enabling it to better accommodate the varying capabilities and needs of different practitioner groups. These revised processes through interviews with participants representing different professional backgrounds and levels of design expertise. A roboticist engaged with the short process, a design engineer with the medium, and a product designer with the long process. Each participant was interviewed to assess the usefulness and applicability of the process assigned to them, thereby providing insight into the overall utility and effectiveness of the toolkit. The toolkit, and as such all three processes were also tested but the author of this thesis.

3.9.2. Conclusion on the Phases

This six-phase research process is summarised in Figure 41, which identifies the individual phases and illustrates their interrelationships. Each phase is defined by distinct aims, processes, and outputs, which collectively inform the progression to the subsequent stage of the research. Having established the overall research design, the next step was the implementation of the empirical component of the study. Chapter 4 presents the first study, demonstrating how the methodological principles outlined above were applied to investigate perceptions of robot morphologies and styling dimensions.

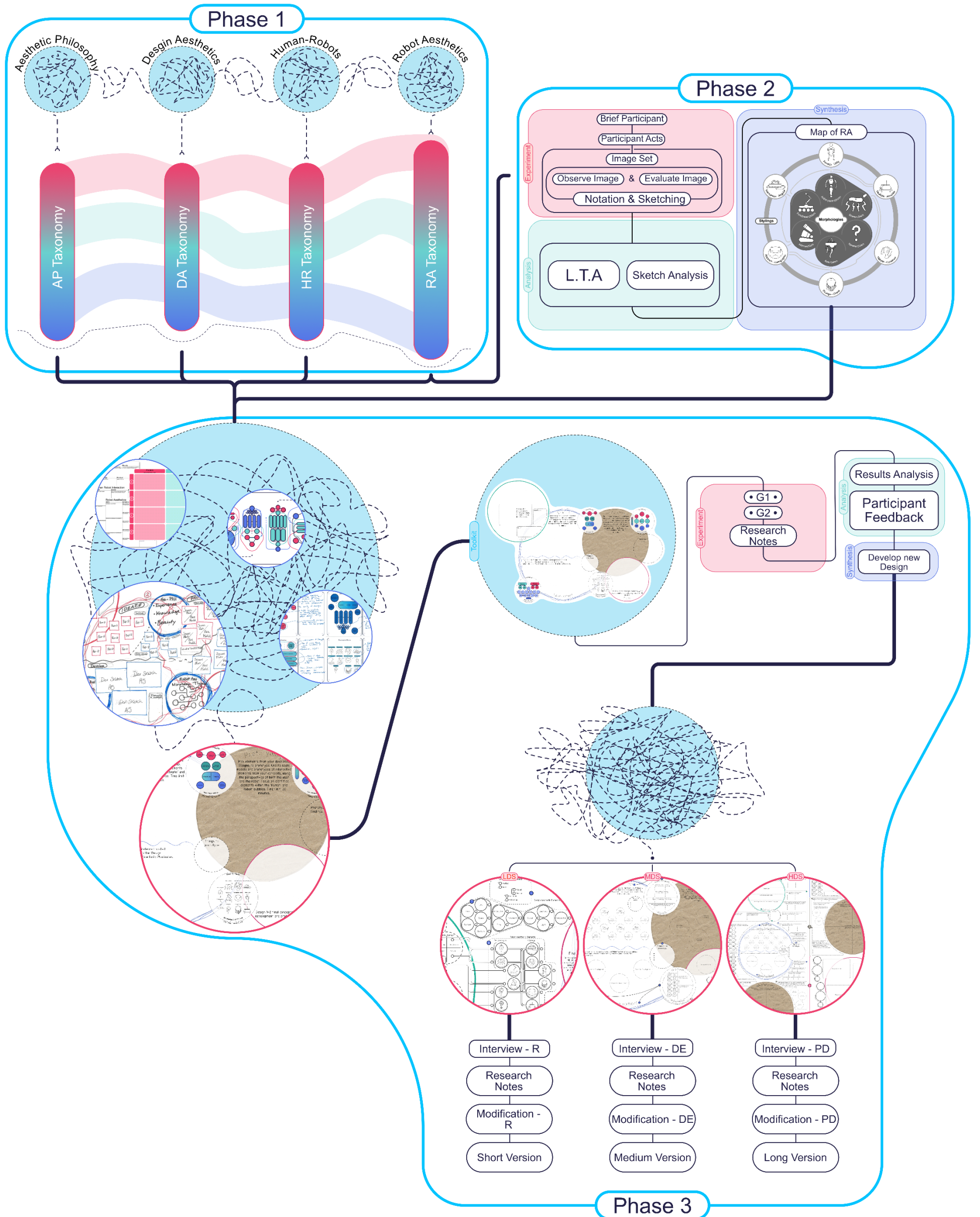


Figure 41 - All Phases

Chapter 4 – First Study Development and Results

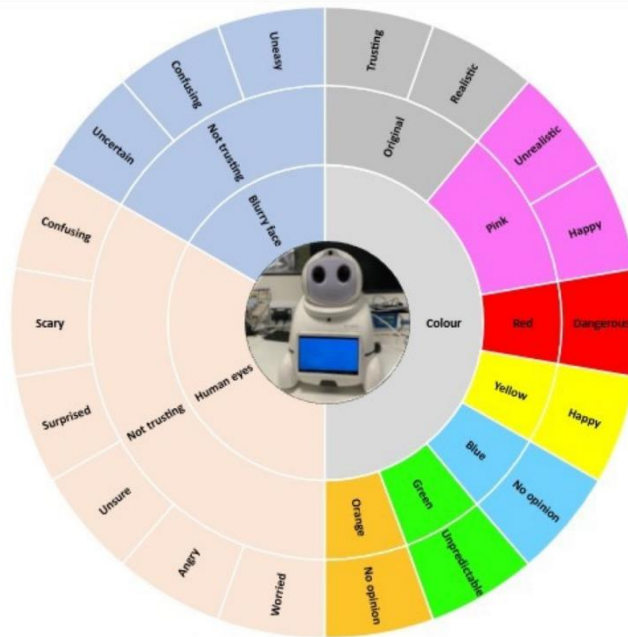
Following the methodology and research phases outlined previously, this chapter presents the development, implementation, and findings of the first study. The study investigated which robot morphologies and aesthetic dimensions are perceived as meaningful and distinct, thereby establishing the empirical foundation for the subsequent stages of the research.

4. The Approach

The multimethod approach generated a rich dataset capturing the participants' perceptions of robot morphology, styling, and aesthetic meaning. The findings presented below summarise these results and demonstrate how participants engaged with and interpreted the categories identified in the literature. This chapter begins with a review of key related studies and the pilot study, before outlining the development of the final study, including its methodology and analytical methods. It then presents the results, concluding with a discussion of the study's contributions to knowledge.

4.1. Related Studies in Robot Aesthetics

Most of the research on robot aesthetics has focused primarily on evaluating user experience rather than understanding the underlying principles of aesthetic perception. For example, Pinney et al. (2022) conducted a survey to evaluate trust by modifying specific features of a robot's face and chest, finding that blurry facial features and human-like eyes were perceived as less trustworthy. This aligns with previous research linking Western cultural associations to certain colours, such as a subtle blue causing a lack of affective response (Figure 42) (Pinney et al., 2022). As such a subtle blue background was chosen for grounding the robot images in our experiment (See Figure 42, as it has similar colour in the upper left area, although no colour code was given in the paper), and this appeared to work well, and participants did not report any negative associations from it.



perceived humanness (DiSalvo et al., 2002). While informative, such narrowly focused tests neglect the broader visual, cultural, and artistic context of human perception, which includes pareidolia and stylized representations in art and comics. Humanoid robotic faces, like drawings of humans, are perceptual illusions, and testing them exclusively risks over-specification. Kunold et al. (2023) took a larger-scale approach with online surveys: study 1 included 46 robots and 673 participants, and study 2 refined the set to 20 robots and 573 participants, using five morphologies, functional, caricatured, zoomorphic, humanoid, and android (Kunold, et al., 2023). This research demonstrated that positive perceptions of technology are necessary for adoption and linked morphology to perceived capabilities. However, it did not investigate which morphologies are “realistic” or meaningful in a broader aesthetic context.

Previous research in robot aesthetics has identified a significant gap in the literature, as relatively few studies systematically investigate the relationship between robotic morphologies and aesthetic properties, even where concepts such as “zoomorphism” are referenced. By asking participants to sort robot images and explain their reasoning, it becomes possible to map aesthetic experiences and generate insights relevant to designers, producing knowledge that is more broadly generalisable rather than tied to a single set of robot designs. Current approaches to studying robot aesthetics often adopt a reductionist perspective, focusing on isolated variables such as preferences for curvilinear versus angular forms or attempts to engineer trust through specific design features. However, aesthetic experience is inherently more complex and context-dependent, involving the communication of ideas, meanings, and cultural associations through design. Accordingly, the aim of this study is to investigate how humans perceive robot aesthetics and how their conceptual understanding of robots is constructed through the perception of morphology and aesthetic qualities. By considering the wider typology of robotic forms and the cultural contexts in which they are interpreted, the research seeks to move beyond simplistic manipulations of user perception, such as trust or engagement, and toward a richer, more human-centred understanding of robot design.

4.2. Pilot Study – Testing Variations

The pilot study was conducted to determine how the four variables should be refined and to assess the extent to which the proposed theory of aesthetic dimensions and morphological categories should be used by participants during evaluation. It also examined whether the theoretical framework could instead be applied as an interpretive lens for analysing participant responses (Table 3). In turn this determined how to gather information about the aesthetic experience when viewing robots:

- Do one or multiple sets yield better results? (Fixed vs breadth of sorting)

- How do the participants analyse robots? (What is considered part of the morphology or aesthetics?)
- Is the analysis of sets by the researcher vs the analysis of participant analysis of a set better? (Is isolated or involved analysis more appropriate?)
- Do defined categories or participant interpreted categories yield more value? (How are the categories perceived?)

Table 3 - Study Variations

	Defined Categories	Participant Created Ones	
Image Set Evaluation Only	V1.	V3.	Researcher does Analysis
Analysis by Participants	V4.	V2.	Research does Analysis of Participant Analysis
	One Set	Multiple Sets	

Each participant was provided with a deck of 25 cards, each featuring a robot image. They evaluated the images based on both stylings and morphologies in Figure 43 (which was published in Proceedings of the Design Society, 4), then sorted them into morphological categories. Participants were asked to explain their reasoning throughout the process, allowing the researcher to take detailed notes on why particular choices were made and how the study structure influenced their evaluations. The study included eight participants, with two participants assigned to each version of the study. During the card sort, the images were displayed on a black circular viewing mat, which separated the viewing area from the sorting area and highlighted the images as the primary focus. The participant group consisted of five males and three females, all holding at least a BSc in Product Design.

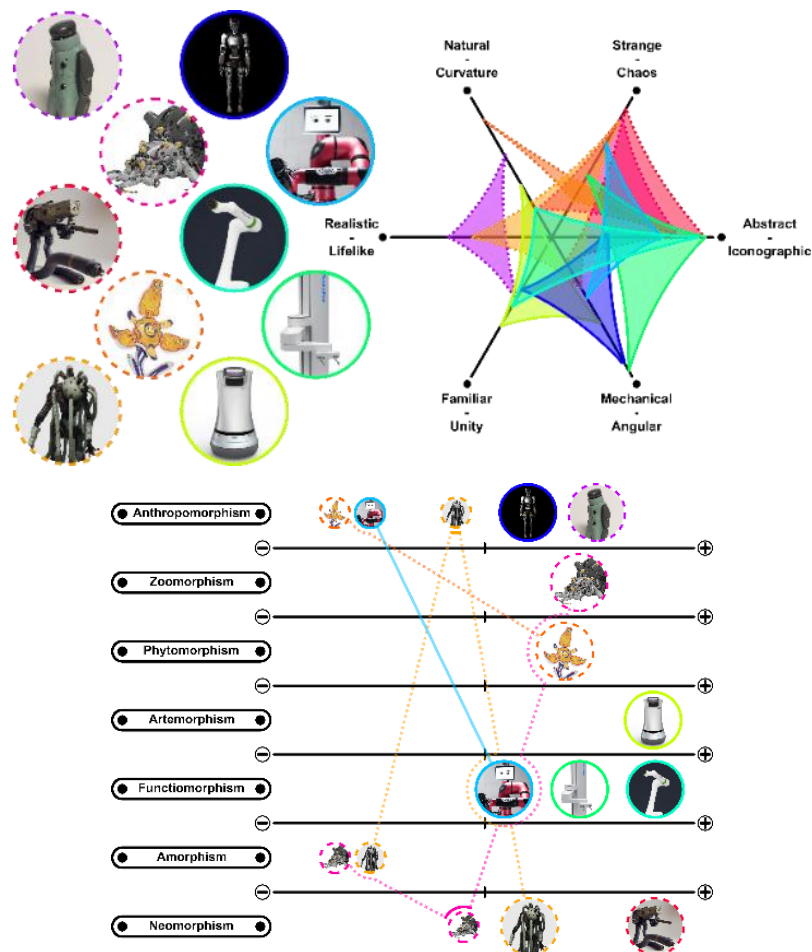


Figure 43 - Robot Aesthetic Dimensions and Aesthetic Morphologies

This iterative piloting phase was conducted prior to finalising the study design and protocol, with the aim of refining both the research process and the format of the outputs. Further detail on the four iterations is provided in Appendix A – Pilot Study Iteration. The following section presents a synthesis of the pilot study findings and discusses their implications.

4.2.1. Holistic Discussion on Pilot Study

It was determined that an optimal study design would integrate the strengths of the previous iterations by:

- Providing participants with space to annotate and sketch directly on the cards, enabling richer visual reasoning.
- Priming participants with an example card to encourage consistent marking and reduce initial uncertainty.
- Using predefined categories to generate intensity maps while also allowing participants to sort images into emotive, symbolic, or thematic groupings.

Although this approach requires more time for both participant engagement and post-study analysis, it would produce more nuanced and detailed insights. Initially there was a visceral emotional reaction following a degree of reflection on what it reminded them of. Primarily the aesthetics determined how the participant imagined how it would move, and function. This continued to be quite prevalent after the initial visceral and emotional reaction to the presented design. Parting lines and clear joints implied the manner of movement according to participant perception and Amorphism and Neomorphism seem unclear to most participants. In terms of methods, eye tracking was not used because it indicates only where participants are looking, without providing insight into why they are looking there or how they are interpreting what they see. In this study, participants instead explicitly identified what they were observing on the robot and explained their reasoning, making eye tracking unnecessary and adding additional complexity and time requirements. Overall, the study structure proved effective, and it was concluded that the most useful elements from all four iterations should be combined into a single refined approach.

4.3. First Study – Sorting Robots

4.3.1. Research question and study objectives

Given this research investigates how humans perceive robot aesthetics and how these interpretations are shaped by perceptions of form, appearance, and design cues. In particular, it seeks to identify how morphologies, structural features, and stylistic dimensions contribute to meaning-making and perceived function, with the aim of articulating principles of robot aesthetics that can be intentionally applied by designers. To address this, the study adopts a pragmatic, design-oriented mixed-methods approach. Qualitative methods were used to capture participants' meaning-making processes, emotional responses, and interpretive reasoning, while quantitative methods supported the identification of recurring morphological and stylistic patterns across responses. Specifically, this study intends to test and solidly define the morphological and styling categories across three types of designers. To the create maps, principles and guidance for robot aesthetics.

The study was structured into three phases (Figure 44). In the study phase, participants, including roboticists, product designers, and design engineers, were presented with cards depicting robots on grounding shapes. Each card included space for annotation and sketching, allowing participants to record their perceptions while verbalising their interpretations, the researcher then documented these discussions in real time. In the analysis phase, reflexive journaling was conducted after each session to capture emerging insights and participant behaviours. These reflections informed the development of thematic codes, which were then systematically applied to the dataset. A sketch analysis was

subsequently undertaken to identify dominant morphologies and aesthetic dimensions across the evaluated designs.

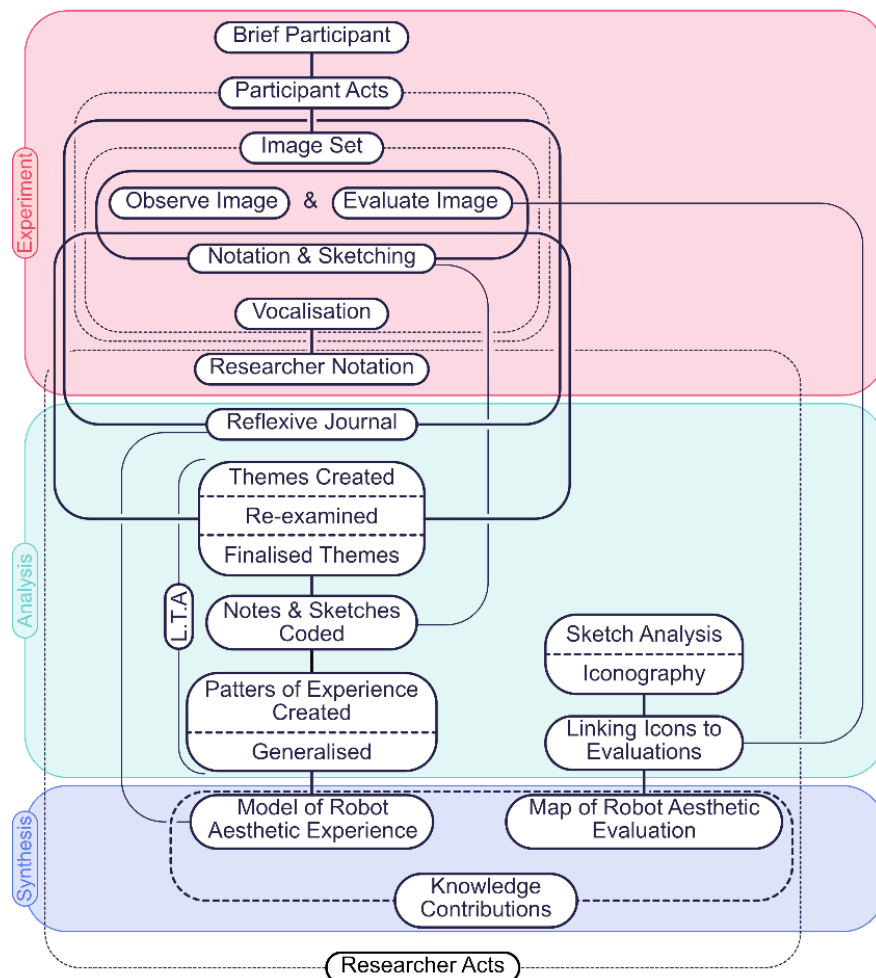


Figure 44 - First Study Design

4.3.2. Protocol

Prior to the study, participants were fully briefed on its purpose and procedures. An example card was then presented to demonstrate how to complete the evaluation task (Figure 45). During the study, participants were instructed to verbalise their analytical and decision-making processes for each card, explaining how they interpreted the robot's aesthetics and the meanings they associated with them. While participants completed the task, the researcher recorded these verbal accounts alongside detailed observational notes, documenting participant behaviour and focal points in a structured, step-by-step manner. Following the evaluation phase, participants were asked to organise the images into self-defined categories based on perceived similarities and differences between the robot designs. Once categorisation was complete, the researcher photographed each participant's arrangement to preserve the structure of the groupings for documentation and subsequent analysis.

The design of the page has three distinct areas; the robot area (Figure 45, A), where the image of the robot is placed on top of a focusing and grounding shape. This focuses the eye onto the robot and grounds it on the page, whilst giving them all a similar sense of scale. Considering that there was no opinion about a subtle blue from Pinney, et al. (2022) it was a desirable choice for the grounding shape. As the aim is to analyse the aesthetic morphologies (**Anthropomorphism, Zoomorphism, Phytomorphism, Artimorphism, Functionismorphism, Amorphism, and Neomorphism**) and styling dimensions, derived from the literature. Although, with a flat image of a robot the sense of scale cannot be experienced, but the aesthetics experience of the visual and form elements can be approximated as shown previously. The next area is the analysis area (Figure 45, B), which allows the participants to record their visual thinking onto the page, acting as a recording of behaviours that would otherwise be difficult to verbalise fully. The last area is the evaluation area (Figure 45, C) where the participants evaluate the aesthetics of the robot. The aesthetic themes were bipolar semantic styling dimensions (**Natural/Curvature-Mechanical/Angular, Abstract/Iconographic-Realistic/Accurate, and Familiar/Unity-Strange/Chaos**) all having a neutral point in the middle of the dimension, and the closer to one edge means that the aesthetics are more intensely felt for that end of the scale. Considering that each end of the scale are opposites there can only be one point per dimension. In contract to Bartneck, and Forlizzi, (2004) bipolar dimension mixes styling, morphology, knowledge and interactive with unevenly separated dimensions. Here the separations are clearer and without sub-term withing the evaluative sections to avoid confusion on the part of the participant.

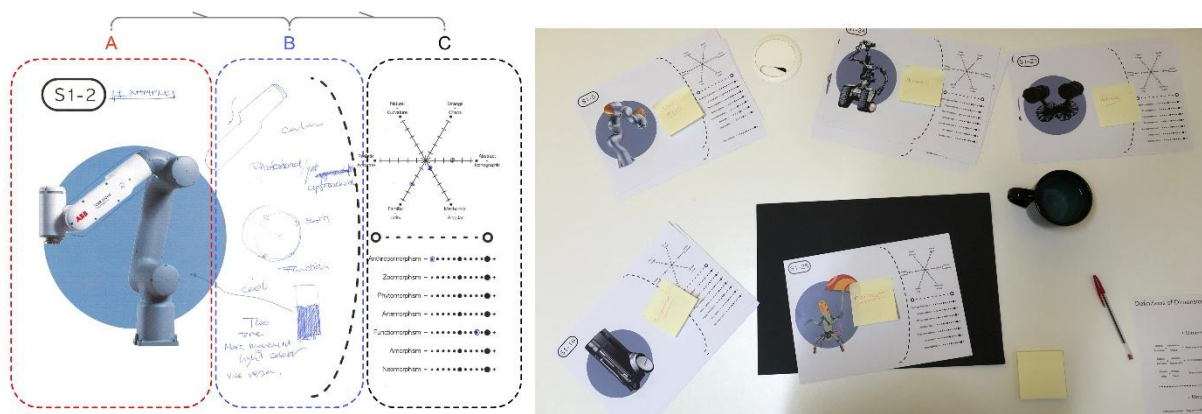


Figure 45 - First Study Example Card and Setting

There was a total of 24 participants, and each one evaluated 25 images from 1 set of the 4 image sets. Each set has 25 images, with the four sets, there are a total of 100 images being evaluated (Figure 46). The participants are separated into three groups relevant to the design and development of robots: Product Designers, Design Engineers, Roboticists.

Meaning that there will be 8 participants for every group and that there will be 2 participants per image set for every group, meaning that there will be 6 participants per set.



Figure 46 - Robot Image Sets

One improvement compared to the related studies cited previously, is the sample size. With this, the separate image sets would improve generalizability of findings and remove the effects of nongeneralizable patterns existing in the image sets that may interfere with the interpretation of findings. There are also the variety of the designs and the fact that they were created by designers rather than artificially generated images as this may bias the results towards a meaning embedded in the images sets. One bias in the study that should be noted is that although the participant size is valid, the participants are still separated into three groups which would mean that specific interpretations about one field may be less applicable.

4.4. Methods for First Study

4.4.1. Linkographic with Thematic Analysis (LTA).

To analyse participants' aesthetic interpretations, a hybrid approach combining Thematic Analysis (TA) and Linkography was employed, referred to as **Linkographic Thematic Analysis (LTA)**. This approach was designed to capture both the content of participants' responses and the structure of their interpretive processes. TA was used to identify recurring patterns of meaning across the dataset, while Linkography traced the sequence and relationships of interpretive "moves," revealing how participants revisited and re-evaluated form, function, and meaning throughout the task where codes were developed to identify different types of moves (Table 4).

Thematic Analysis followed the six-step framework outlined by Braun and Clarke (2012): familiarisation with the data, generating initial codes, searching for themes, reviewing themes, defining themes, and producing the final report. Through this process, codes and themes were developed systematically across the dataset. Given the large volume of qualitative material from researcher notes and participant verbal accounts, text segmentation was used to divide the data into manageable units. While segmentation can reduce local contextual continuity, it is necessary for mapping meaning across large datasets and identifying relationships between segments (Guest, MacQueen and Namey, 2012, pp. 50–51). TA was selected because it enables the identification of "patterns of meaning" (themes) within qualitative data and can be flexibly applied across different research paradigms. In more structured approaches, such as Applied Thematic Analysis (Guest and Greg, 1963), coding is used systematically to enhance reliability. Within TA, codes represent the smallest units of meaning, while themes represent higher-level patterns that organise multiple codes around central ideas. Unlike codes, which indicate recurrence, themes integrate interpretation across the dataset. TA also allows for the analysis of both explicit and implicit meanings, extending beyond participants' literal statements (Clarke and Braun, 2017). Additional techniques, such as code co-occurrence analysis and visual mapping of relationships between codes, further support interpretation.

To strengthen reliability, inter-coder agreement (ICA) was applied. Two researchers independently coded the same data using a shared codebook and then compared results to identify areas of agreement and divergence. Discrepancies were resolved through discussion until consensus was reached, ensuring that the final coding reflected shared interpretation rather than individual bias (Guest, MacQueen, and Namey, 2012, pp. 10–11, 85–89).

To complement TA, Linkography was used to visualise the cognitive structure of aesthetic interpretation. Originally developed by Goldschmidt (1990), Linkography maps design activity by breaking it into discrete "design moves" and identifying relationships

between them. These relationships form patterns such as chunks, webs, sawtooth tracks, backlinks, and forelinks (Kan and Gero, 2008). Although traditionally used to analyse design processes and productivity, in this study Linkography was adapted to trace how participants' perceptions and interpretations evolved over time, with a focus on aesthetic experience rather than design output.

Table 4 - Codes

Types of Thinking	Descriptions	Subcategories	Types of Sketch Thinking	Descriptions
Functional Thinking	Reference to functional behaviour (e.g. joints, movement pattern, DoF)	Functional; Movement; Design; End-effector	Annotations	Direct notation of design elements
Emotional Thinking	Reference to emotions or emotional states (e.g. fear, anger, happiness)	Positive; Negative	Analysis	Questions and answers
Personal Experiences	Reference to memories	Life; Work	Analogous	Reference to other related things
Analogous Thinking	Reference to related objects or creatures (e.g. "hammer-like")	Object; Creature; Interaction	Explorative	Drawings beyond the presented idea but linked to the design
Aesthetic Thinking	Reference to design elements (e.g. form, flow, colours, themes)	Themes; Styling Details; Morphology; Branding; Meaning	Expressive	Drawing emotions and states
Confused Thinking	Showing a lack of understanding of the design	—	Imaginative	Drawing other unrelated thoughts
Cultural Thinking	References to media, rituals, or cultural artefacts	Art; Acts	—	—
Comparative Thinking	Comparison with other robots in or outside the set	—	—	—
Contextual Thinking	Relating to purpose and moral intent	Purpose (Neutral); Good; Evil	—	—
Perceived Designer Intent	Reference to explicit design intentions	—	—	—

The coded transcripts were entered into Excel, and the dominant codes for each move and participant type were visualised as pie charts for the two coders. Following this, a discussion was conducted between the coders to interpret the results and consider the reasons behind the observed patterns. Through this combined approach, LTA provided a

dual analytical lens capable of capturing content and process simultaneously (Figure 47). The method enabled the development of a conceptual model of robot aesthetic experience and informed the articulation of principles of robot aesthetics by grounding them in both recurring interpretive themes and the structure of participants' cognitive engagement (See Appendix B – Researcher Coding Data).

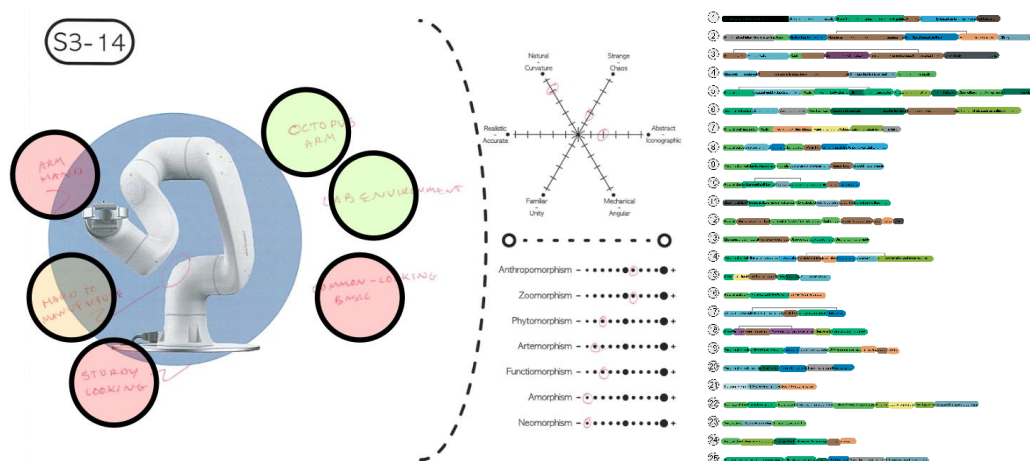


Figure 47 - Analysis Example

4.4.2. Sketching Analysis Autopsy and Thematic Icon Grouping

After the dominant robot designs were identified with as one or more morphological evaluations at or above 9. The dominant robot designs were analysed to identify salient aesthetic elements and compositional structures. This analysis informed the identification of design features contributing to the resulting LTA moves diagrams (Figure 49). To define the morphologies and stylings, designs were grouped into visual categories through sketch-based analysis, following De Sausmarez's (2007) approach to visual dynamics, which emphasises the role of abstraction in revealing underlying formal principles.

Design elements were further examined using a modified product autopsy method from Milton and Rodgers, (2023). This adaptation employed exploratory sketching. Where the design was analysed by overlaying tracing paper to find the visual dynamics in red, the main forms in blue and the details in black. After which the sketching analysis is done by drawing the overall morphology, detailed analysis and then an icon is created with a red background, (Figure 48 (Left)). The resulting abstractions were distilled into thematic icons, comparable to gesture drawings as described by Cooper (2018). Where in the figure on the right is shows the icons of different designs (Figure 48 (Right)). These icons were then grouped according to participant evaluations of aesthetic dimensions, enabling the identification of specific design elements responsible for eliciting aesthetic experiences (See Appendix C – Sketching Autopsy Analysis Data).

By adapting the product autopsy technique into exploratory analytical sketching and abstracting designs into thematic icons, we utilised sketching as a structured means of deconstructing and evaluating robot aesthetics. This novel methodological contribution situates sketching as an analytical tool, integrated with LTA, to reveal how aesthetic elements are perceived, and cognitively structured by participants. This combined approach, sketch analysis autopsy and thematic icon grouping, enabled the creation of a comprehensive map of robot aesthetic experience.

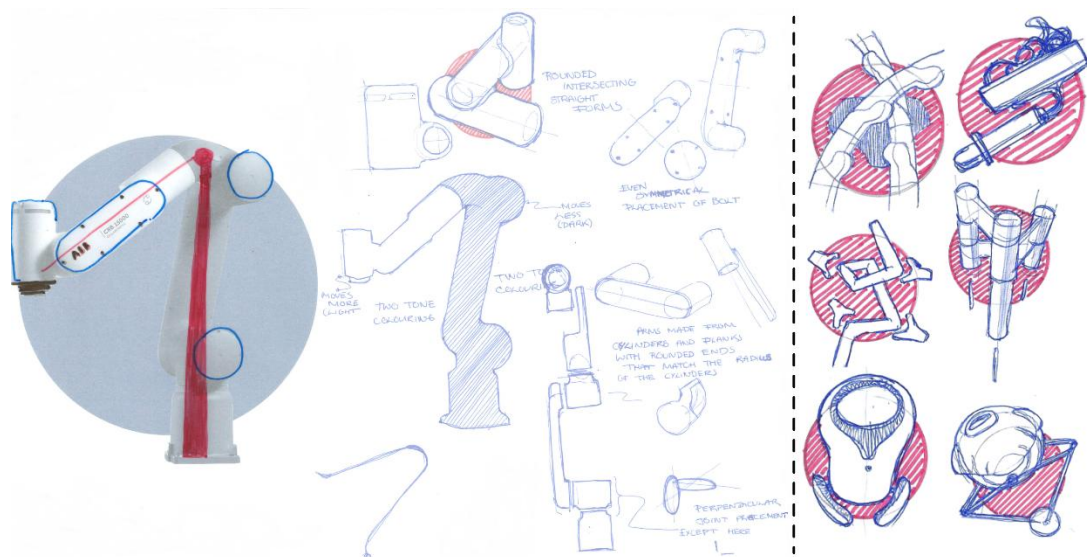


Figure 48 - Sketching Analysis Autopsy (Right), and Thematic Icon Grouping (Left)

4.4.3. Inter-Coder Agreement

There are multiple approaches for assessing inter-coder agreement (ICA). Of these, Holsti's method is particularly relevant for longer or less well-defined codebooks, as it produces an overall agreement score. Percent agreement is another common method, calculating the proportion of times coders agree, and is typically suited for simpler codebooks or when coders have extensive familiarity with the categories (Halpin, 2024). In this study, we calculated the percentage agreement across all three participant types and the average overall for the coded transcripts. Given the experience of both researchers in design, this approach was appropriate. The agreement was measured at the level of main categories rather than subcategories, since coding choices for subcategories showed greater variation. Additionally, the structure and type of thinking exhibited by each participant type were diagrammed to illustrate the form of their cognitive moves (Figure 49).

4.4.4. Reflexive Journal

A reflexive journal was maintained after each participant completed their study, capturing observational insights, and emerging analytical interpretations. The journal was used to document shifts in the researcher's understanding, notable moments of participant reasoning, and recurring patterns across sessions. These reflexive entries supported the

iterative development of codes and themes by providing a trail of analytic decisions and help reveal points of convergence or tension within the data and analysis. This was done by summarising each of the observations and organising them by participant group and creating the themes and codes (See Appendix D – Reflexive Journal).

4.5. Results of First Study

The seven morphologies; Anthropomorphism (An), Zoomorphism (Zo), Phytomorphism (Ph), Artimorphism (Ar), Functionism (Fu), Amorphism (Am), and Neomorphism (Ne), were evaluated alongside three bipolar styling dimensions: Natural/Curvature (N/C) versus Mechanical/Angular (M/A), Abstract/Iconographic (A/I) versus Realistic/Accurate (R/A), and Familiar/Unity (F/U) versus Strange/Chaos (S/C).

4.5.1. Inter-Coder Agreement Results

For our intercoder agreement, the average rate was 79.49%. However, since the results did not always include the same number of dominant moves, a 10% penalty was applied per participant type, resulting in an adjusted average agreement of 62.82%. Despite this adjustment, the agreement rate per matched move remained 79.49%, indicating that coders agreed beyond chance (Table 5). The coding of participant-created themes and notes, however, did not yield any significant findings. Indicating the need for a more sophisticated method to interpret sketching and notation in future studies.

Table 5 - Intercoder Agreement

ICA - Moves	Average Agreement	Moves missing	Agreement with Move penalty (-10%)
Product Designers	79.447 %	M6, M7 (R1)	59.447 %
Designer Engineers	75.790 %	M8 (R1)	65.79 %
Roboticians	83.218 %	M5, M6 (R1)	63.218 %
Total	79.485 %		62.818 %

For the ICA moves agreement the PD group shows an average agreement of 79.447%, with moves M6 and M7 (R1) missing and an agreement-with-move value of 59.447%. The DE group has an average agreement of 75.70%, missing move M8 (R1), and an agreement-with-move value of 65.97%. The R group reaches an average agreement of 83.218%, missing moves M5 and M6 (R1), with an agreement-with-move value of 63.218%. Overall, the total average agreement across groups is 79.485%, with a combined agreement-with-move value of 62.818%. For the results of the styling evaluation the groups leaned in the same directions of the styling dimensions except for product designers (See Appendix E – Sorting Experiment Data).

4.5.2. Model of Aesthetics Experience towards Robots

Participants began with visceral impressions, echoing Norman's (2013) model of rapid, pre-cognitive aesthetic processing, then progressed to interpretation and meaning-making, consistent with Lehar's (2003) account of sensory input consolidation. Contextual cues and affordances echoing Gibson (2015) further shaped judgment. Across groups, interpretation followed a layered process; visceral, to analogous (complex), to functional/contextual (settling/referential) reasoning, rather than a linear sequence. Expertise amplified functional reasoning but did not replace aesthetic or metaphorical thinking, indicating augmentation rather than substitution. Emotional responses acted as initial anchors but rarely dominated. Taken together, the model reveals a dynamic interplay between immediate effect, visual metaphor, functional affordances, and cultural framing, situating robot aesthetics as contextually grounded and action oriented. The diagram below (Figure 49) displays the dominant codes identified by both researchers, with each move arranged sequentially. To determine these moves, all evaluations were averaged, and those exceeding a threshold were considered dominant.

Regarding participants' mode of perception, there is typically an initial visceral response to a robot's aesthetics, often expressed through immediate analogies. This initial reaction then develops into a more structured form of analysis, in which participants consider aesthetic qualities, functional attributes, and additional comparative associations. In this process, meaning and purpose are progressively constructed rather than derived solely from visual appearance, reflecting a form of reification of meaning. Participants then tend to stabilise on whichever interpretive dimension becomes most salient in their perception, while occasionally returning to their initial visceral impression as a reference point. This process is driven by different modes of aesthetic and analogical thinking, in which participants draw on familiar objects and living forms to interpret the robot based on its visual and stylistic cues. It can be understood as an abstract extension of Lehar's (2003) concept of reification, or alternatively as a meaning-based form of reification, in which perceptual qualities are progressively organised into coherent conceptual meaning.

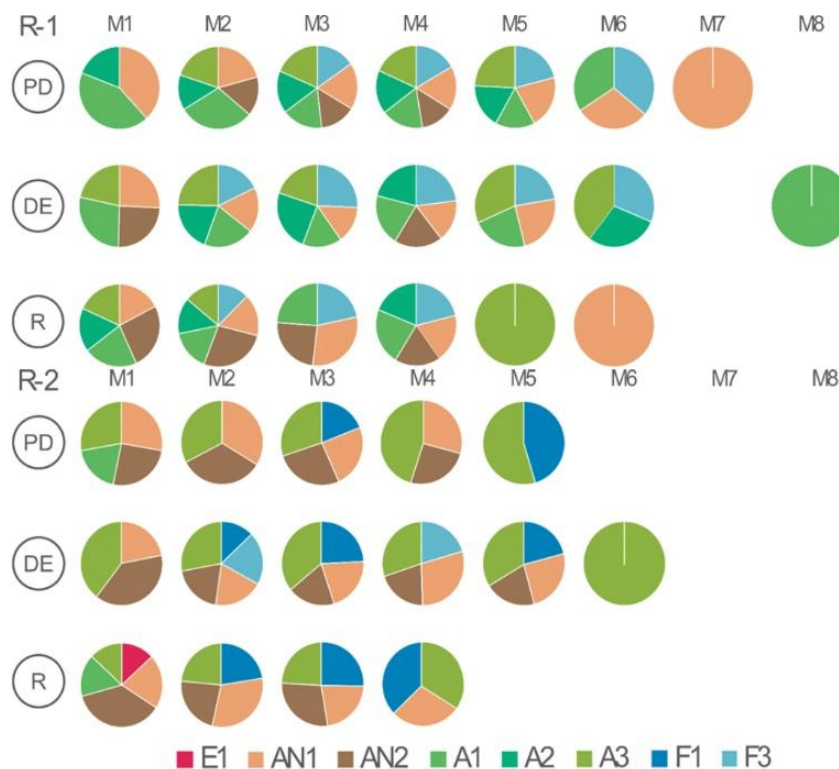


Figure 49 - Moves/Types of thinking per Moves, R1 (First Researcher), R2 (Second Researcher), Product Designers (PD), Design Engineers (DE), Roboticians (R). Bottom is the generalized description.

- Aesthetic Thinking: A1 – Themes, A2 – Styling Detail, A3 – Morphology
- Functional Thinking: F1 – Function, F3 – Design
- Analogous Thinking: AN1 – Object, AN2 – Creature
- Emotional Thinking: E1 – Positive

These modes illustrate how participants constructed meaning by combining visceral impressions with functional, aesthetic, and cultural references, ultimately shaping their perception of robot design. The findings are detailed below:

- **Consistent multimodal reasoning across participant groups:**

Each pie chart shows that participants rarely relied on a single mode of thinking when interpreting robot designs. Instead, evaluations consistently combined aesthetic (A1–A3), functional (F1/F3), analogous (AN1/AN2), and emotional (E1) components. This supports the interpretation that robot perception is constructive and integrative, rather than driven by one dominant cognitive pathway.

- **Aesthetic and analogous thinking dominate early interpretation:**

Across PD, DE, and R groups, aesthetic thinking (themes, styling detail, morphology) and analogous thinking (object/creature references) occupy the largest proportions in most charts. This indicates that participants initially frame robots through visual pattern recognition and metaphor, rather than technical reasoning.

- **Functional thinking increases with expertise but does not replace aesthetic judgment:**

Design Engineers and Robotacists show a greater presence of functional modes (F1, F3) than Product Designers, yet these never fully replace aesthetic or analogous thinking. This suggests that expertise adds interpretive layers rather than overriding visceral or aesthetic responses.

- **Emotional responses are present but rarely dominant:**

The relatively small but persistent E1 segments indicate that positive emotional reactions occur early but are quickly embedded within broader interpretive structures. Emotion appears as a catalyst rather than a sustained mode of reasoning.

- **Stability across repetitions (R-1 vs R-2):**

Comparing the two rows (R-1 and R-2) shows strong consistency in the distribution of thinking modes, suggesting that initial impressions are resilient and continue to influence later interpretation even as reflection increases.

From this, it was theorised, and a model developed (Figure 50), that participants initially experienced a visceral response, consistent with Norman (2013), followed by a more elaborate interpretive process involving the construction or “reification” of meaning, similar to Lehar (2003). Participants then tended to settle on a dominant interpretation, while occasionally revisiting either their initial visceral reaction or their subsequent analytical assessment. This interpretive stage was shaped by perceived affordances and culturally embedded cues, as outlined by Gibson (2015).

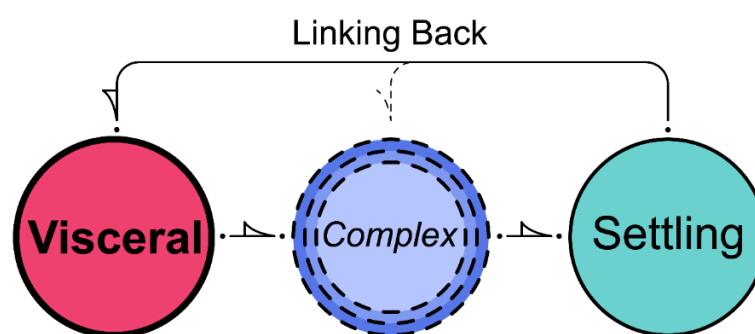


Figure 50 - Model of Robot Aesthetic Experience

4.5.3. Morphological evaluations

As the styling dimensions were implemented as bipolar semantic differential scales, and responses were analysed as directional distributions rather than averaged values, following established semantic differential methodology by Osgood et al. (1957). All three participant groups: Design Engineers, Product Designers, and Robotacists exhibited broadly

similar perceptions of morphology strength across categories, with function-driven forms (Functionism) rated most strongly overall (Figure 51). This suggests a shared baseline understanding that robots are primarily interpreted through their functional expression. Zoomorphism and Anthropomorphism occupied a middle range, indicating moderate but consistent recognition across groups. Phytomorphism was rated weakest by all participants, reinforcing the finding that plant-like references are not strongly associated with robotic form. Amorphism also remained comparatively low, reflecting limited engagement with formless or non-referential morphologies. Neomorphism and Artimorphism formed a secondary tier, suggesting openness to novel or artefactual forms, particularly among Design Engineers. While Design Engineers generally reported slightly higher morphology strengths, followed by Roboticists and then Product Designers, these differences were modest, indicating more convergence than divergence between groups.

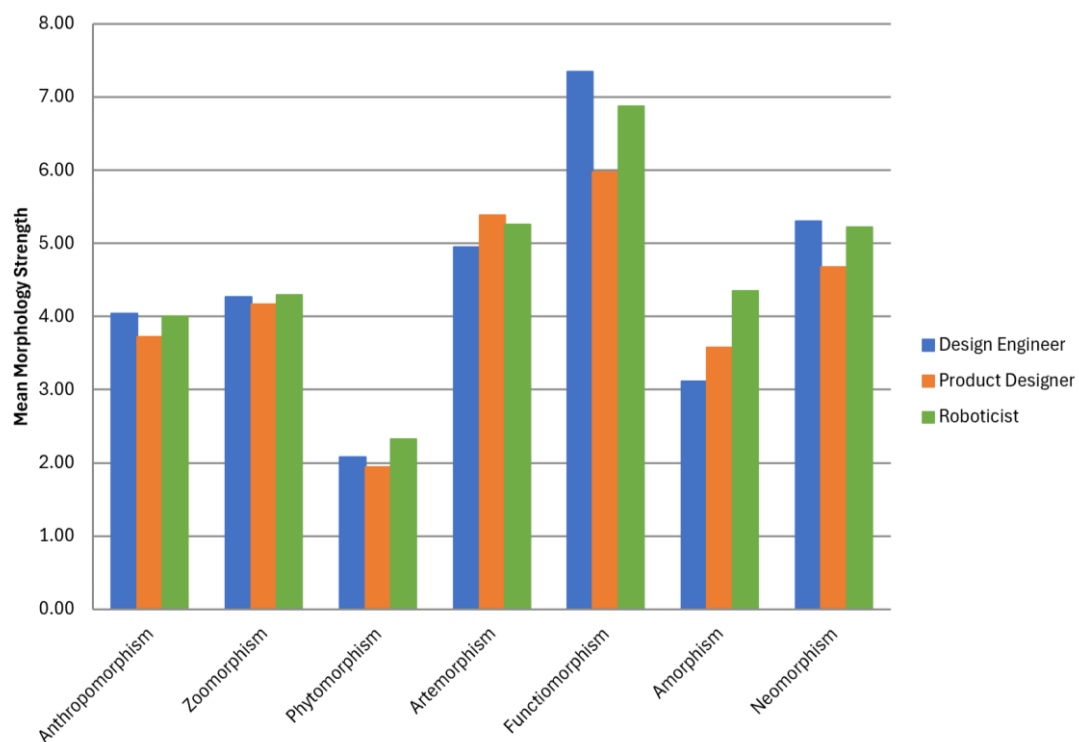


Figure 51 - Mean Quantitative Morphology Strength by Participant Group

The morphologies in the table above are Anthropomorphism (An), Zoomorphism (Zo), Phytomorphism (Ph), Artimorphism (Ar), Functionism (Fu), Amorphism (Am), and Neomorphism (Ne). The rating scale ranges from 1–2 for very low, 3–4 for low, 5–7 for medium, 8–9 for high, and 10–11 for the highest levels.

To examine associations between morphology and styling, responses were filtered to include only cases where a morphology was strongly perceived (≥ 9). For each morphology, the distribution of styling responses across bipolar semantic differential axes was then calculated separately for each participant group. This presents the mean perceived strength

of each morphology across participant groups and reveals a consistent perceptual hierarchy independent of professional background. Functionomorphism was rated strongest across all groups, followed by neomorphism and artimorphism, while phytomorphism was consistently rated weakest, with anthropomorphism, zoomorphism, and amorphism occupying intermediate positions.

Although absolute ratings varied slightly between design engineers, product designers, and roboticists, the relative ordering of morphologies remained stable, suggesting a shared perceptual structure rather than group-specific categorical interpretations. These results indicate that morphologies differ in inherent perceptual salience rather than mere presence, with stronger morphologies being more readily recognisable across stylistic variation. This hierarchy provides an important baseline for interpreting subsequent analyses, when morphologies were perceived as weaker, most notably phytomorphism, later exhibited narrower stylistic bandwidths in semantic-differential and convex-hull representations, whereas stronger morphologies such as functionomorphism tolerated a broader range of stylistic expression. Thus, the morphology strength results do not contradict later findings but instead contextualise them, supporting the interpretation that styling dimensions modulate recognisability rather than determine morphological classification. Qualitative feedback supports these patterns as participants often interpreted zoomorphism broadly as biomorphic, explaining its robustness compared to phytomorphism.

4.5.4. Overall Styling and Morphology Evaluations

The stylings are Natural/Curvature (N/C) versus Mechanical/Angular (M/A), Abstract/Iconographic (A/I) versus Realistic/Accurate (R/A), and Familiar/Unity (F/U) versus Strange/Chaos (S/C). The ratings system goes from 1–4 indicating Realist/Accurate, Natural/Curvilinear, or Familiar/Unity qualities; scores from 5–7 represent a neutral style; and scores from 8–11 correspond to Abstract/Imaginative, Mechanical/Angular, or Strange/Chaos characteristics.

The triangular semantic differential plots of styling evaluations for high-morphology robot designs (≥ 9) (Figure 52 (A)) where each axis represents a bipolar styling dimension extending symmetrically from a neutral origin. Individual image evaluations form triangular configurations across the three dimensions. The Colours indicate the morphology type, and each triangle represents a single image evaluation across three bipolar styling dimensions. This representation preserves distributional structure without averaging, enabling comparative interpretation across participant groups.

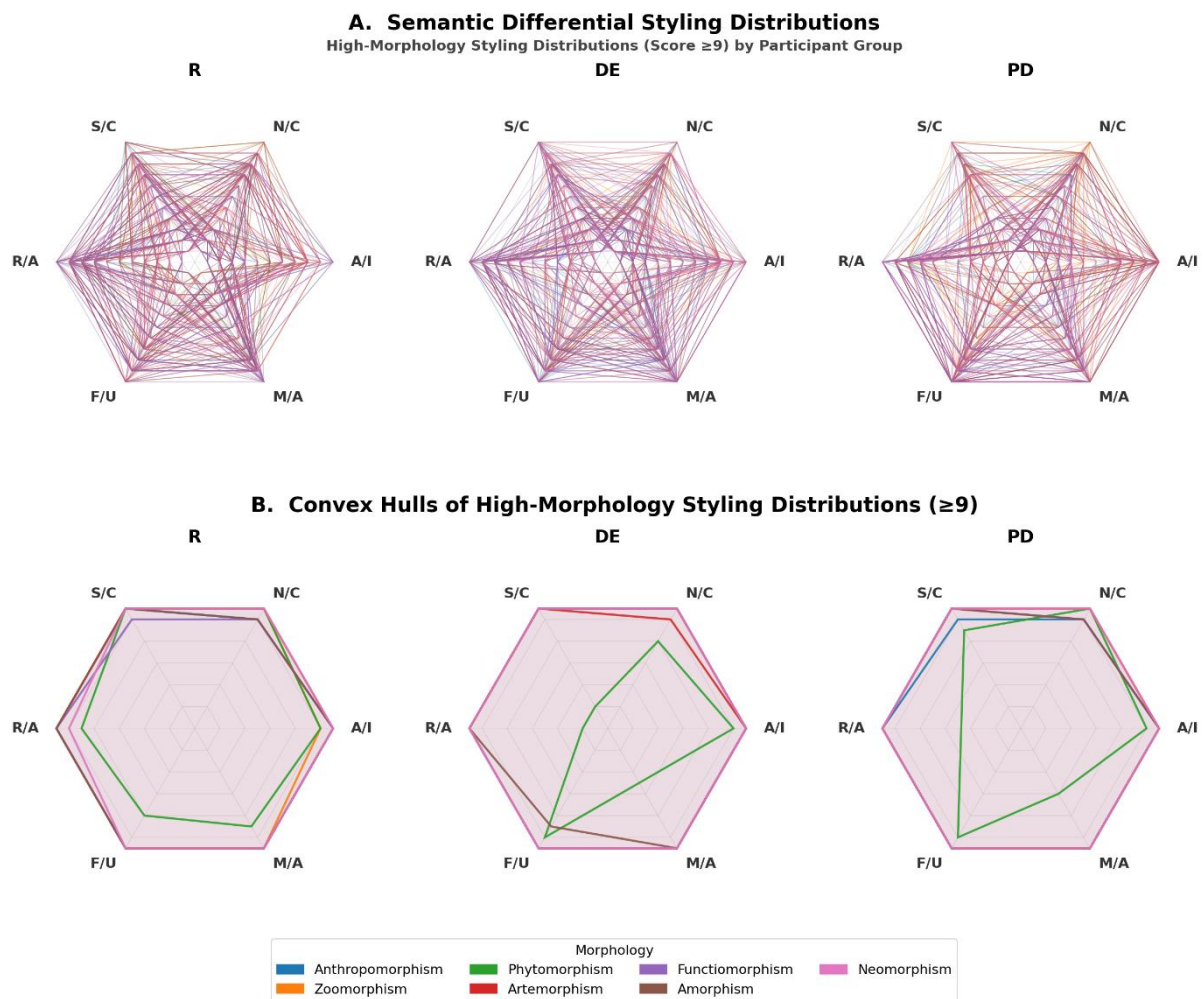


Figure 52 - Styling Evaluations, Semantic Differentials (A), Convex Hulls (B)

Across all three participant groups, the high-morphology (≥ 9) styling diagrams (Figure 52) indicate that strong morphological attribution does not map to a single, dominant styling dimension in a consistent or deterministic way. Instead, even when a morphology is perceived as strong, its associated styling responses remain distributed across multiple poles, suggesting that morphology functions as a semantic anchor rather than a prescriptive stylistic outcome.

For roboticists, high anthropomorphic and functional morphologies show a tendency toward realistic/accurate and familiar/unified styling, but this tendency is moderated by substantial proportions of abstract/iconographic and strange/chaotic responses. This indicates that while roboticists may cognitively associate strong morphology with recognisable or functional clarity, they still tolerate, and possibly expect, stylistic abstraction. Notably, phytomorphism exhibits more even but still weaker stylistic alignment, reinforcing the interpretation that plant-like morphology is weakly associated to robotic designs.

For design engineers, the association between high morphology and styling is somewhat tighter, particularly for anthropomorphism, zoomorphism, and functionomorphism,

which lean more consistently toward realistic, natural, and familiar poles. However, even here, amorphous and neomorphic morphologies demonstrate high variability and stronger associations with abstract, mechanical, and strange styling dimensions. This suggests that design engineers differentiate more clearly between “structured” and “non-structured” morphologies, rather than mapping morphology directly to a specific aesthetic styling. Phytomorphism was the most weakly coupled to stylings, only relating to natural/curvature, abstract iconographic, and familiar/unity but weaker than any other morphology.

For product designers, high-morphology cases display the greatest stylistic openness. While functional and anthropomorphic morphologies still lean toward realism and familiarity, zoomorphism and neomorphism show substantial abstraction and stylistic divergence. Phytomorphism again stands out as weakly constrained, related to the same stylings as the design engineers associated with it but adding strange and chaos, indicating limited shared understanding and applicability of what strong plant-like morphology means in a robotic context.

Even at the highest levels of perceived morphology, stylistic evaluations remain distributed across bipolar dimensions, supporting a multidimensional rather than categorical relationship between morphology and styling. Maximum morphology ratings were associated with consistent but non-exclusive stylistic tendencies, indicating that morphology functions as a perceptual amplifier rather than a stylistic determination. Morphologies exhibit stylistic tendencies rather than stylistic definitions. Morphological perception and stylistic evaluation remained largely weakly coupled, suggesting that morphology does not prescribe a singular stylistic expression. Across participant groups, even maximally perceived morphologies were associated with diverse and overlapping stylistic configurations, indicating that styling dimensions function as independent perceptual axes rather than direct proxies for morphology and that styling is not determinant for a morphology. The morphologies that are weakly grounded in robotics (e.g., phytomorphism, amorphism, neomorphism) exhibit broader stylistic spread as participants lack a stable internal reference.

Convex hull representations of styling distributions for high-morphology robot designs (≥ 9) (Figure 52 (B)), shown separately for each participant group. Hulls indicate the stylistic envelope occupied by each morphology across the three bipolar dimensions. Convex hull representations of high-morphology evaluations revealed that morphologies occupy broad and partially overlapping stylistic regions rather than discrete stylistic preferences. While certain morphologies exhibited directional biases along specific styling dimensions, no morphology was confined to a singular stylistic configuration. Differences in hull extent and overlap across participant groups further suggest that the perceived relationship between morphology and styling is shaped by professional framing rather than being intrinsically fixed.

Morphology constrains style weakly by defining a permissive region, not by prescribing a specific stylistic outcome.

The narrower stylistic envelope observed for phytomorphic designs does not contradict the weak overall association between morphology and styling dimensions. Rather, it reflects the comparatively low perceptual salience of phytomorphism, which appears to require more constrained stylistic conditions to be reliably recognised. In contrast, more salient morphologies exhibited broader stylistic bandwidths, indicating greater tolerance to variation in styling. Phytomorphism requires a more constrained stylistic expression to be recognised. If a morphology is weakly perceived, fewer stylistic configurations reliably evoke it. Therefore, weakly perceived morphologies exhibit narrower stylistic bandwidths, not because styling determines morphology, but because fewer stylistic configurations reliably evoke them.

The consistently low strength of phytomorphism across participant groups suggests that plant-based metaphors are weakly associated with robotic artefacts, likely reflecting broader cultural and functional expectations of robots as agents characterised by movement and intentionality. As a result, phytomorphic cues may require more explicit and constrained styling to be recognised, accounting for the limited stylistic bandwidth observed in later analyses. In contrast, qualitative feedback indicated that participants often interpreted zoomorphism broadly, incorporating a range of biological references beyond animals alone, aligning more closely with the concept of biomorphism. This broader interpretation helps explain the relative robustness of zoomorphic ratings compared to phytomorphism and does not conflict with the quantitative findings; rather, it highlights how biological morphologies are perceptually grouped in practice. Together, these results suggest that morphological categories are not equally salient within the domain of robotics and that participant interpretation can inform refinement of morphological taxonomies without undermining theory or consistency of the underlying data. The weak performance of phytomorphism reflects domain-specific perceptual associations rather than methodological limitations, while participant-driven expansion of zoomorphism toward biomorphism illustrates how morphological categories may be refined through empirical use.

4.5.5. Analysis by Participant Type

For roboticists, the analysis of high morphology evaluations (≥ 9) revealed no singular stylistic profile associated with any morphology; however, consistent directional tendencies were observed across semantic-differential axes (Figure 53). Functionism was most frequently associated with realistic and mechanical styling, while neomorphism and amorphism exhibited greater tolerance for abstraction and perceptual novelty. Phytomorphism, despite being weakly perceived overall, showed a strong bias toward

natural and curvilinear styling, indicating a constrained stylistic envelope rather than random variation. Importantly, substantial neutral ratings persisted across all morphologies, suggesting that even expert evaluators do not require stylistic extremity to perceive strong morphological characteristics. These findings support the interpretation that, for roboticists, styling dimensions act as permissive or restrictive conditions rather than primary determinants of morphological classification. Among roboticists, morphology perception appears robust to stylistic variation, with styling functioning as a constraint rather than a defining factor.

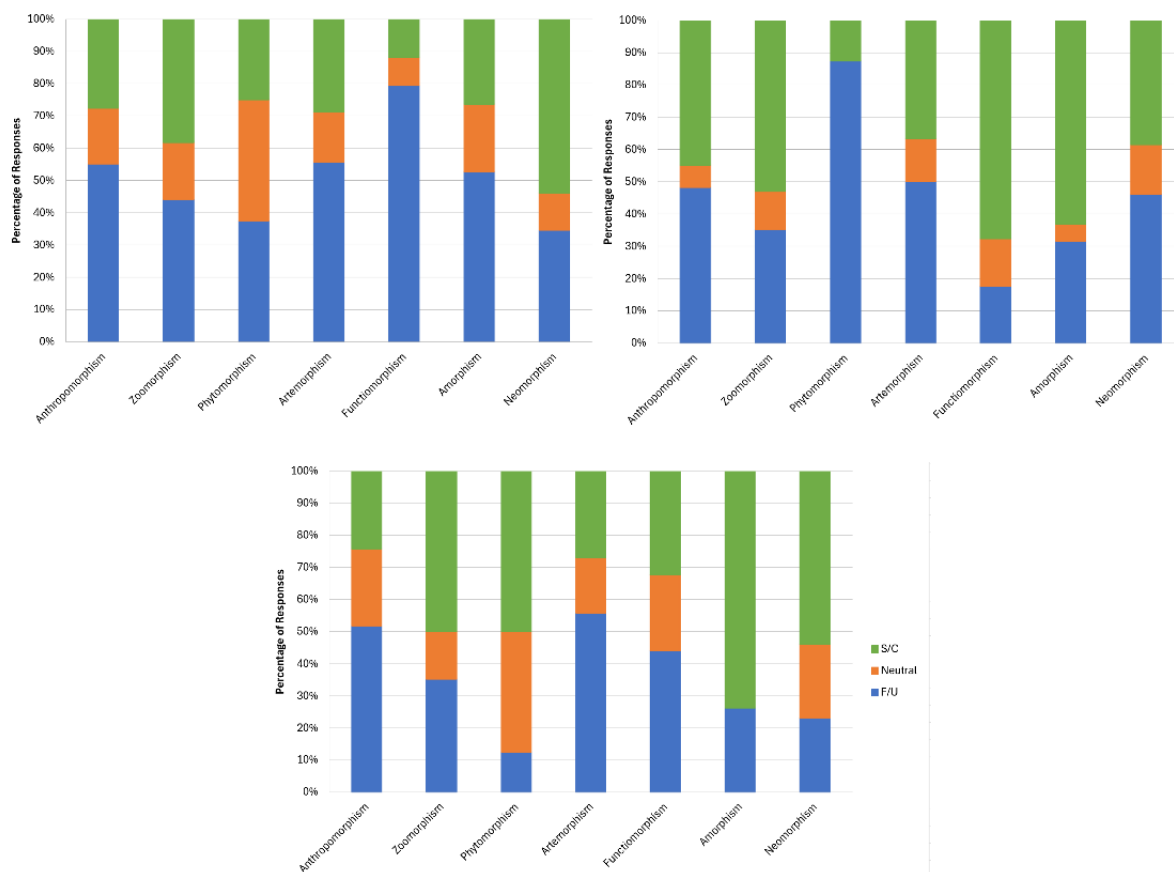


Figure 53 – Roboticists - Styling Differentials per Dimension R/A – A/I (Left), N/C – M/A (Right), F/U – S/C (Bottom)

For design engineers, the analysis of high morphology evaluations (≥ 9) revealed stronger stylistic polarisation than observed for roboticists, with fewer neutral ratings and more pronounced directional biases across semantic-differential axes (Figure 54). Phytomorphism exhibited the most constrained profile, appearing exclusively abstract, natural, and familiar when strongly perceived, indicating a narrow stylistic envelope and high dependence on specific formal cues. Functionorphism was predominantly associated with realistic and mechanical styling, reflecting an emphasis on formal and structural clarity in functional interpretation. In contrast, neomorphism and amorphism showed greater tolerance for abstraction and perceptual novelty, frequently aligning with strange or chaotic styling.

Despite these tendencies, no single styling dimension uniquely determined morphology, supporting the interpretation that, for design engineers, styling dimensions function as constraining conditions rather than defining criteria for morphological classification.

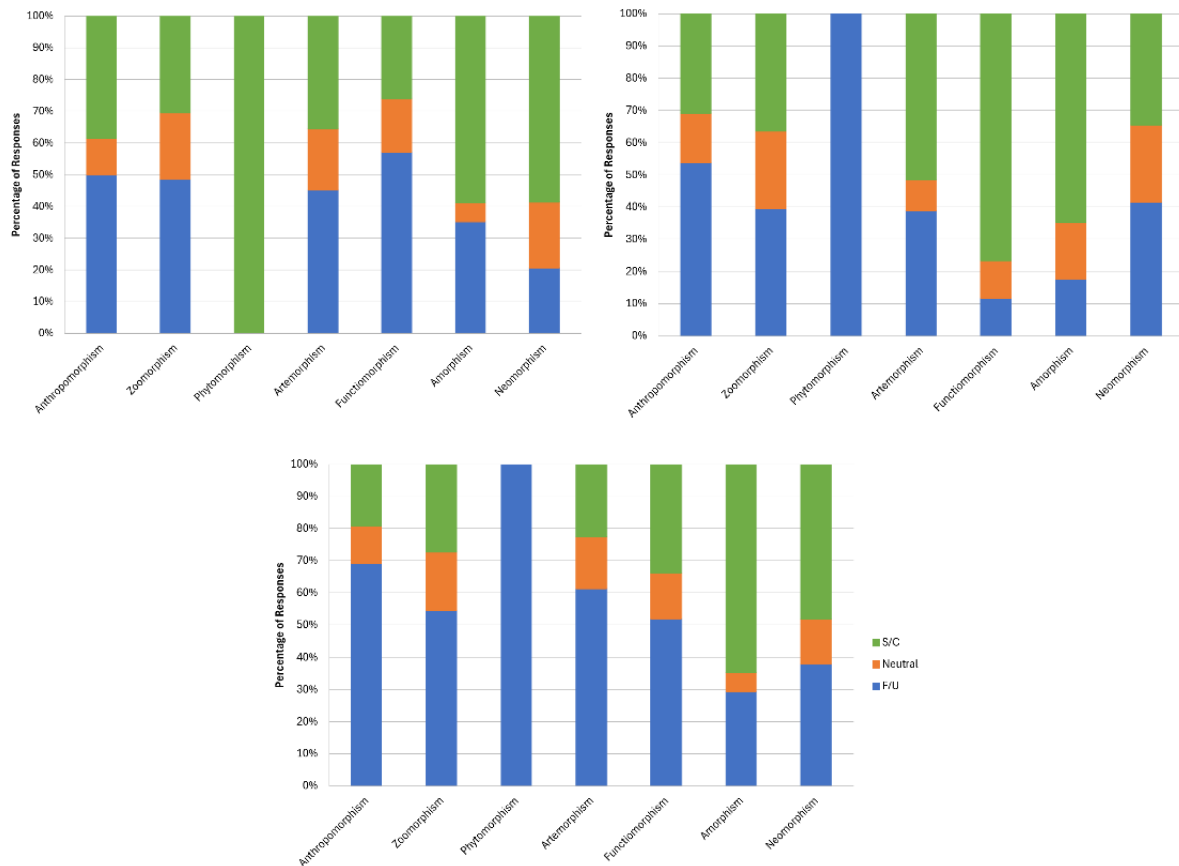


Figure 54 - Design Engineers - Styling Differentials per Dimension R/A – A/I (Left), N/C – M/A (Right), F/U – S/C (Bottom)

Compared to roboticists, design engineers exhibited stronger stylistic polarisation, suggesting greater reliance on formal cues while maintaining a constraint-based rather than deterministic relationship between styling and morphology.

For product designers, the high-morphology (≥ 9) styling results show that strong morphological attribution does not lead to a single or dominant stylistic outcome (Figure 55). Even when a morphology is clearly perceived, styling responses remain distributed across both poles of each semantic differential, indicating that morphology functions more as a conceptual reference than a prescriptive visual constraint. Anthropomorphic and functional morphologies show mild tendencies toward realistic, natural, and familiar styling, but these are consistently accompanied by substantial abstract, mechanical, or strange interpretations. Zoomorphic and neomorphic forms exhibit particularly broad stylistic dispersion, reflecting a high degree of interpretive freedom. Phytomorphism, despite occasional high morphology ratings, lacks a coherent stylistic signature, reinforcing its weak association with robotic form language. Overall, these findings suggest that product designers weakly couple morphology

from styling, allowing strong morphological intent to coexist with diverse aesthetic expressions.

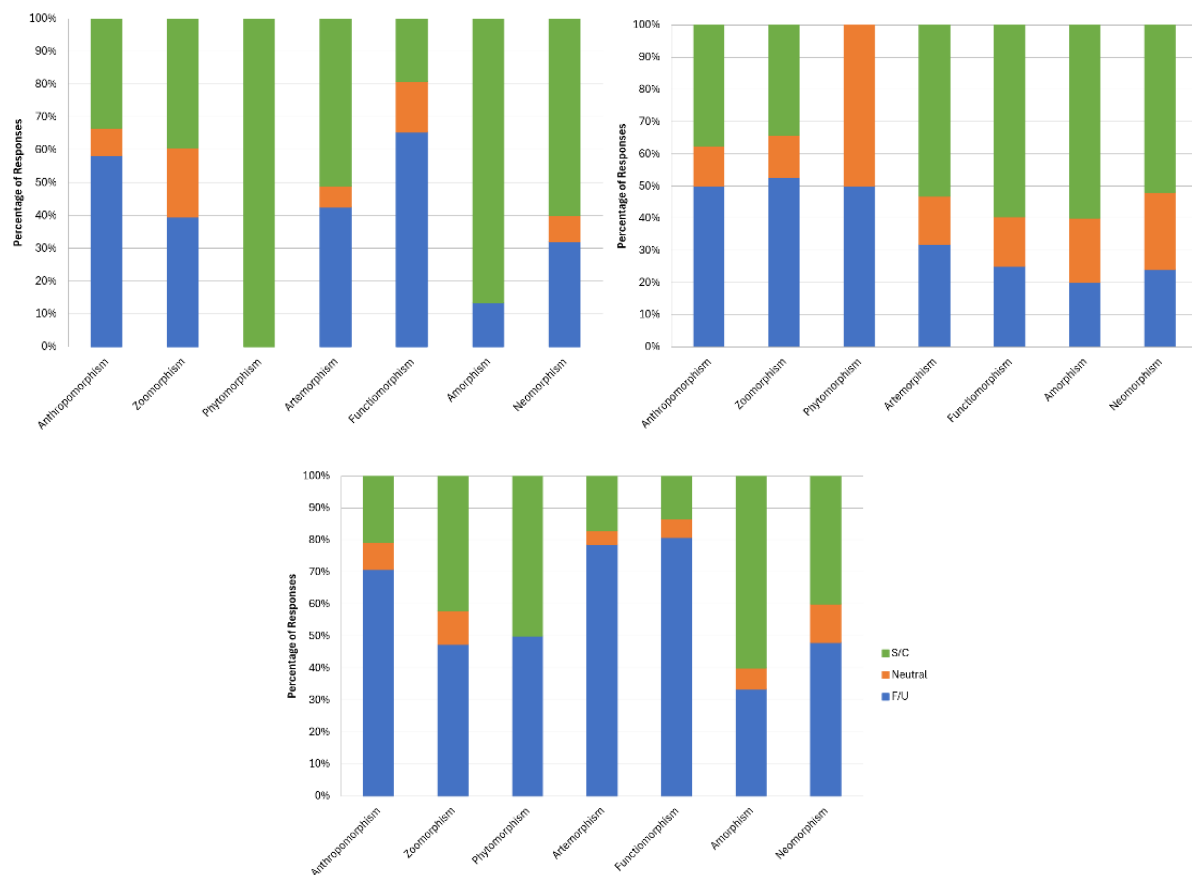


Figure 55 - Product Designer - Styling Differentials per Dimension R/A – A/I (Left), N/C – M/A (Right), F/U – S/C (Bottom)

4.5.6. Reflexive Journal Notes

From the perspective of morphology perception, participants frequently distinguished partial human-like elements, such as an "arm" or "head," as objects rather than truly anthropomorphic unless the design constituted a complete humanoid form (e.g. participants 1, 5, 9, 15). Mechanical elements, including exposed joints and wires, typically excluded classifications as zoomorphic or phytomorphic, often leading to descriptions as "alien" and suggestions for a separate morphology category (e.g. participants 4, 9, 13). Arms were commonly interpreted as phytomorphic, resembling plant roots or flowers due to tapering or fixed bases (e.g. participants 6, 7, 19). Combinations of morphologies, such as anthropomorphic with functionomorphic, diminished perceived functionality and clarity, frequently appearing unfinished or impractical (e.g. participants 3, 5, 7, 12). Eyes strongly signalled anthropomorphism even when absent of a full head, while mouths were generally undesired and reduced appeal (e.g. participants 9, 12, 13, 20).

For the aesthetic dimensions, realism was associated with functional feasibility, such as clear joint articulation for movement, or biomimetic qualities, with prior exposure

increasing realism ratings (e.g. participants 1, 5, 9, 16). Chaos was correlated with danger or poor integration, exemplified by exposed mechanics in humanoid forms, whereas form repetition reduced chaos (e.g. participants 1, 2, 5, 7). Natural or curved elements could appear strange when combined with angular mechanical features, though curves evoked novelty unless animal-reminiscent (e.g. participants 1, 5, 8, 24). Covered joints promoted unity and calm, contrasting with exposed joints that induced chaos or displeasure (e.g. participants 2, 6, 7, 19). Colours significantly influenced perceptions: red connoted luxury or danger, black evil or mechanical traits, blue neutrality or modularity, and white hospital or lab settings, with subdued tones feeling domesticated (e.g. participants 2, 6, 12, 13, 20). Flowing forms implied soft or rapid movement, and joint spacing affected naturalness, with closer seams appearing more organic (e.g. participants 5, 6, 15). Perceived scale derived from detail complexity and composition, where small scales suggested toys or lab suitability and large scales industrial applications (e.g. participants 4, 6, 9, 13, 19).

As for the participants emotional and stated subjective experiences, anthropomorphic designs elicited intensified emotions, positive for cute, rounded, iconographic-faced robots and negative for uncanny or incomplete features like "skinned" faces (e.g. participants 2, 5, 7, 12). Strange or chaotic designs provoked unpleasantness or fear, including uncanny valley effects from excess curvature or mismatched morphologies (e.g. participants 1, 5, 7, 8, 18). Humanising elements like clothing were often rejected as mismatched (e.g. participants 9, 18). Positive experiences elaborated broadly, while negatives ones resulted in a fixation on flaws (e.g. participant 2).

From the perspective of the perceived functions and purpose, functionomorphic classifications depended on apparent fulfilment of inferred purposes, with unclear movement reducing this perception (e.g. participants 3, 5, 9, 13). End effectors prominently signalled function, and their absence obscured purpose (e.g. participants 7, 9, 19, 20). Social or human interaction was not considered a legitimate function, as robots were viewed as non-living objects incapable of true socialization (e.g. participants 5, 9, 14). Aesthetics were frequently seen as superfluous, though alignment with function enhanced perceived value (Participants 5, 8, 12, 19). Imagined movement was critical as ambiguity led to abstraction or reduced functionality, while perceived speed and precision impacted safety and trust (e.g. participants 7, 8, 13, 24).

Looking at the differences in the participant background, roboticists prioritised technical feasibility, kinematics, and KPIs, treating aesthetics as secondary and evaluating morphologies before aesthetics, (e.g. participants 1, 3, 4, 9, 13, 15, 16). Design engineers balanced functional and aesthetic analyses, exhibiting pronounced emotions, expansive for positives and flaw-focused for negatives, and identified joint/link details creatively (e.g.

participants 2, 10, 11, 12, 18, 22, 23). Product designers explored openly and imaginatively, emphasising aesthetics, purpose extensions, and drawing on pages more frequently (e.g. participants 5, 7, 8, 14, 17, 19, 20, 24).

For more general patterns, pre-existing object or phenomenon recall (e.g., toys, animals, medical tools) predominantly shaped meaning, function, context, and emotion, surpassing pure aesthetic influence (e.g. participants, 7, 9, 12, 13, 20). Dominant features like heads or end effectors were evaluated first, with unclear elements provoking unease (e.g. participants 8, 9, 22). Evaluation order typically progressed from eye-catching to unclear/incorrect elements, then body, and ornamentation (most participants). Prior knowledge diminished aesthetic dependency, with morphology dominating in aesthetic voids (most participants). When laboratory environments aligned with aesthetics, perceived movement, and context, positive profound emotions arose; however, participant 5 reacted negatively for unconventional designs, interpreting robot (6) initially as angelic but ultimately determined it was equipped with bumpers which to them reduced the perception of safety/functionality, with exposed mechanisms seen as unpleasant.

4.5.7. Dominant robot designs and sketching analysis.

The quantitative evaluations were analysed to identify which robots were rated most highly by participants, allowing us to determine the morphological designs associated with each category (Table 6). This analysis also helped identify which design details contributed to the aesthetic dimensions and morphologies, as well as the visual energies, arising from composition, linked to them. Out of the 100-images in the 4 sets, the dominant designs were distributed as follows: Set 1 had 17, Set 2 had 15, Set 3 had 9, and Set 4 had 16. In total, 67 designs were identified as having aesthetics strongly associated with at least one morphology. These selected designs then underwent sketching analysis and thematic icon grouping, forming the basis for the map of robot aesthetic.

Table 6 - Dominant Robot Designs

Morphology Results								Styling Results		
Set	An	Zo	Ph	Ar	Fu	Am	Ne	R/A - A/I	N/C - M/A	F/U - S/C
Set - 1	9, 18, 24	11, 12		7	2, 17, 21, 22			R/A - 2	M/A - 6, 14, 20, 21, 22, 23	F/U - 2, 3, 7, 12; S/C - 19
Set - 2	8, 12	16, 17			2, 10, 23	10			N/C - 3, 8, 14, 17; M/A - 10, 13, 21, 22, 23	F/U - 8, 12, 17, 18, 19; S/C - 10
Set - 3	17	9						R/A - 17, 22, 23	M/A - 1, 23, 24	F/U - 1, 12, 17,

										23; S/C - 18
Set - 4	9,	16, 24		2	3, 11, 16			R/A - 17; A/I - 6, 7, 18	M/A - 1, 4, 15, 16, 17	F/U - 9, 20, 21; S/C - 13

These dominant designs were then mapped into that visualises the which icons were used later on to develop the map of robot aesthetic principles - morphologies and stylings (Figure 57).

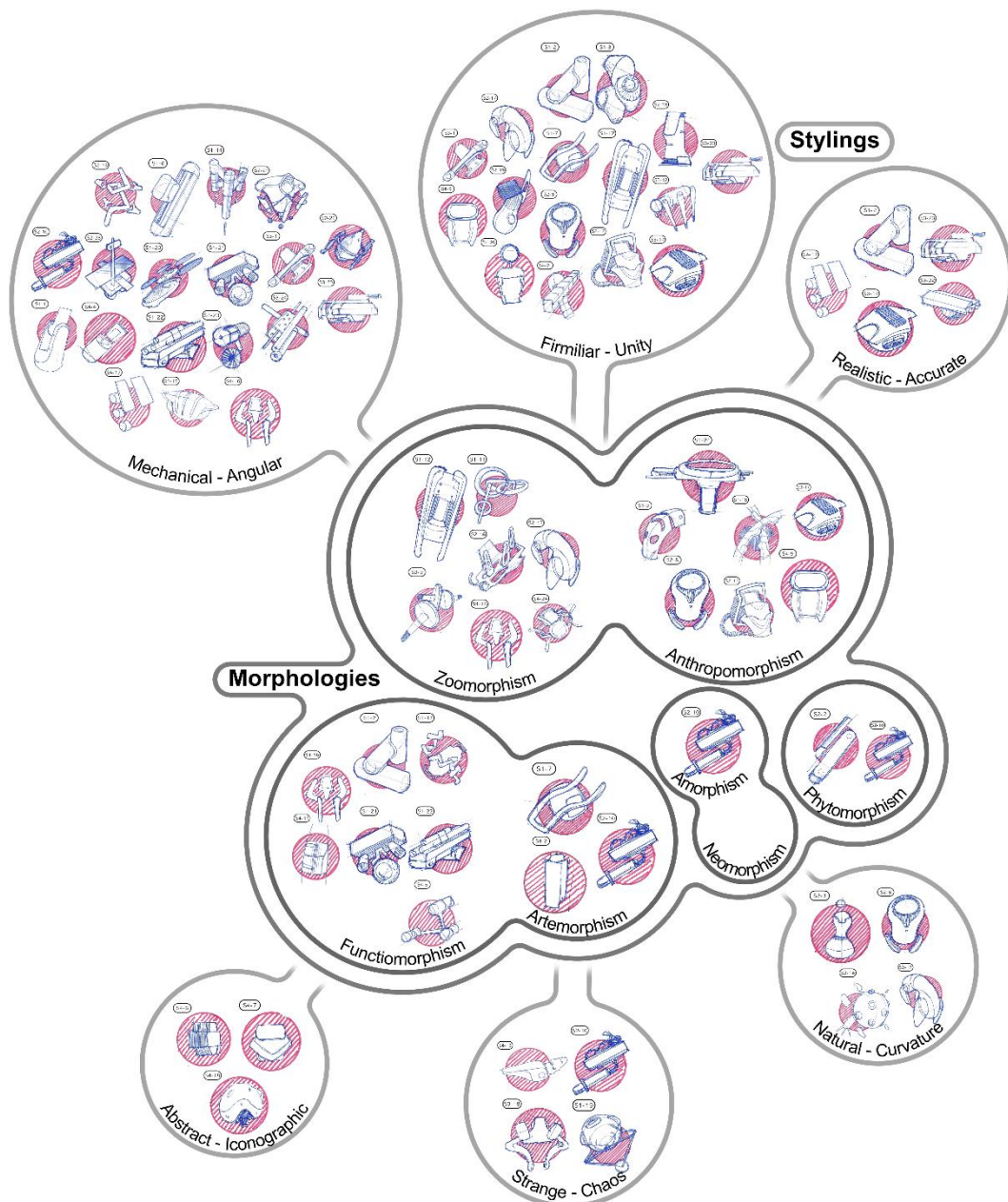


Figure 56 - Dominant Robot Icons by Category

4.5.8. Summary of Results

The findings confirm that morphology and styling operate as independent design layers. Even at the highest morphology ratings (≥ 9), styling responses remained widely distributed across bipolar styling dimensions, supporting a multidimensional, not categorical, relationship between form and aesthetic treatment. Convex hull analyses reinforce this independence as stylistic envelopes overlapped across morphologies, indicating weak coupling and broad creative bandwidth for designers. This finding resonates with Osgood et al.'s (1957) semantic differential theory, which treats evaluative dimensions as perceptually independent. At a participant-group level roboticists leaned toward realistic and familiar styling for anthropomorphic and functional morphologies yet tolerated abstraction and chaos, echoing Hegel's (2012) observation that social capability attribution begins with appearance but adapts to context. Design engineers showed tighter associations for structured morphologies but high variability for amorphous and neomorphic forms, reflecting Steffen's (2010) notion of aesthetic innovation as balancing clarity and novelty. Product designers exhibited the greatest openness, consistent with Desmet and Hekkert's (2007) emphasis on emotional experience as a driver of creative latitude. The dominant designs (67 of 100) were analysed through sketch-based autopsy and thematic icon grouping, which linked salient morphological elements to aesthetic dimensions and informing the morphology and styling map. This methodological contribution builds on Goldschmidt's (1990) linkography and Cooper's (2018) work on gesture in design drawing, using sketching as an analytical lens rather than purely creative. For the reflexive notes, eyes, even abstract, trigger anthropomorphic categorization, echoing DiSalvo et al.'s (2002) findings on facial cues. Modularity and exposed mechanics signal "engineered" design, consistent with Hanson's (2006) aesthetic principles for humanoid robots. Analogies to familiar objects dominated interpretation, supporting Lam et al.'s (2016) argument that product aesthetics rely on experiential reference points. Interpretation followed a layered process where visceral impressions, to aesthetic/analogous, functional/contextual reasoning mirroring Norman's (2013) three-level model and Lehar's (2003) account of sensory input consolidation and our view that something we term a reification of meaning is occurring. Contextual cues shaped judgment, reinforcing Gibson's (2015) affordance-based perspective and Wagemans et al.'s (2012) Gestalt principles of perceptual grouping. These insights extend design theory by using classic perceptual and emotional frameworks within robotics and addressing gaps in HRI research, which often relies on static imagery and fragmented morphology sets (Blow et al., 2006; Gan et al., 2021). By integrating qualitative linkography, thematic analysis, and sketch/icon methods, this study provides actionable guidance. This is in line with Freyberg and Hauser's (2023) morphological paradigm, with the evidence reframing form as central to engagement and innovation while clarifying that styling remains an independent, high-

bandwidth layer for cultural/contextual and emotional expression. Collectively, the contribution is threefold: (1) empirical weak coupling of morphology and styling; (2) a validated, layered model of aesthetic interpretation grounded in designers' and roboticists' cognitive moves; and (3) a morphology and styling map and principles that translate perceptual patterns into designable choices.

Phytomorphism's weak anchoring and limited bandwidth highlight the need for motion and contextual cues to secure robotic identity, while zoomorphism operates more broadly as biomorphism without contradicting quantitative trends, echoing Gemeinboeck's (2021) call for relational aesthetics and Lam et al.'s (2016) emphasis on cultural appropriateness. The value of aesthetics clearly gives greater value to the findings of Eggink and Snippert (2017). As the aesthetics and the design movements positive outlook and reception determine the success of the technology, and the technology conforms to the positive values of the movement.

4.5.9. Robot Aesthetic Categories

Based on the empirical findings, robot aesthetics is refined into two independent but interacting sets of principles: morphological categories, which define how bodily form establishes interpretive expectations, and styling categories, which modulate those expectations through surface treatment, abstraction, and visual coherence. Rather than treating morphology and styling as hierarchical or causally dependent, the results indicate that they function as separable yet interacting design layers, each contributing distinct perceptual, emotional, and functional cues. The morphological categories are defined first, as they characterise how overall form shapes ontological expectations regarding a robot's likely behaviour and capability. The styling principles are then defined as secondary modifiers that influence emotional tone, perceived trustworthiness, and cultural/contextual legibility across different morphologies. Although users may show a preference for alignment between morphology and styling, the two remain decoupled in practice. These alignments can be followed, intentionally disrupted, or reconfigured to generate new meanings, depending on design intent. Importantly, such preferences are not inherent properties of the robot itself, but assumptions made by the perceiver during interpretation.

4.5.10. Morphology Categories

- **Anthropomorphism**

Robots with human-like morphology are most effective when paired with familiar and realistic stylings, as facial cues (especially eyes) trigger recognition, emotional resonance, and lifelike perception.

- **Biomorphism**

Organic morphologies communicate natural motion when expressed through curvature and abstraction, enabling participants to interpret robots via creature analogies and biological traits.

- **Functionomorphism**

Functionomorphic designs achieve clarity when styled as mechanical/angular and realistic/accurate, reinforcing affordances and credibility through visible circuitry, modularity, and engineered articulation.

- **Artimorphism**

Artemorphic robots, resembling utilitarian appliances, are best conveyed through mechanical/angular and abstract/iconographic stylings, which communicate purpose efficiently without reliance on emotional cues.

- **Amorphism**

Amorphic forms, lacking clear affordances, are perceived as strange/chaotic or abstract/iconographic. Their incoherence often elicits unease, highlighting the importance of perceptual completion in aesthetic design.

- **Neomorphism**

Neomorphic designs function as a category of novelty rather than a consistent styling. They are perceived as “new” or “modern,” reflecting innovation but lacking codified visual traits.

4.5.11. Styling Categories

- **Mechanical / Angular**

Angular styling signals engineered function and credibility, reinforcing functionomorphic and artemorphic clarity.

- **Natural / Curvature**

Curved styling conveys organic motion, strengthening biomorphic associations and creature analogies.

- **Abstract / Iconographic**

Minimalist styling communicates efficiently, supporting biomorphic, artemorphic, and amorphic forms where detail is reduced to symbolic cues.

- **Realistic / Accurate**

Detailed styling enhances believability, aligning with anthropomorphic and functionomorphic morphologies by matching perceived purpose and context.

- **Familiar / Unity**

Cohesive styling strengthens recognition and emotional resonance, particularly in anthropomorphic designs.

- **Strange / Chaos**

Disordered styling triggers unease or perceived threat, often linked to amorphic morphologies.

4.5.12. Map of Robot Aesthetics

The mapping (Figure 56) illustrates how morphologies and stylings are organised and related. The diagram should be read from the inside outward: morphologies are encountered first as a semantic framing layer that structures initial interpretation, while styling operates as a secondary, affective layer that modulates this initial perception. The six morphologies are loosely grouped into pairs based on observed associations between them. These groupings may offer designers opportunities to draw conceptual or aesthetic inspiration from related forms, while also clarifying distinctions between morphologies that are perceived as connected. The lines linking morphologies to stylings represent associations inferred by participants when relating form to aesthetic expression. Although the findings suggest that morphologies contain only weak intrinsic stylistic qualities, these initial perceptual assumptions remain valuable, as they can be deliberately used by designers to shape user experience and perceived meaning. Styling itself is treated as a less discrete set of categories and more as a continuous spectrum, with observable patterns in its distribution across the diagram. Nevertheless, it retains bipolar characteristics, and its application depends on designer judgement regarding what is contextually and conceptually appropriate.

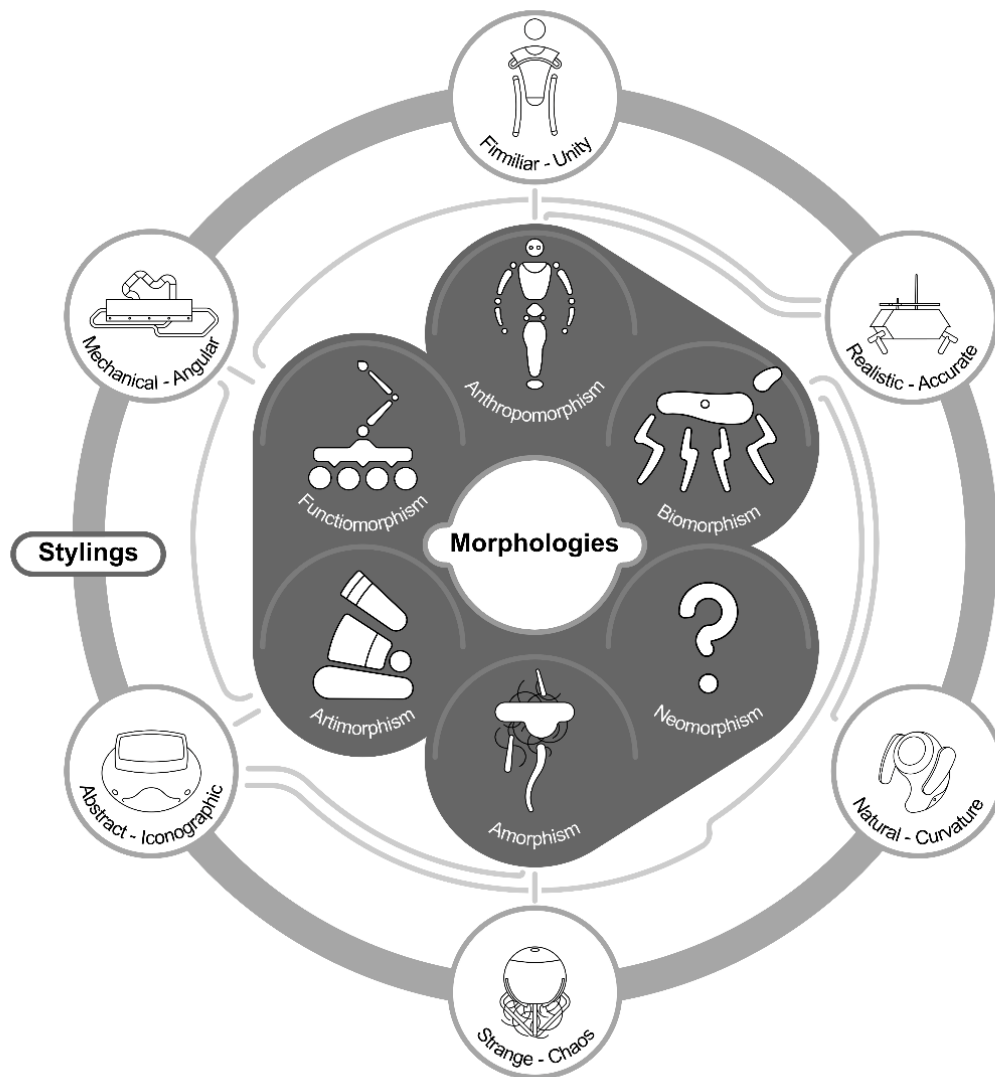


Figure 57 - Map of Robot Aesthetic Principles - Morphologies and Stylings

4.5.13. Implications for Designers

The findings of this study have direct implications for design practice, particularly for designers working across robotics, interaction, and product form. By showing that robot morphology and styling are weakly coupled yet still interact in shaping meaning, the results challenge the common assumption that morphology alone determines perception or acceptance. Instead, aesthetic interpretation emerges through the combination of morphological framing, stylistic treatment, and contextual cues. Moreover, designers should explore other areas such as biomorphism and biological metaphors contextually, address the limitations of phytomorphism, and exploit styling strategically given its weak coupling. The findings, patterns of perception and interpretation were used to develop practical aesthetic principles and categories for robot design. Rather than prescribing specific visual outcomes, they are intended to help designers make intentional aesthetic decisions that balance clarity, emotional response, and legibility across a range of robotic contexts.

4.5.14. Robot Aesthetic Principles

From this study there are three clear contributions to knowledge which are that morphology is a semantic frame shaping interpretation. With styling being a weakly coupled affective layer that allows for greater flexibility for the designer to excite different emotions. Along the functionality or purpose of the design being the strongest guide after these first two have had their effect on the user, general to all populations.

- **Morphology is a semantic frame:**

Morphology provides orientation but does not determine aesthetic outcome. Designers must deliberately specify morphological characteristics and compositional language to achieve the intended meaning they seek to frame.

- **Styling as a weakly coupled affective layer:**

Styling dimensions function as perceptual axes rather than proxies for morphology. This independence offers broad creative bandwidth and flexibility in adapting designs across contexts.

- **Functional clarity is the strongest perceptual anchor:**

When consistency or safety is critical, as in collaborative or industrial robots, function driven morphologies provide more reliable interpretive coherence than anthropomorphic or biological metaphors. This is due to the clarity of the functionality and the perceived movement envelope.

4.5.15. Limitations on First Study

This study was limited by variability in participant sketching skill and manual coding, which can affect reliability. Phytomorphism could have been weakly represented in the stimuli and in participant judgments, limiting generalisability of plant-like robot forms, future studies should explore phytomorphism in terms of motion and context. Future work could also explore automated tracking of sketching, larger participant pools, and real-world tests of adaptive robot movement.

4.5.16. Conclusion on First Study

Analysis of the reflexive journals revealed several consistent patterns. Robots featuring multiple overlapping morphologies were frequently described as incoherent or unsettling. The presence of “eyes,” even in highly abstract forms, had a strong influence on anthropomorphic interpretation. Similarly, features such as modular construction or exposed circuitry tended to reinforce perceptions of engineering functionality and technical realism. Differences also emerged between participant groups. Product designers generally adopted more interpretive and exploratory readings of the robots, often engaging with them

imaginatively. In contrast, roboticists tended to focus on functional realism, drawing on prior experience with mechanical systems and technical constraints. Design engineers occupied a middle position, balancing aesthetic considerations with functional requirements and typically favouring clear mechanical articulation over more abstract forms. Across all groups, however, participants consistently attempted to infer how the robots would move, with aesthetic cues shaping judgements related to attraction, repulsion, and perceived threat. Quantitative evaluations indicated that aesthetic themes were consistently recognised across participants. In terms of morphology, three dominant categories emerged, artimorphism, functionmorphism, and neomorphism, alongside three subdominant categories: anthropomorphism, zoomorphism, and amorphism. Phytomorphism was largely unrecognised, which may be attributed to the limited movement characteristics of plants, contrasting with the dynamic expectations typically associated with robots. Functional morphology emerged as the most stylistically coherent category, implying that performance legibility and task-oriented form provide a stronger perceptual anchor than biological metaphors alone. Zoomorphism, meanwhile, appeared to operate as a broader biomorphic category, encompassing diverse biological inspirations beyond animals without contradicting the quantitative findings. Convex hull analysis further reinforces these observations, showing substantial overlap between morphologies and limited stylistic segregation, thereby indicating that perceived morphological strength does not translate into strong stylistic coupling. Taken together, these findings align with semantic differential theory by demonstrating that evaluative dimensions remain perceptually independent, and they suggest that designers, particularly experts, navigate morphology and style as separable design layers rather than fixed pairings. Generally, rating strength across participant groups was comparable, suggesting a broadly shared perceptual structure, however, the qualitative emphasis of interpretations varied between groups.

Building on this, we propose a layered interpretation model in which designers and roboticists move from visceral impressions to aesthetic and analogous reasoning, and finally to functional and cultural judgment. This trajectory reflects Norman's (2013) rapid processing, Lehar's (2003) perceptual consolidation, and Gibson's (2015) affordance-based contextualization, showing how visual cues, analogies, and affordances co-construct meaning in robotic artefacts. Methodologically, the morphology, styling map and sketch/icon analysis translate perceptual patterns into actionable design principles, addressing gaps in HRI research that often rely on static imagery and fragmented morphology sets. These tools use classic perceptual frameworks for robotics and provide designers with practical guidance. In relation to practice, our findings advise treating morphology as conceptual orientation or sematic frame, not stylistic prescription. Use functional clarity as a perceptual anchor where safety or consistency is critical. Reinforce biological metaphors with motion

and context to ensure legibility if used. Designing the morphology and styling layers independently enhances flexibility, allowing intentional control over cultural resonance, emotional engagement, and functional clarity. Yet they can be used together where meaning can resonate or contradict to achieve a design intent. Theoretically, this work advances the morphological paradigm by positioning form as central to engagement while clarifying styling as a culturally expressive, high-bandwidth layer. It extends Gestalt and product semantics into robotics by demonstrating how grouping, completion, and experiential reference shape interpretation. The role of aesthetics reinforces Eggink and Snippert's (2017) argument that positive design movements and cultural outlooks shape technological success, as technologies thrive when they align with the values and aspirations embedded in those movements.

Overall, the study demonstrates that robot morphology and styling function as independent yet interacting design layers. Even at high morphological ratings, stylistic responses were widely distributed across bipolar dimensions, confirming a multidimensional rather than strictly categorical relationship between form and aesthetic treatment. Morphology operates primarily as a semantic framing device, while styling functions as an affective layer with broad expressive bandwidth, enabling designers to shape emotional tone and cultural interpretation without being constrained by form alone. Robots with multiple overlapping morphologies were often described as incoherent or unsettling. The presence of "eyes," even in abstract form, strongly influenced anthropomorphic categorization. Features such as modularity or exposed circuitry reinforced perceptions of engineering practicality. Ultimately, by clarifying how form and styling co-construct meaning and by providing principles and visual tools, this study supports the design of human-centric robots that communicate purpose, foster trust, and adapt to contexts. This acts as fundamental research in robot aesthetics and part of a building body of knowledge that is forming the emergent field of automation design.

4.6. Discussion on First Study

These findings show that there are consistent patterns and divergence in how robot aesthetics is perceived. The discussion interprets these findings in relation to existing literature. Highlighting their implication to design research and practitioners as well as robot design. This study clearly demonstrates the central importance of aesthetics in robotics and its implications for design. As Ornelas et al. (2023) notes, robots should respond to cultural behaviours rather than impose them. Our findings show that a robot's aesthetic qualities significantly shape user perception, particularly when its morphology affords clear and legible movement. Participants used their imagination to interpret robot behaviour, predict actions, and assess potential threats, highlighting the interplay between cultural interpretation and

functional analysis. Given the complexity of robotic movement, this level of appraisal may be uniquely relevant to robots, as reactivity and mobility are typically only associated with animals. The method developed in this study yielded more informative results than previous two-source approaches and produced a rigorously tested set of metrics to guide the design of human-centric robots. Notably, phytomorphism was absent from evaluations, suggesting that perceptible movement is critical for aesthetic perception, slower or static designs may be interpreted as structures rather than robots. Sketching analysis and iconography were effective for synthesising robot aesthetics into visual definitions, functioning similarly to refined mood boards. Such tools could evolve into sophisticated design aids for ongoing aesthetic evaluation. While anthropomorphic assumptions can help interpret perceived cognitive intent, they should not constrain morphological variety. Aesthetics serve as a medium for meaning and communication between user and designer. Morphologies offer a source of inspiration, prioritizing the user's aesthetic experience to enhance interaction and enjoyment, echoing the findings of Lam, Liu, and Yee-Nee Lam (2016). This supports the philosophical view that robot aesthetics should accommodate the user while enabling and affording automation. Consequently, robotic design should focus on both movement and behaviour in response to inputs.

Our proposed model of robot aesthetic experience aligns with theories of visual perception and aesthetics from Norman (2013) and Gibson (2015), demonstrating that humans perceive robots similarly to other objects. However, by analysing movement, we found that participants reify meaning by mapping their knowledge of various objects onto the robot, guided by its aesthetic features. Imagination played a key role, as participants projected functional and behavioural expectations from source objects onto the robotic forms. Future research could investigate how humans perceive and respond to real-world robot movement, particularly for designs that adapt to user input rather than requiring user adaptation.

Aesthetic experience appears to involve the three neural systems proposed by Chatterjee and Vartanian (2016). Participants' responses were shaped by sensory input, emotional reactions, and symbolic interpretation (Steffen, 2010), with visual reification playing a role in the perception of completion (Lehar, 2003; Wagemans et al., 2012). Morphologies and categories were mapped visually, with icons representing the designs associated with each category. Each category included six key defining elements, some shared across categories and color-coded to indicate overlap. These insights underscore aesthetics as a conduit for meaning, emotion, and cultural resonance. By mapping user perceptions and aesthetic categories, the study provides a foundation for designing more intuitive, human-centric robots. Sketching and ideation proved critical for capturing aesthetic perception,

though variability in participants' skill and confidence suggests the need for tailored methods. Future research could incorporate automated tracking of sketching sequences and journaling behaviours, enabling participants to work naturally while generating rich, analysable data. Recording design activities and analysing concept order could reveal how high-skilled designers' structure and develop ideas, offering potential training insights for students and practitioners.

Finally, creating bespoke technological design research tools could enhance repeatability and efficiency, allowing designers to explore aesthetic development more systematically. Such tools could integrate sketching, ideation tracking, and visual evaluation, supporting a more rigorous and accessible approach to robot design research.

4.7. Final Thoughts on First Study and relation to Thesis

These interpretations clarify how robot aesthetics influence perception, meaning making, and acceptance. The conclusion synthesises these insights to restate the contributions of the thesis and to outline directions for future research and design practice. In this data collection phase, a broader range of robot designs and a larger image set were used than in previous studies, enabling a more comprehensive analysis of robot aesthetics. Seven morphological categories were evaluated alongside three bipolar aesthetic dimensions, here reframed as aesthetic stylings, to clarify where robotic designs sit within broader aesthetic spectra, and how specific visual elements (such as straight or curved lines) correspond to these overarching themes. Participants perception was model with a model of based off their process perception of robots in which responses typically progressed from an initial visceral reaction to more elaborate interpretation and the construction or "reification" of meaning. While participants often settled on a dominant interpretation, they occasionally revisited either their initial response or a more analytical reading. Clear definitions and visual representations of the dominant robot morphologies and aesthetic themes were provided, establishing them as guiding reference points. The study introduces a novel analytical method for aesthetics, Linkographic Thematic Analysis (LTA) and consolidates descriptions of five distinct robot morphologies and six aesthetic dimensions, presented in both visual and linguistic form. These outputs are intended to support designers in creating robots with greater aesthetic coherence and contextual appropriateness. This work demonstrates that design research into aesthetics must preserve both its cultural and experiential dimensions. It is argued that the philosophical purpose of robot aesthetics is to support human accommodation, enable meaningful interaction, and facilitate forms of automation that extend rather than replace human intent through considered design.

The findings of the first study clarify how participants perceive morphology and styling, providing empirical findings for the structure of the robot aesthetic taxonomy. These

findings must now be translated into a practical design process that can be used by designers. The following chapters therefore develop a robot aesthetic design method directly informed by the empirical results.

4.8. Sketching Study

This section documents an exploratory sketching study conducted after the first study, aimed at investigating how sketching could be effectively studied within this research context. Although the study did not yield results suitable for formal analysis, it served an important developmental function by informing the methodological decisions that shaped later phases of the thesis. This section therefore summarises the study's purpose, design, and structure, outlines its limitations, and identifies the key methodological lessons that informed subsequent refinement of the research approach.

4.8.1. Purpose of the Sketching Study

The sketching study was designed to explore how designers generate, structure, and visually communicate aesthetic ideas when developing robot concepts. It was motivated by the limited results of sketching data obtained in the first (sorting) study, which suggested that an alternative and more effective approach to capturing sketch-based reasoning may be required. Although this attempt did not produce analysable results, it nevertheless provided valuable insight that helped shape and refine the direction of subsequent methodological development and future work.

4.8.2. Sketching Study Structure

Participants were asked to produce a sequence of sketches across three short phases: Ideation – rapid generation of rough concepts. Development – elaboration of selected ideas. Final Sketch – a more refined representation of the preferred concept. Participants annotated their sketches to indicate idea progression, changes, and the rationale behind aesthetic decisions. The study aimed to track concept evolution over time and to determine whether identifiable morphological or stylistic patterns could be extracted for comparison with empirical taxonomy findings (Figure 58).

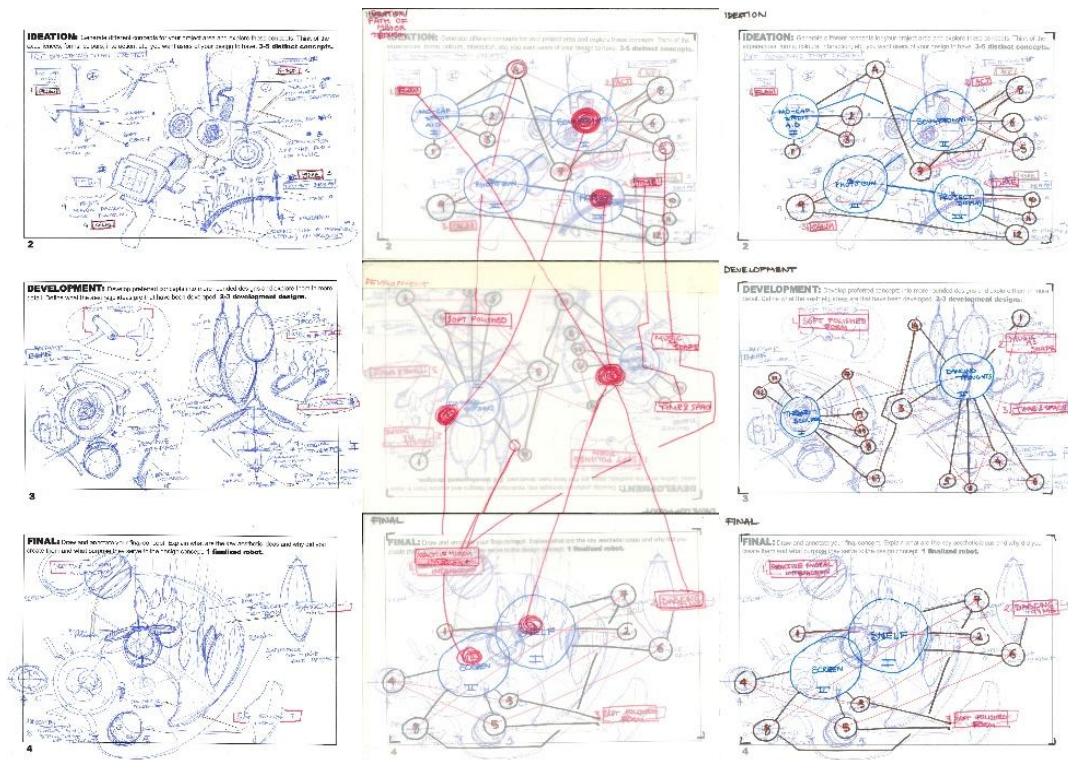


Figure 58 - Sketching Study Test, Sketch Pages (Left), Concepts and Related Ideas (Middle), Elements Taken Forward (Right)

4.8.3. Limitations, Discussion, and Conclusion on Sketching Study

Despite careful structuring, the study revealed several methodological issues that made the results unsuitable for integration into the main analysis (Figure 59).

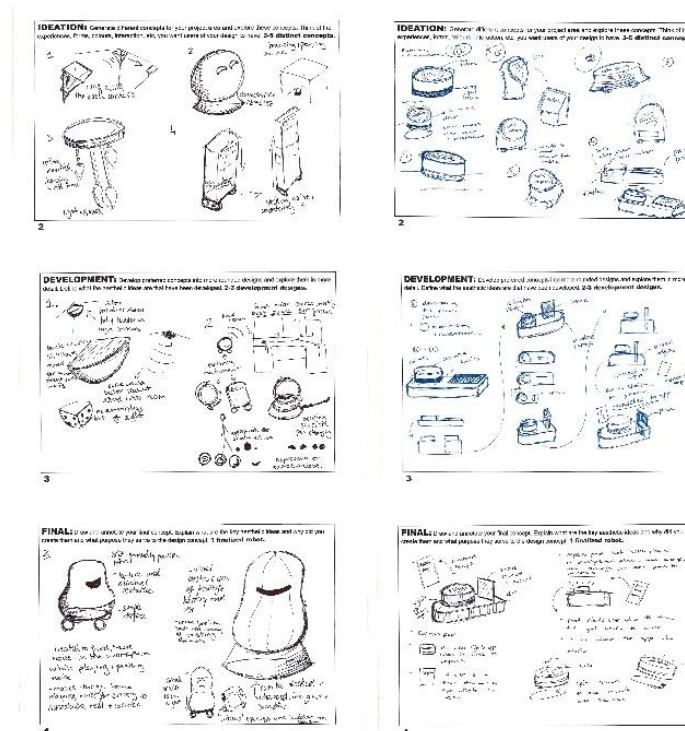


Figure 59 - Sketching Study, Participant 1 (Left), Participant 2 (Right)

Participants differed widely in sketching ability, visual clarity, and speed. One produced communicative sketches with clear design. The other relied heavily on shorthand marks, a linear approach. This made cross-participant comparison unreliable and inconsistent. Although the sketches captured the visual output, they did not sufficiently reflect the embodied and cognitive processes shaping aesthetic reasoning. Missing elements included gesture, gaze, pauses, sequencing, and verbalised thought, factors essential for understanding how designers interpret aesthetic prompts. The resulting drawings varied too greatly in style, scale, and detail to be coded meaningfully. The temporal structure of idea formation could not be reconstructed with enough consistency to support formal interpretation as the participants failed to number their moves appropriately. Although the sketching study did not produce directly usable empirical data, it was methodologically valuable. It identified several critical issues that informed later design decisions. In particular, it highlighted the need for richer behavioural data, suggesting that future investigations of sketch-based reasoning would benefit from methods capable of capturing gesture, hesitation, attention shifts, and real-time decision-making processes, rather than relying solely on static artefacts. It also underscored the importance of structured tools. The challenges encountered in this study directly informed the development of more guided, scaffolded processes within the toolkit, designed to reduce ambiguity and produce more comparable outputs across participants with different levels of design expertise.

Chapter 5 – Process for Robot Aesthetic Design

Building on the empirical insights derived from Chapter 4, this chapter develops a structured process for designing robot aesthetics. The process translates perceptual findings into practical steps that designers can use to define, ideate, and refine robot concepts.

This chapter presents the development of a robot-aesthetics framework, the **Human-Centred Robot Aesthetic Design Toolkit**. The framework is not intended as a definitive method for producing meaningful, aesthetically pleasing, or human-centred robots. Rather, it functions as an abstract yet practical tool that highlights key design elements, considerations, and activities to guide the design process. Its purpose is to support a shift from instinctive, ad-hoc decision-making toward more intentional, insight-driven design practice. A key priority in its development was ensuring that design briefs determine the designer's focus, rather than prescribing fixed morphological outcomes. The research did not support the utility of enforcing specific morphologies in specific contexts, as aesthetic effectiveness appears to depend more on execution, conceptual intent, context of use, and target users than on predetermined form selection alone.

5. Creative Design Applied to Robot Design

Design projects are typically structured around a central problem and a set of related sub-problems, with designers iteratively moving between problem framing and solution development. Within this process, creativity can emerge through a range of mechanisms: free association (e.g., brainstorming), forced association (e.g., synectics), combination (combining existing ideas into new configurations), mutation (modifying specific features), analogy (transferring ideas from one domain to another), first principles reasoning (deriving ideas from fundamental facts or theories, though this can be difficult in ill-defined problems), and emergence (identifying latent properties within a design and bringing them into focus) (Cross, 1997). The processes embedded within the toolkit reflect Cross's view that design operates in cyclical phases, in which problems are progressively defined and decomposed into sub-problems, and these creative strategies are applied throughout that cycle.

Designing robots, regardless of morphology, requires an integration of both design and engineering expertise. Robots are developed for a wide range of contexts, including industrial applications such as logistics and manufacturing, as well as service domains such as healthcare, domestic environments, education, entertainment, and defence. Due to this complexity, robot development increasingly depends on interdisciplinary approaches that combine technical fields such as computer science and mechatronics with insights from the humanities, including psychology, anthropology, and the arts. As a result, design has become

a critical component of robotics, particularly in addressing ongoing challenges related to form, function, interaction, and human–robot relationships (Germak and Abbate, 2021).

5.1. The Toolkit Development

A wide range of early concepts was explored during the development of the toolkit, each aiming to translate the taxonomy into a usable and engaging design resource (Figure 60).

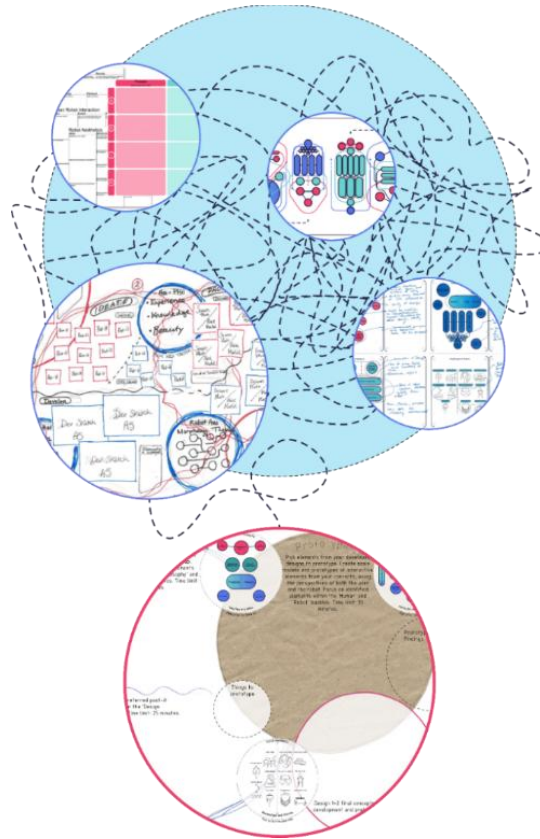


Figure 60 - Toolkit Design

One of the more developed but ultimately unused concepts was a card-based toolkit in which each card isolated elements of the taxonomy (Figure 60). Designers would select the components most relevant to their brief and use them as prompts for ideation. The taxonomies were organised into three colour-coded zones: red for abstract considerations, green for embodied qualities, and purple for detailed components. In principle, designers could begin at any point and move flexibly between levels, starting with red (high-level concepts), progressing through green (initial embodied interpretations), and then engaging with purple (specific attributes). However, in practice, the format implicitly suggested a linear progression. Although no explicit sequence was prescribed, the visual layout of the cards, together with the positional map placed in the bottom-right corner, reinforced an unintended sense of ordered workflow. This may have encouraged designers to follow a step-by-step process rather than adopting a more open, exploratory approach.

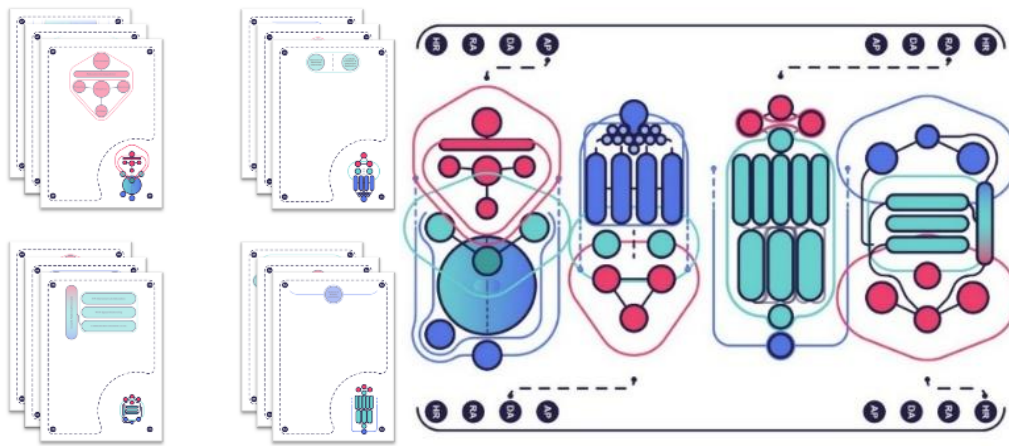


Figure 61 - Cards Concept

Another iteration of the toolkit simplified the process further (Figure 62). Users were first provided with two curated mood boards: one representing common, well-established robot designs, and another showcasing experimental or conceptual examples. Participants would have been asked to identify which designs aligned with the aims of their brief. Despite its intuitive appeal, this approach risked becoming overly leading, with the predefined options unintentionally influencing user decisions. Following this exploratory stage, participants would have been given four sheets containing deconstructed elements of the taxonomy. Rather than presenting each taxonomy independently, these sheets grouped the elements by the three colour-coded zones: red for abstract qualities, green for embodied attributes, and purple for component-level considerations. The intended workflow progressed from abstract intentions, through embodied interpretations, toward specific components, concluding with a sheet dedicated to morphologies and aesthetic themes. Users would then continue to conventional ideation, development, and conceptualisation phases. Despite offering clarity and structure, this version also revealed significant challenges. Many taxonomy terms were highly technical and would require considerable simplification before being accessible to a broad user base. Furthermore, the volume of options risked overwhelming participants. The icons designed to accompany each term were insufficiently refined, lacking semantic connection to their respective concepts and limiting their usefulness.



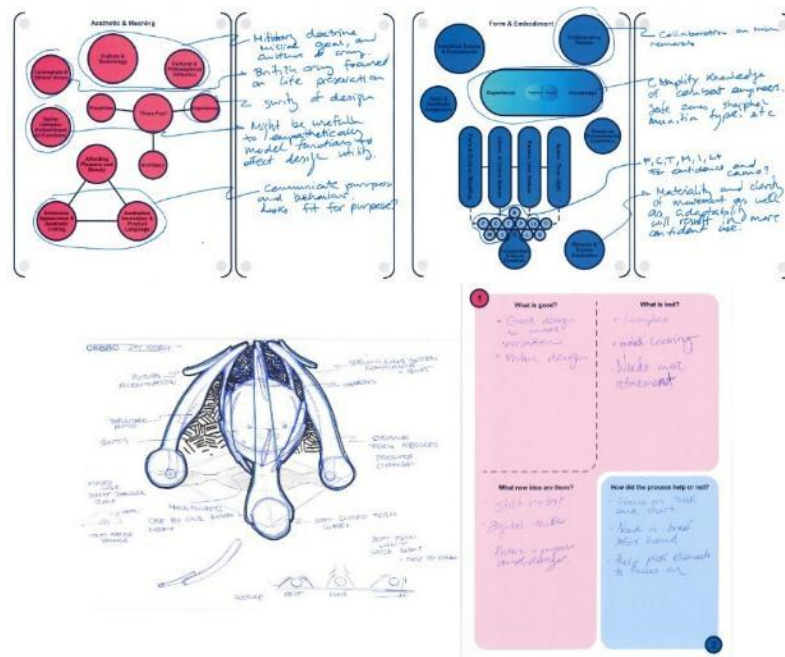


Figure 62 - Abstractions Concept

A further simplified version was developed, but it proved too reductive, akin to a business-planning exercise than a creative design method (Figure 63). This approach adopted a strongly linear structure aimed at reducing uncertainty rather than stimulating exploratory thinking. Users responded to a series of guided questions, generated ideas on Post-it notes, and placed these onto a colour-coded sheet representing the three taxonomy zones (red, green, and blue). Although the taxonomy prompts offered some value, the method bypassed essential design skills such as sketching, prototyping, and synthesis. However, it may function effectively as a workshop activity for non-designers, provided it is facilitated by an experienced practitioner who can contextualise the process.

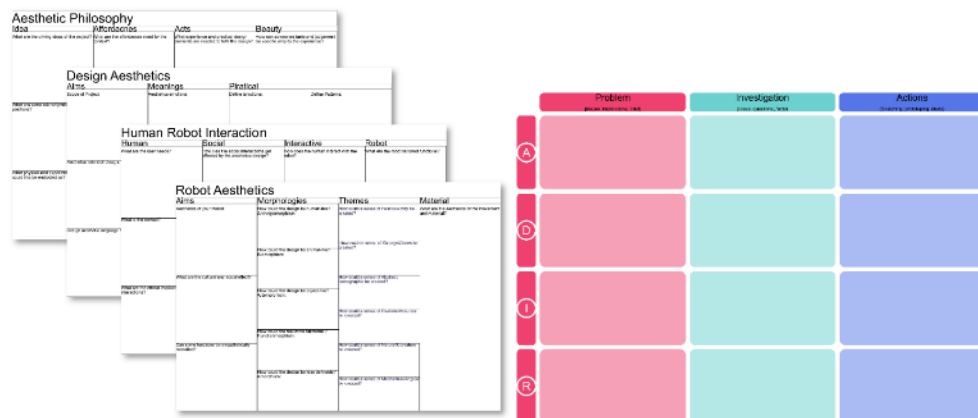


Figure 63 – To-Do Concept

Recognising the limitations of these earlier iterations, a more robust and adaptable approach was ultimately developed. Instead of relying on a simplified worksheet, which would not have generated meaningful or sufficiently rich design ideation, the final approach incorporated multiple creative activities and allowed for variation according to participants'

design experience and the required level of novelty. Working from a provided brief (which can be substituted for any project), users move through four major stages, represented as large interconnected “bubbles”: Define, Ideate and Develop, Prototype, and Final. Each stage is linked to the most appropriate taxonomy. The Aesthetic Philosophy taxonomy supports the Ideation stage; the Design Aesthetics and Robot Aesthetics taxonomies inform development; and the Human–Robot Interaction taxonomy supports the prototyping stage.

5.2. Prototype of Framework

From those concepts a more creative design process and toolkit was developed. A hand drawn scale model (Figure 64) of the concept was developed before pilot testing which was an A4 version of the A1 design.

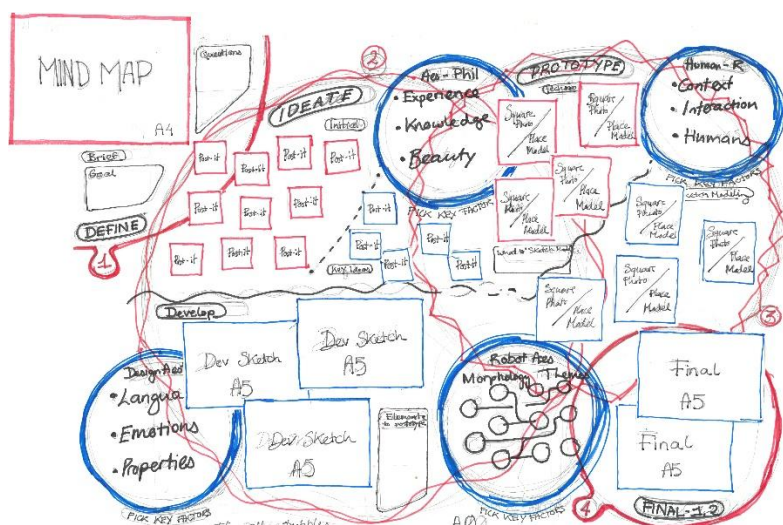


Figure 64 – Hand Drawn Scale Model

The design process begins with the construction of an initial mind-map based on the design brief. This activity enables participants to articulate, interpret, and refine the specific problem they aim to address. By mapping associations, constraints, and contextual factors, participants identify the underlying problems and generate the key guiding questions that will shape subsequent stages of the process. This early framing establishes a boundary for the design space and ensures that later decisions remain aligned with the project intent. Following this, participants engage in an ideation phase informed by a simplified selection of elements drawn from the Aesthetic Philosophy taxonomy. These distilled philosophical ideas and serve as prompts that encourage participants to consider broader aesthetic intentions and theoretical directions. Using these prompts, participants generate an initial set of ten divergent concepts on Post-it notes, ensuring a wide exploration of possibilities before narrowing their focus. From these, each participant selects their five strongest concepts to develop further, based on coherence with the brief, aesthetic potential, and perceived feasibility. The development phase requires participants to translate these abstract ideas into

more concrete A5 concept sketches. Before sketching, participants consult the Design Aesthetics and Robot Aesthetics taxonomies to identify the aesthetic elements most relevant to each concept. This encourages deliberate aesthetic reasoning rather than purely intuitive or arbitrary styling decisions. After producing their sketches, participants determine which components of their concepts require prototyping, whether morphological, behavioural, or interactional, before they can be meaningfully evaluated. During the prototyping stage, participants incorporate insights from the Human–Robot Interaction taxonomy and undertake a form of techno-mimesis. In this activity, participants physically act out the interactions between the user and the robot, simulating behaviours, gestures, and spatial relationships to explore potential limitations and opportunities. Techno-mimesis enables participants to examine dynamic aspects of the design without committing to detailed engineering development, functioning similarly to the Wizard-of-Oz technique by allowing assumptions about interaction, perception, and functionality to be tested at an early stage. Alongside this performative exploration, participants construct basic scale models to establish physical proportions, evaluate volumetric relationships, and assess the spatial feasibility of their emerging concepts. The final stage involves the synthesis of insights and artefacts accumulated throughout the process. Participants consolidate their mind-maps, ideation notes, sketches, prototypes, and interaction simulations to produce one or two refined concepts for a robotic system. These concepts represent a considered integration of aesthetic reasoning, morphological exploration, and functional interaction design.

Testing the full toolkit and design process required approximately two hours and was conducted using the brief of developing an internal satellite assistant for a space station (Figure 65). The workflow proved feasible within this timeframe, with each stage clearly guiding participants into the next and supporting a coherent progression from conceptual framing to refined outcomes. The techno-mimesis stage, however, proved challenging to execute effectively within the limited time available. Despite this difficulty, it revealed notable design considerations, such as optimal sensor placement, as it helped visualise and simulate the robots' effective "vision cones" relative to the proposed form.



Figure 65 – First Prototype Test

Another pilot test with two designers exceeded the two-hour target duration, indicating the necessity of engaging the intended multidisciplinary participant mix comprising a product designer, a design engineer, and a roboticist (Figure 66). This composition was found to be essential for balancing aesthetic, technical, and functional perspectives. The “bubbles” taxonomy concept was well received and functioned effectively as guiding and prompting the users, although feedback highlighted that simplifying the accompanying language would improve usability. Techno-mimesis remained challenging when only two participants were present, primarily due to the need for multiple roles (user, robot, observer) to enact interactions convincingly. Nevertheless, it proved valuable in refining the design and enabling clearer communication of functional behaviour. The scale models were similarly effective, offering participants a tangible means to interrogate proportion and spatial relationships.



Figure 66 – Second Prototype Test

Overall, this initial testing indicates that the methodology is viable within a compressed session but could be substantially expanded into a full-day or multi-day series of design sprints. Such an extension would allow deeper engagement with each stage, more detailed prototyping, and richer collaboration. While this chapter outlines the initial design process, its effectiveness must be tested through application. The next chapter documents the process in use, showing how teams of product designers, engineers, and roboticists applied it to a real design brief.

Chapter 6 – Second Study and Application of Process

6. Second Study – Designing with the Toolkit

To evaluate the design process developed in Chapter 5, this chapter presents its application within a controlled group study with two groups of three participants. The results offer practical insights into how effectively the process supports reasoning, ideation, and decision-making across different design disciplines. The final design of the toolkit was tested with key participant groups: a product designer, a design engineer, and a roboticist (Figure 67). This toolkit was tested for usability and to ascertain if it was not cognitively overwhelming. For the exercise, the brief was:

“How might we design a robot to improve engagement at museums or galleries, enhancing guidance, interaction, or understanding?”

Participants worked through four large “bubbles”: ‘Define’, ‘Ideate’ and ‘Develop’, ‘Prototype’, and ‘Final’, each linked to specific taxonomy bubbles. The Aesthetic Philosophy bubble guided ideation, Design Aesthetics and Robot Aesthetics bubbles informed development, and Human-Robot Interaction guided prototyping.

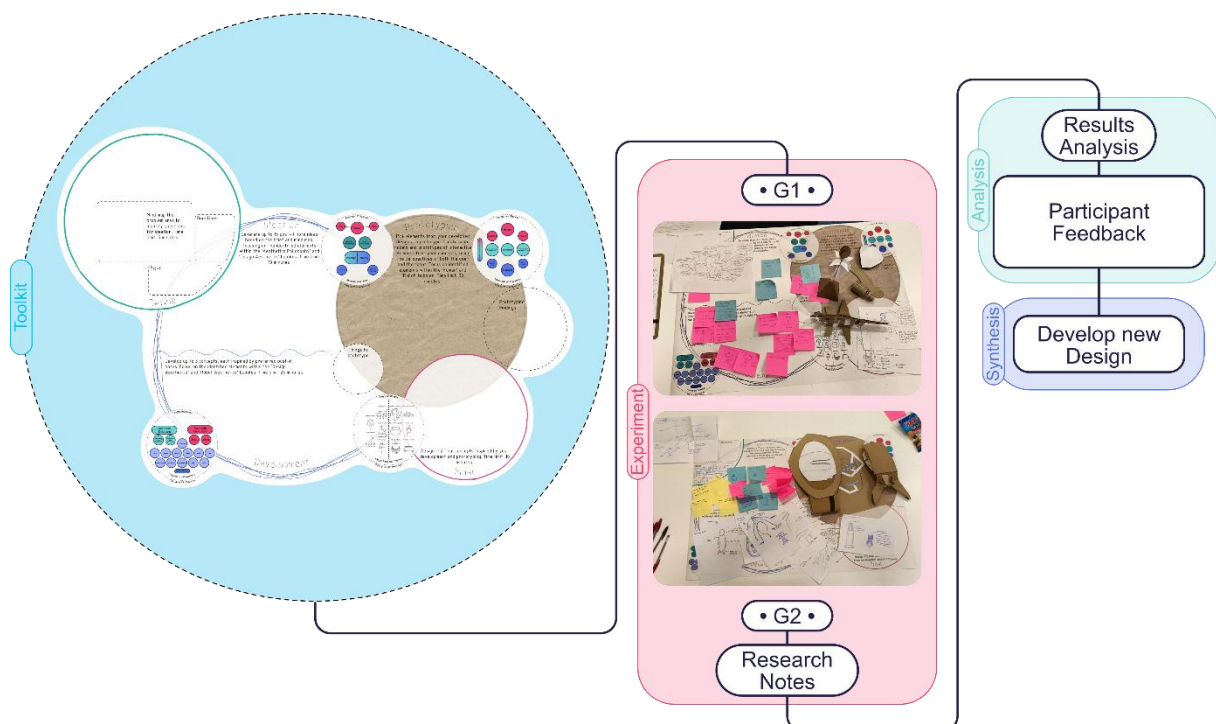


Figure 67 - Second Study Structure

Participants began by creating a mind-map of the brief to refine the problem focus and generate questions to guide the activity. During ideation, they selected relevant elements

from the Aesthetic Philosophy taxonomy and produced 15 post-it notes, where some were selected for development. A5 sketches were created in the development phase, guided by Design Aesthetics and Robot Aesthetics. From these sketches, elements requiring prototyping were identified using the Human-Robot Interaction taxonomy (Figure 68). Prototyping involved techno-mimesis, where participants acted as both user and robot to explore interactions, similar to the Wizard of Oz technique, helping uncover interactive, and conceptual limitations before building physical prototypes. Scale models were also used to refine proportions. Finally, participants synthesised their findings from the full process to produce one or two final robotic designs.

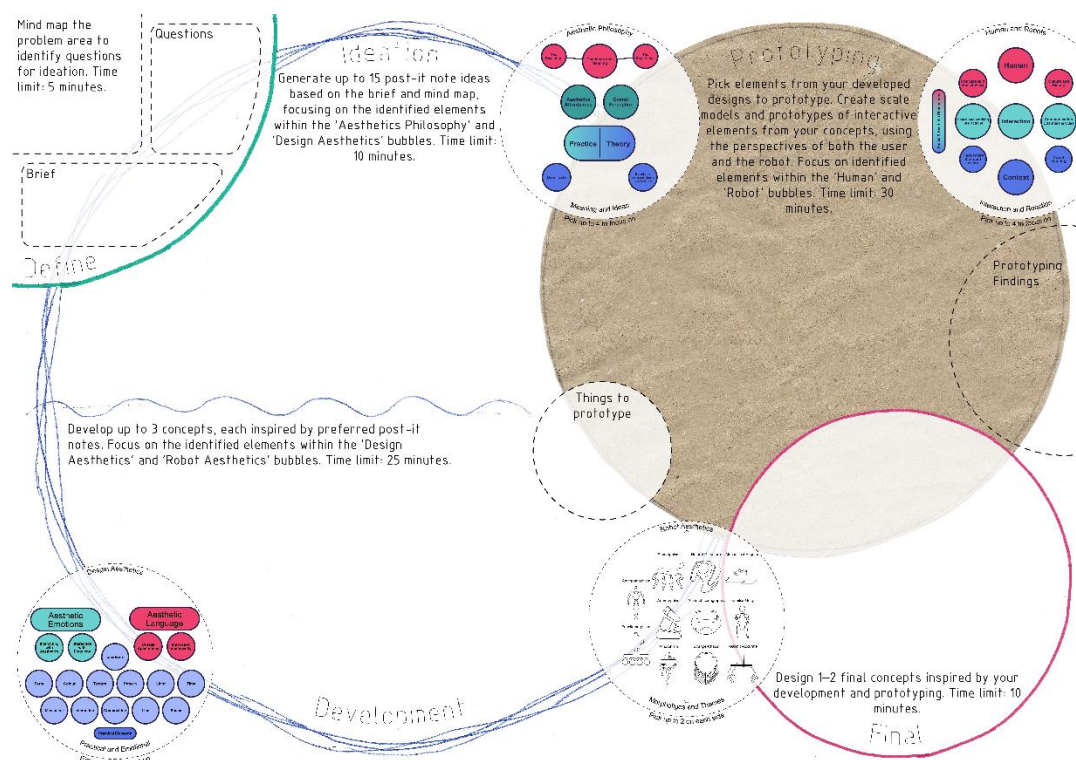


Figure 68 – Initial Robot Design Process

There were two groups comprising of a product designer, design engineer, and roboticist who conducted the study in two hours. A total of 6 participants volunteered and were put into two groups: Group 1 and Group 2.

6.1. Sampling Size Justification

Given that this study assesses the usability of a design method for robot aesthetics, a large sample size was not required. Nielsen and Landauer (1993) demonstrated that usability problems follow a Poisson distribution, meaning the probability of discovering new issues drops sharply after a small number of participants (Figure 69). Their work suggests that approximately 7 users are sufficient for user tests, and 9 for heuristic evaluations in small projects, increasing to 15–16 for medium to large projects and 20–21 for the largest. These

figures represent optimal conditions, but when the cost of iteration is low, fewer participants per cycle are adequate (Nielsen and Landauer, 1993).

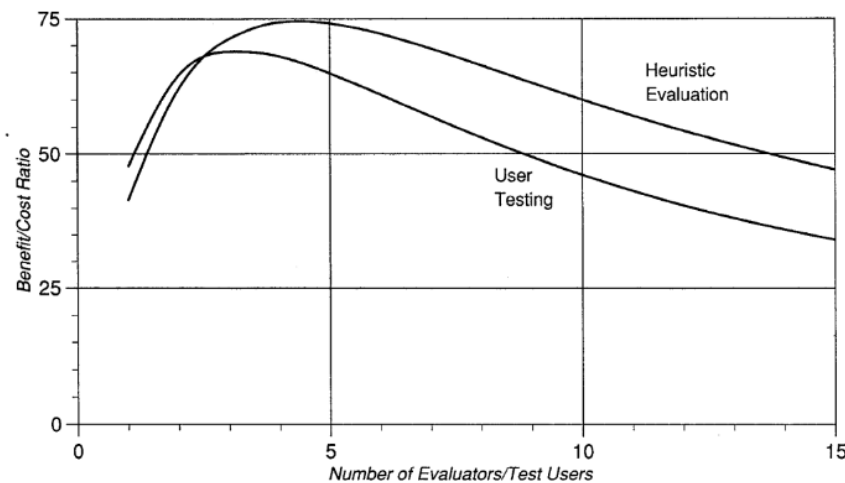


Figure 69 - Sampling Size Justification, (Nielsen and Landauer, 1993)

Later, Nielsen (1994) further argued that testing with just five users can reveal 75–80% of usability issues, after which the cost–benefit ratio declines. Using Nielsen and Landauer’s (1993) average value of $\lambda = 0.31$ in their detection model:

$$P(n) = 100 \times [1 - (1 - \lambda)^n]$$

For this study, with $n = 6$:

$$100 \times [1 - (1 - 0.31)^6] = 100 \times [1 - 0.1079] \approx 89.2\%$$

Thus, six participants would be expected to reveal approximately 88–89% of usability problems. Given that multiple iterations and tests were conducted, it is reasonable to assume that most major issues were identified. At this stage, the priority shifts from problem discovery toward adapting the design to accommodate the necessary refinements and the varied skill levels of users. Within this context, the depth and quality of the insights gathered are more valuable than sheer sample size.

6.2. Results of Second Study

6.2.1. Group 1 Notes and Results

Reflecting on the team’s progress with the mind map, it is clear that while ideation was underway, the structure still requires refinement (Figure 70). The “Questions” section was not particularly useful, as mind maps are better suited to identifying focus areas, using terms like “Key Points” or “Goals” may better support momentum. The current organisation felt somewhat fragmented and time limits were not always helpful, at times making users feel pressured or rushed. Greater clarity and a more pronounced visual direction are needed to

ensure that focus points within the bubbles are clearly identified, supporting deeper development. While the bubbles themselves worked, they may benefit from further simplification and clearer, less abstract language. Overall, the team moved in the right direction, but additional time and clearer sequencing will be essential to strengthen the conceptual flow and make the mind map a more effective tool. Progress was not strictly linear, yet the toolkit did support discussion, and the bubbles were helpful in prompting exploration of different elements.

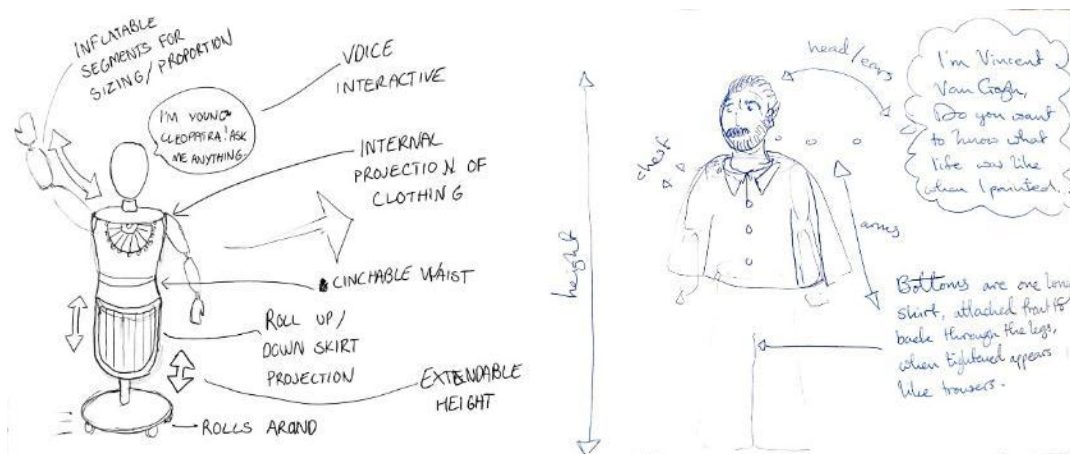
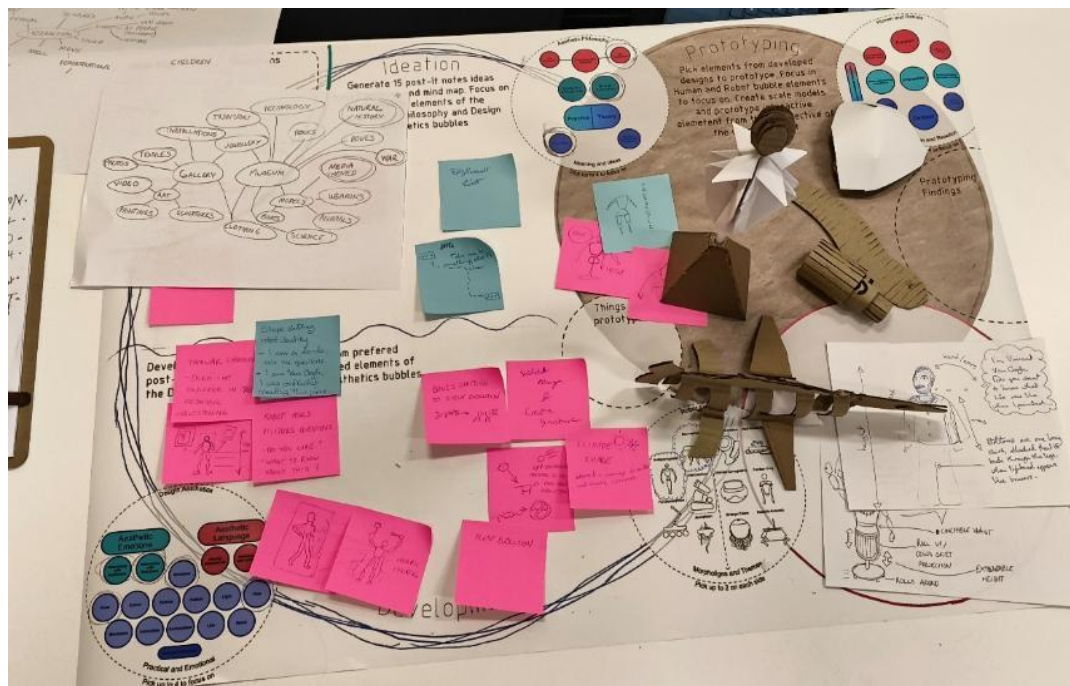


Figure 70 - Group 1 - Output

6.2.2. Group 1 Feedback

Group 1's feedback was overall very positive. Participants found that the taxonomy bubbles capturing aspects of aesthetics were important without being overwhelming, helping them consider useful elements that might otherwise have been overlooked. The sections were seen as valuable, and the mind-mapping stage was considered essential before

ideation. The “Questions” box, however, was largely unused, as the brief felt too broad at that stage; one participant suggested moving it to after ideation, when they had a clearer sense of potential directions. Some wording within the bubbles was difficult to understand without researcher guidance. One participant noted that without such direction, they might have overlooked certain sections, such as the “Humans and Robots” bubble, which they felt would have been useful during prototyping. Additionally, aspects of the visual design, bubble placement, layout within circles, and dark text on dark backgrounds, made some sections less inviting to engage with. Participants suggested that making interaction with the bubbles more explicit could improve engagement. Their suggestions included:

- Tick boxes.
- Colouring in selected elements.
- Follow-up questions after each section to ensure considerations were applied.
- Allocated time (e.g., 2 minutes) for discussing the stage’s aesthetic considerations.

Participants also felt somewhat rushed at times. They recommended using quantitative limits for certain stages (e.g., 15 post-it notes for ideation) rather than time limits, while still allowing flexibility for reflective discussion within the bubbles, such as the aesthetics bubble.

Key Positive Feedback

- Taxonomy bubbles were effective and appropriately balanced.
- Mind-mapping was seen as essential before ideation.
- Overall section structure supported engagement.
- Aesthetic prompts were thought-provoking.

Key Issues and Limitations

- The “Questions” box was under-utilised early on.
- Terminology required facilitation.
- Visual design reduced engagement with some sections.
- Separate prototyping from “Techno-mimesis” as it was unclear term, may need clarification.

6.2.3. Group 2 Notes and Results

Feedback from Group 2 emphasised the cognitive load associated with the current design process (Figure 71). Many participants, particularly those less familiar with the method, struggled to get started, highlighting a need for clearer guidance, such as visual

cues or a more focused brief. Visual pathing could help indicate the workflow and show the sequence of steps more clearly. The layout, especially the use of bubbles, was sometimes overwhelming, suggesting that simplification, reordering, or placing key points centrally could improve clarity. Encouraging open discussion and collaborative idea generation among participants could lead to more meaningful contributions. Additionally, separating prototyping activities from more abstract concepts, such as “Techno-mimesis,” may help clarify the workflow. Morphology-related themes could also be anchored in abstract foundations to better support creative thinking. Overall, these reflections point to a need for both structural and facilitative adjustments, including simplifying the language in the bubbles, to make the process more understandable, and productive.



Figure 71 - Group 2 - Output

6.2.4. Group 2 Feedback

Participants appreciated the structured stages of the toolkit, which provided clear expectations for the level of detail at each phase and allowed them to build complexity

gradually. The prompts regarding the different aesthetics of robots were particularly useful, as participants had little prior knowledge in this area. The example images of museum scenarios were clear, and having two similar images helped users consider the transferability of designs between different settings. The structure also facilitated collaboration, allowing multiple users to contribute ideas in the same space. Additionally, the openness of the brief encouraged ideation, and the segmented nature of the toolkit supported focused work in each stage. However, participants found the flow between stages confusing. Without the guidance of the researcher, they were uncertain about where to start, how to progress, and which parts of the toolkit to use at each point. Some interpreted the process as following a circular path, while others moved from top to bottom, indicating a lack of clear direction. The diagram was considered busy, and participants often focused only on the small section they were working on, relying on others to understand the overall process. Terminology within the taxonomies was sometimes unclear and could be simplified for users less familiar with aesthetic, design, or robotics concepts. Participants also reported difficulty transitioning from individual concept creation to collaborative group ideas, suggesting a need for clearer guidance on integrating ideas to streamline the overall workflow.

Key Positive Feedback

- Structured progression supported engagement.
- Aesthetic prompts addressed knowledge gaps.
- Scenario imagery aided contextual transfer.
- Collaboration was actively supported.
- Openness encouraged ideation.

Key Issues and Limitations

- Unclear process flow between stages.
- Ambiguity in overall directionality.
- Cognitive overload from visual complexity.
- Terminology presented accessibility issues.
- Difficulty transitioning from individual to group work.

6.3. Second Study Conclusion

The second study demonstrated that the toolkit effectively supported early-stage ideation and encouraged consideration of aesthetic dimensions, yet several structural, visual, and linguistic limitations constrained its overall usability. Across both groups, participants

valued the taxonomy bubbles for prompting aesthetic reflection and widening the scope of considerations that might otherwise have been overlooked. The structured stages, scenario imagery, and collaborative format further enabled focused engagement and gradual progression in idea development. However, the study also revealed consistent challenges. The mind map and its “Questions” section lacked clarity and did not align with participants’ workflow at the earliest stage of ideation, suggesting a need to reposition or alter this component. Visual complexity, ambiguous directionality, and unclear sequencing frequently caused confusion, with participants unsure where to begin or how to move between stages without researcher guidance. Terminology within several bubbles required interpretation, indicating that simplified, less abstract language would increase accessibility, particularly for those unfamiliar with design or robotics vocabulary. Additionally, time pressures often hindered deeper reflection, with participants expressing a preference for quantitative output limits (e.g., number of ideas) rather than fixed time constraints. Both groups highlighted opportunities to make interaction with the toolkit more explicit, such as through tick boxes, colour-coding, or embedded follow-up prompts, which could support more deliberate engagement with each aesthetic consideration. Streamlining visual pathways, reducing cognitive load, and separating abstract concepts from practical stages, particularly in relation to prototyping, were also identified as important improvements.

One other issue with the sample size is that testing in relation to one participant type is below the usability testing threshold. Therefore, for a team exclusively comprising one type of participant may encounter issues that others would not have. Although, this does mean that it is a participant agnostic toolkit rather than a participant specific one making it more applicable to different designers. One other note is that the participants were of western European origin and therefore if the toolkit was used by those from a very different culture, they may find it less useful.

Overall, the study confirmed that while the toolkit has strong foundational value, its effectiveness depends on clearer sequencing, reduced visual and linguistic complexity, and more intuitive visual guidance. The feedback provides concrete directions for refining the toolkit so that it can better support autonomous use, facilitate a smoother workflow, and enhance the integration of aesthetic thinking throughout the design process. The insights gained from observing how different professionals used the process highlight its strengths and areas needing refinement. The following chapter therefore adapts the process into a comprehensive toolkit, offering short, medium, and long versions tailored to varying levels of design expertise and project duration.

Chapter 7 - Process Adaptation into Toolkit

7. Areas of Improvement

Building upon the previous results, this chapter presents the refined robot-aesthetic toolkit. Each version of the toolkit integrates user feedback, study results, and the theoretical framework to support effective aesthetic decision-making. This chapter explains how the comments and needs stated by the participants fed into the design aims. The findings from the second study highlighted several areas in which the toolkit can be refined to enhance clarity, and usability for future users. Although the existing structure successfully supported early ideation and stimulated aesthetic consideration, both participant groups identified obstacles that limited the fluidity of the design process. These insights have informed a series of targeted improvements aimed at strengthening the toolkit's effectiveness and reducing the cognitive burden placed on users in addition to incorporating the robot aesthetic map to make the process more in line with the theory.

1. Structural Refinement and Workflow Clarity:

Participants frequently reported uncertainty about where to begin and how to progress through the toolkit, even when the overall framework was understood. To address this, the next iteration will incorporate an explicit visual workflow, using numbered steps, directional arrows, and modular sequence (e.g., Define, Ideate, Develop, Prototype, Final). Additionally, a concise "How to Use This Toolkit" panel will be added to provide immediate orientation and reduce reliance on facilitator guidance. This restructuring aims to create a more intuitive progression and minimise ambiguity during transitions between stages.

2. Reconfiguration of the Mind Map Stage:

The mind-mapping component requires tightening. The "Questions" section was consistently underutilised early in the process, as participants lacked sufficient direction at that point. As such, this section will be repositioned later in the workflow or reframed as "Key Points," "Goals," or "Focus Areas," aligning more naturally with designers' early cognitive patterns. Including an example mind map will further clarify expectations regarding scope and depth.

3. Visual Simplification and Reduction of Cognitive Load:

Feedback across both groups emphasised that the visual density of the toolkit contributed to cognitive overload. To improve accessibility, the next iteration will simplify the layout of taxonomy bubbles and implement a clearer hierarchy of information. Colour palettes will be revised to eliminate low-contrast combinations and to introduce consistent colour-coding for each taxonomy category. This adjustment is expected to improve

engagement and reduce instances where participants overlooked sections due to visual complexity.

4. Enhanced Interaction with Taxonomy Bubbles:

Participants expressed a desire for more active modes of engagement within the bubbles themselves. In response, the toolkit will introduce tick boxes, colour-coding areas, short reflective prompts, and aesthetic considerations. These features are intended to encourage intentional engagement with the design concepts and provide users with mechanisms that guide the design process without overwhelming them.

5. Replacement of Time Limits with Output-Based Targets:

Time constraints were found to induce feelings of pressure and reduce the quality of ideation. The next version of the toolkit will shift from strict time-based limits to output-based expectations, such as generating a specified number of ideas (e.g., 15 post-it notes) before moving forward. This approach maintains momentum while allowing users the flexibility needed for deeper and more meaningful exploration.

6. Language Simplification and Improved Terminology:

Certain terms, particularly those originating from aesthetic philosophy or robotics theory, were identified as being too complex or not widely known. To improve accessibility for all participant backgrounds, the next iteration will revise these terms, incorporate brief definitions, and employ more descriptive, intuitive language where possible. For example, concepts such as “Techno-mimesis” will be clarified or rephrased to reduce confusion as this is a very uncommon method.

7. Separation of Conceptual and Practical Stages:

Participants found it challenging to navigate between abstract aesthetic considerations and concrete prototyping tasks. Future versions will more clearly distinguish conceptual exploration from practical testing stages, ensuring that users understand when to focus on morphology, aesthetics, or interaction and when to transition into physical prototyping or behavioural evaluation. This refinement is expected to support easier workflow and reduce confusion around the purpose of each phase.

8. Support for Idea Integration and Collaboration:

Groups had trouble moving from individually generated concepts to shared solutions. To support this transition, the next iteration will incorporate a short consolidation stage between ideation and development, including prompts for selecting complementary ideas, and prioritising features.

9. Adaptability Across Abstract Axes:

To make the toolkit more flexible and responsive to the differing backgrounds, expectations, and ambitions of its users, the next iteration will incorporate adaptability along two abstract axes:

1. **Level of Novelty or Modification** (*Less - More*)
2. **Design Knowledge** (*Lower - Higher*)

As users with lower design knowledge may benefit from more clear prompts, and simplified language whereas those with greater expertise can engage with more advanced abstract aesthetic reasoning, and open-ended prompts. Similarly, tasks at lower novelty levels may require more structured pathways and incremental design options while users aiming for higher novelty modification would benefit from exploratory prompts and processes. By embedding these adaptability axes into the toolkit's structure, it becomes more robust because it can accommodate a wide range of users, from novices to experts, and support design outcomes that vary from modest refinements to creative innovation. This ensures that the toolkit remains useful and is based on the user's skill levels but is also effective at the intended degree of novelty within the design brief, making it more versatile and effective across different design contexts. To apply this adaptability along the axes of novelty modification and design-knowledge level, the next iteration of the toolkit will introduce three distinct versions of the method: **Short**, **Medium**, and **Long**. These versions correspond to differing levels of conceptual complexity, aesthetic ambition, and expected user expertise. The objective is to ensure that the toolkit remains both accessible to novices and sufficiently challenging and stimulating for advanced users, while still maintaining a coherent methodological structure across all variants (Figure 72).

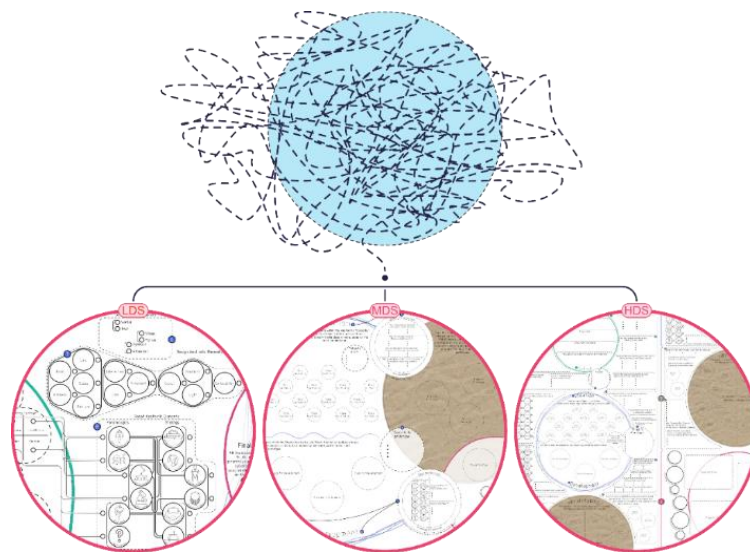


Figure 72 - Toolkit Redesign

7.1. New Toolkit Designs

The **Short** version is intended for users with limited design experience or for projects requiring low levels of novelty. This variant offers a more guided process with simplified aesthetic terminology, and more constrained ideation. It emphasises stability, clarity, and incremental improvement, allowing users to explore aesthetic considerations without being overwhelmed by interpretative or speculative demands.

The **Medium** version is designed for users with moderate design experience and for briefs that require a balanced level of novelty. This version has a structured workflow but incorporates more open-ended prompts and expanded aesthetic considerations. Users at this level are encouraged to explore alternative morphological directions and experiment with multiple styling dimensions.

The **Long** version targets expert users or contexts requiring substantial aesthetic or morphological innovation, used for example by teams. This version will include the most abstract and exploratory elements of the toolkit, inviting users to work with complex aesthetic ideas and processes. The emphasis is on creative risk-taking and transformation which would support radical redesigns, hybrid aesthetics, or completely novel designs.

By differentiating the toolkit across these three levels, the process becomes more scalable. Users can select the version most aligned with their knowledge base and the degree of novelty required in the brief. Designers with higher levels of experience can move directly into advanced conceptual domains, while novices can build confidence through structured prompts. Likewise, design teams can adjust their position on the novelty axis: choosing the **Short** version for refinement tasks, the **Medium** version for moderate updates, or the **Long** version for innovative or disruptive aesthetic explorations. This tiered approach ensures that the toolkit is not a fixed, one-size-fits-all method, but a flexible system capable of supporting a wide range of users, design contexts, as well as aesthetic ambitions. It aligns the method with the realities of contemporary design practice, where both the level of expertise and the expected degree of novelty vary considerably across projects and participants.

7.1.1. Initial Short Design Process

The initial short design process is structured to make the process a series of restricted choices resulting in sufficient information to develop a final concept and then conduct future work (Figure 73), (Figure 74). Simplifying the process down to 3 main phases; Define, Design, and Final. Where the designer selects the relevant elements to move towards the next phase. The process is simplified so that the key points of the project are determined quickly, and the designer can move toward creating a final concept. It is easier to

complete alone and can be done in 30 minutes to 1 hour and printed on an A3. This toolkit has a total of 9 Steps and there is an accompanying explanation sheet, and it is best suited for roboticists and design engineers.

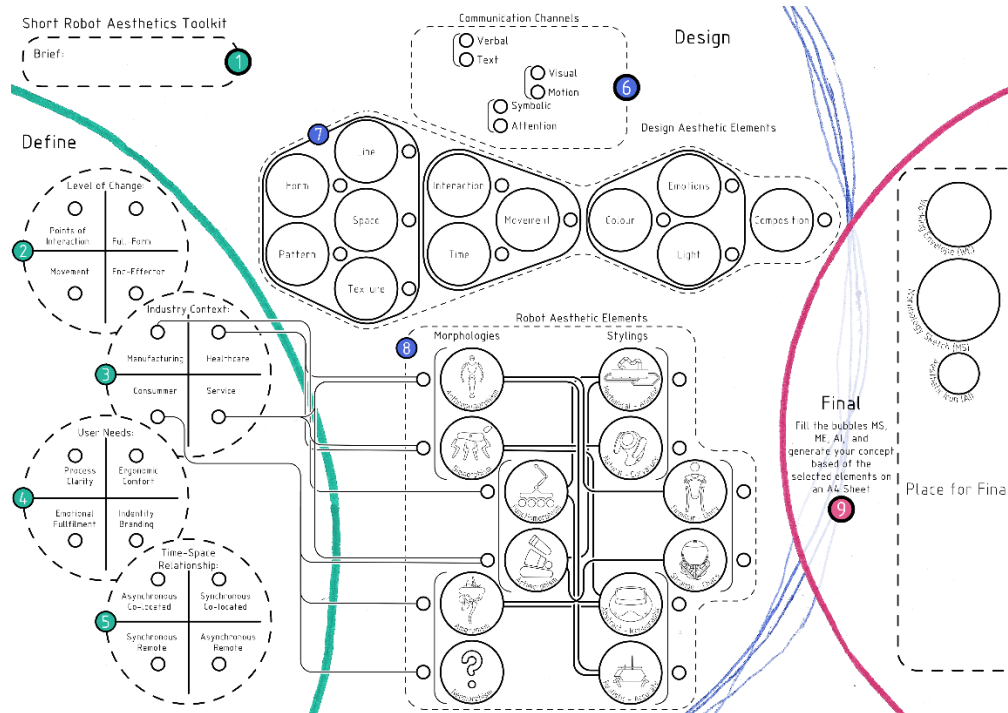


Figure 73 - Initial Short Design Process

Short Robot Aesthetics Design Process

Primer: This version of the process is best suited for those with greater experience in other fields or which to define the direction of the project in short time. You need to go from the Define phase, to Design, to Final and follow the order of steps. There are robot aesthetic definitions to the right of the page and technical terms at the bottom of the page.

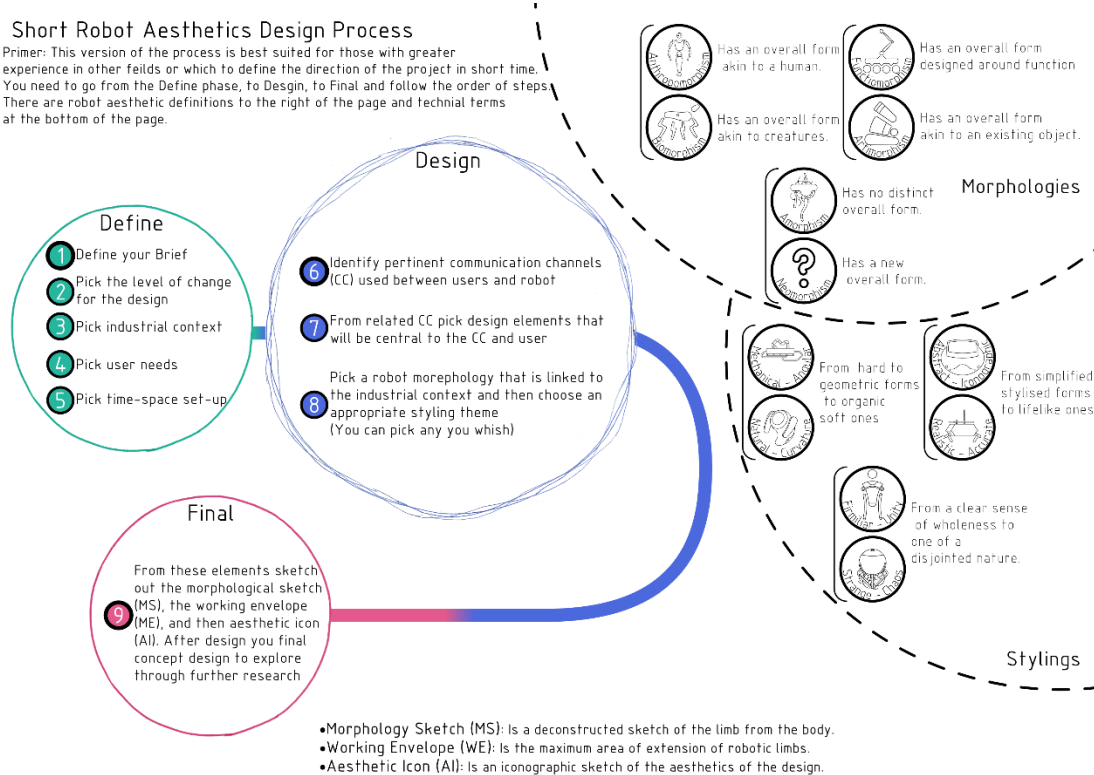


Figure 74 - Initial Short Design Process - Explanation Sheet

7.1.1.1. Define

The Define phase is reduced to 5 main steps where the project limits are set in place (Figure 75). Step 1 is writing down the brief, and this is predetermined by the designer beforehand. Step 2 is determining the level of change require to fulfil the brief, with 4 choices. The first choice is changing the point of interaction on a robot, whether this interaction is physical or not. The second choice is changing the full form of the robot, whether creating a novel design or modifying an existing. The third choice is changing the movement of the robot; this is more focused on the sense of motion and behaviour. The fourth choice is changing the end-effector, this is the tool that the robot uses to affect the environment around it.

Next the designer moves to Step 3 where the industrial context is determined. This should be evident by the brief. There are 4 industrial contexts that are generally used by robots. Manufacturing, where a robot is used to build other products. Healthcare, where a robot is used to provide medical services alongside a professional. Consumer, where a robot is used to provide consumer goods. Service, where a robot provides a temporary activity to a user. These are linked to certain robot morphologies.

Next the designer moves to Step 4 where the user needs are determined by the designer, with 4 choices. Process clarity, where the processes undertaken by the robot appear unclear to the user. Ergonomic comfort, where there is some unpleasant and painful physical interaction occurring during use. Emotional fulfilment, where the emotional experience needs to result in a specific affective state throughout and by the end of an interaction or relationship. Identity branding, where the meaning of the object and commercial identity need to be brought into line with user perception.

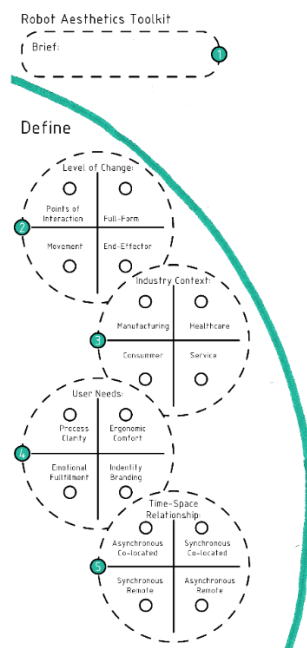


Figure 75 - Initial Short Design Process - Define

7.1.1.2. Design

Once the Define phase is complete, the designer moves on to the Design phase. Which is reduced to 3 main steps where the design elements are determined for the project and act as areas to explore (Figure 76). The designer moves to Step 6, where the communication channels are determined, selecting the ways in which the user and the robot convey information to each other. There are 6 choices that have been grouped into 3 associations, although they do not have to be selected in pairs; verbal and text, which involves auditory and linguistic symbols. Visual and motion, which involves forms and time dependent on actions. Symbolic and attention which involves how meaning communicated and how to attract the focus of the user.

Next the designer moves to Step 7, where there are specific practical design and aesthetic properties that can be changed to convey different abstract meanings or functions. There are 12 choices that have been grouped into 3 associations, which can be selected separately. Firstly, form, line, pattern, space, and texture, are associated together as they relate to fixed physical volumes both positive and negative and define the structural and spatial qualities of an object or robot. These are structural elements that describe what the object is. Secondly, interaction, movement, and time are associated together as they are less tangible and more transient. These are dynamic elements that describe what the object does and how it behaves through time. Thirdly, colour, emotion, and light are associated together due to their multispectral nature and shape the perceptual and affective experience. These are perceptual elements and describe how the object feels. Finally, composition, which envelopes all the elements as their composition can amplify their aesthetic experience. It is the integrative element that combines the other elements into a meaningful whole.

Next the designer moves to Step 8 where the robot aesthetic elements are selected. There are 12 choices, where 6 are associated together as morphologies with 3 subgroupings. The other 6 are associated together as stylings, with 3 subgroupings. Here the designer has to pick the preferred morphologies and then the best associated stylings and industrial contexts. Although these associations are guides, not rules. The 6 morphologies are:

- **Anthropomorphism:** Has an overall form akin to a human.
- **Biomorphism:** Has an overall form akin to creatures. These two are grouped together due to both having natural and lifelike themes.
- **Functionomorphism:** Has an overall form designed around function.
- **Artimorphism:** Has an overall form akin to an existing object. These two are grouped together due to both having artificial and man-made themes.
- ❖ **Amorphism:** Has no distinct overall form.

- ❖ **Neomorphism:** Has a new overall form. These two are grouped together due to both having unknown or exciting themes due to their novelty and lack of information.

The 6 stylings are:

- **Mechanical – Angular:** Has hard geometric forms.
- **Natural – Curvature:** Has soft organic forms.
- **Abstract – Iconographic:** Has simplified or stylised forms.
- **Realistic – Accurate:** Has lifelike or rational forms.
- ❖ **Familiar – Unity:** Has a clear sense of wholeness or analogous forms.
- ❖ **Strange – Chaos:** Has a disjointed or unclear nature.

The stylings were all grouped based on their bipolar styling dimensions defined in previous chapters. The lines act as associations between the morphologies and stylings based on the participant responses from the first experiment.

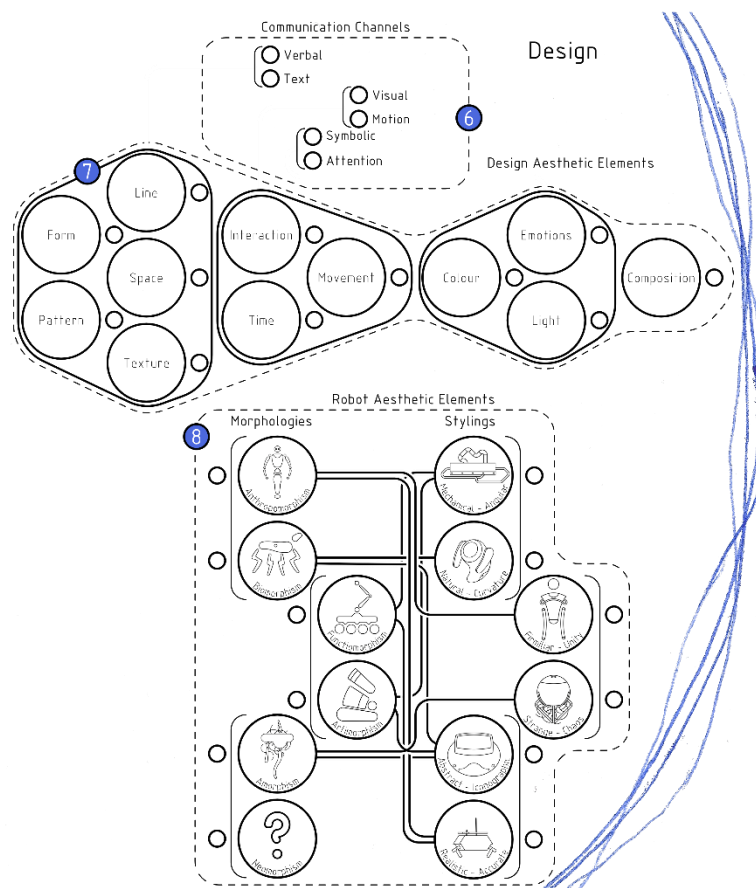


Figure 76 – Initial Short Design Process - Design

7.1.1.3. Final

Once the Design phase is complete, the designer moves on to the Final phase, which is reduced to 1 step with the main conceptual elements drawn to inform the design concept (Figure 77). From the elements that have been chosen in the work sheet, the designer then

sketches out the morphological sketch (MS), the working envelope (ME), and then aesthetic icon (AI). After this they can design the final concept to then explore through further research.

Morphology Sketch (MS): Is a deconstructed sketch of the limbs and the body. Working Envelope (WE): Is the maximum area of extension of the robotic limbs. Aesthetic Icon (AI): Is an iconographic sketch of the aesthetics of the design. These sketches help define the structure of the robots, the styling and the working envelope that the robot will have during use. All sketches become useful technical and aesthetic information to help inform any later choices.

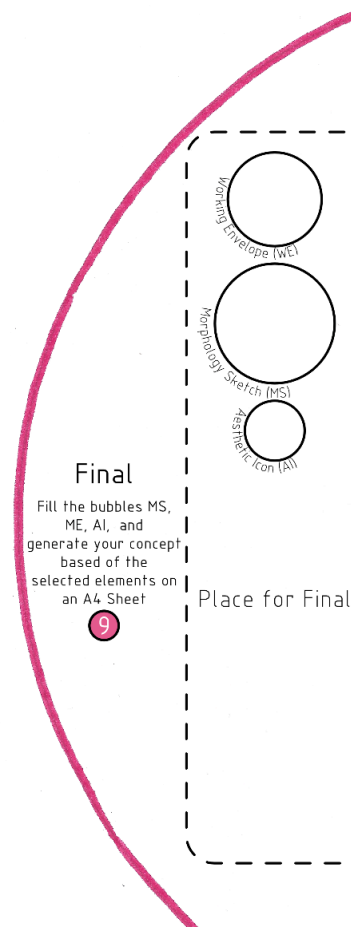


Figure 77 – Initial Short Design Process - Final

7.1.2. Initial Medium Design Process

The initial medium design process version was designed for those with some experience in design. It has been developed as a series of design sprints where the designer goes through 4 main phases; Define, Design, Prototyping, and Final (Figure 78), (Figure 79). The designer fills out the sheet and conducts short external activities. The process is geared towards generating design artefacts to aid in the design process and generating multiple final concepts. It is easier to complete as a small team, can be done in 2 hours or more, and is ideally printed in A1. This toolkit has a total of 13 Steps and there is an accompanying explanation sheet. It is best suited for design engineers and product designers.

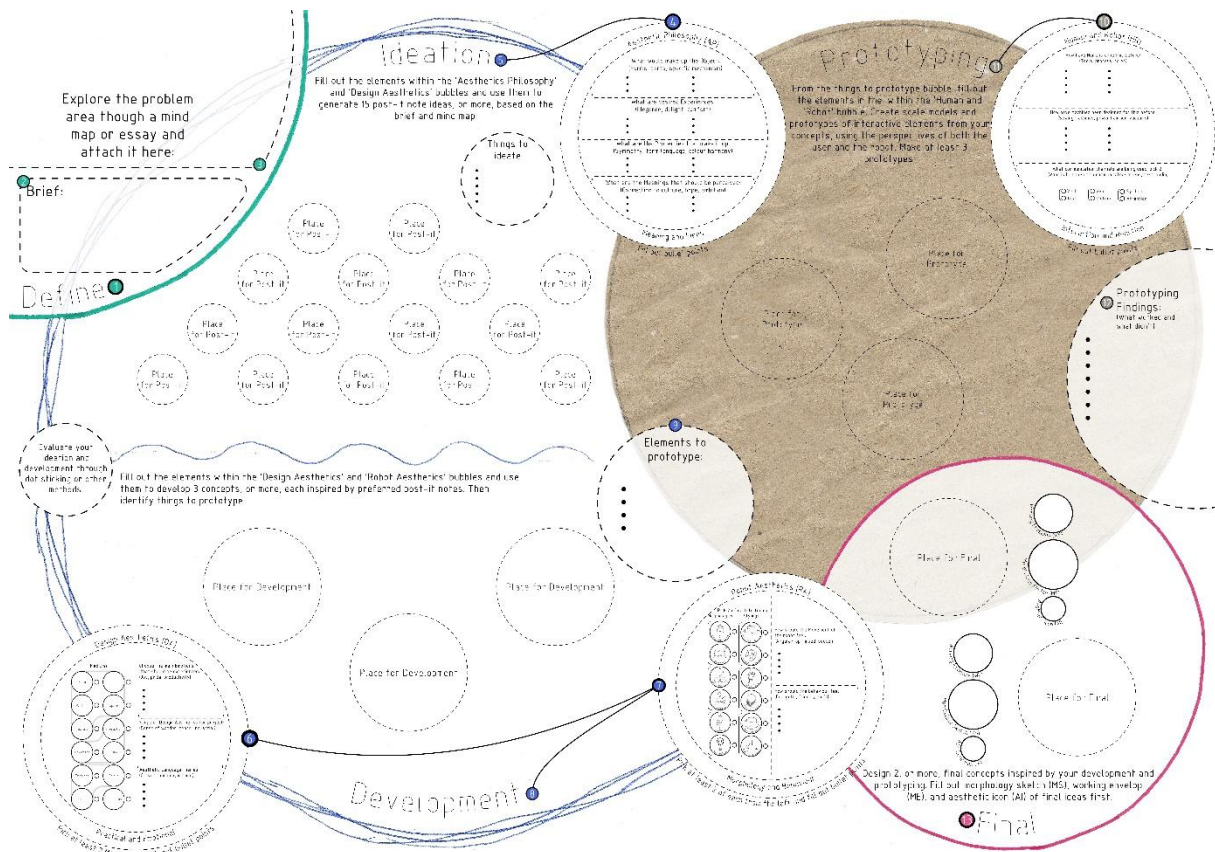


Figure 78 - Initial Medium Design Process

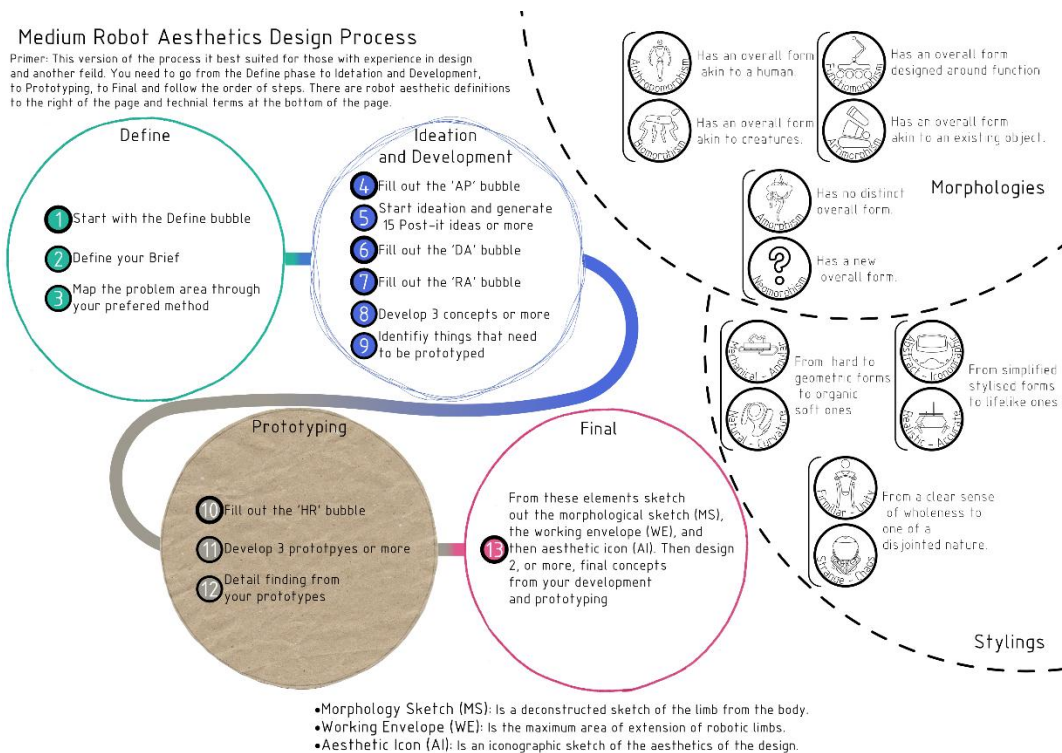


Figure 79 - Initial Medium Design Process - Explanation Sheet

7.1.2.1. Define

The Define phase has 3 main steps where the designer explores the problem area (Figure 80). Step 1 is simply to start at the define phase. Next the designer moves to Step 2, which is writing down the brief and has been predetermined by the designer beforehand. After the designer moves to Step 3 where a mind map of the problem is generated to focus the project further.

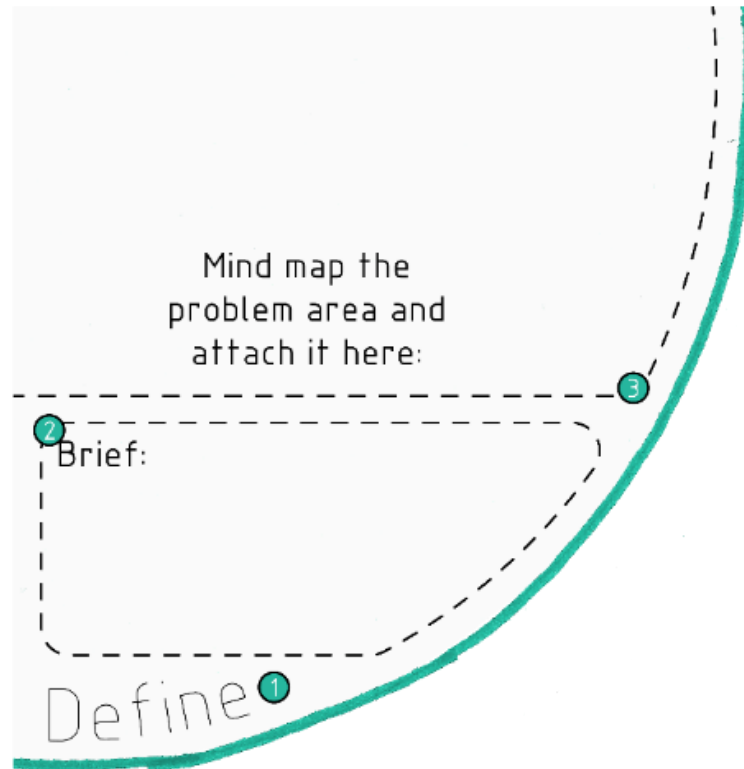


Figure 80 - Initial Medium Design Process - Define

7.1.2.2. Ideation and Development

Once the Define phase is complete the designer moves on to the Ideation and Development phase which has 6 main steps, where ideation and development are undertaken, and the design elements are determined through the conceptual bubbles (Figure 81).

to culture, hope, ambition). The aim here is to generate a loose set of abstract and cultural elements that are to be evoked when associated with the design.

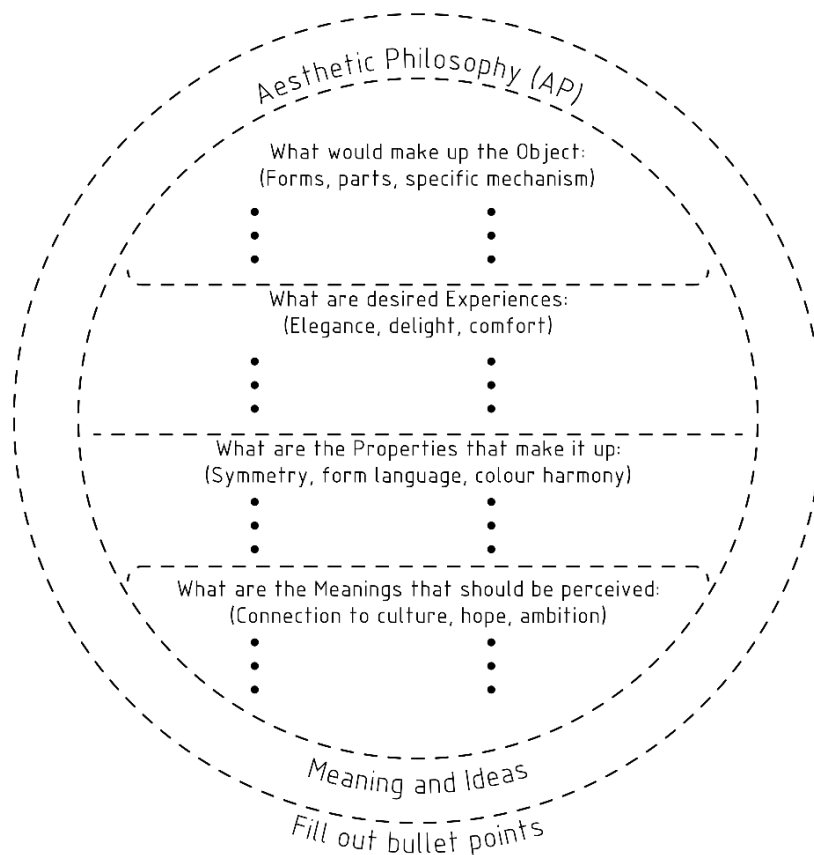


Figure 82 - Initial Medium Design Process - Aesthetic Philosophy Bubble

Next the designer moves to Step 5 where they need to generate at least 15 Post-it note concepts to be placed on the sheet informed from the previous steps. After which they can then evaluate the best ideas to take into development.

Next the designer moves to Step 6 where they fill out the Design Aesthetics conceptual bubble covering the practical and emotional (Figure 83). This bubble helps define the more practical aesthetic elements that may make up the design and will help in generating the developments. The DA bubble has one selection area where the 12 major practical design mediums are identified. It also has 3 questions with prompts that are meant to generate focal terms for the development. The mediums section has: Form, Line, Pattern, Space, Texture, Interaction, Movement, Time, Emotions, Colour, Light, and Composition. These were grouped in the same manner as the short tool kit. Then the designer moves on to the questions. The first question is: Choose the main Emotions that should be experienced: (Joy, pride, productivity). The aim here is to generate a set of terms that create the emotional core of the developments. The second question is: Scope of Design Aesthetics for project: (Sense of wonder, peace, industrial). The aim here is to generate a set of terms

that form the aesthetic purpose of the developments. The third question is: Aesthetic Language themes: (Curved, complex, minimal). The aim here is to generate the terms of visual grammar that results in the previous chosen terms.

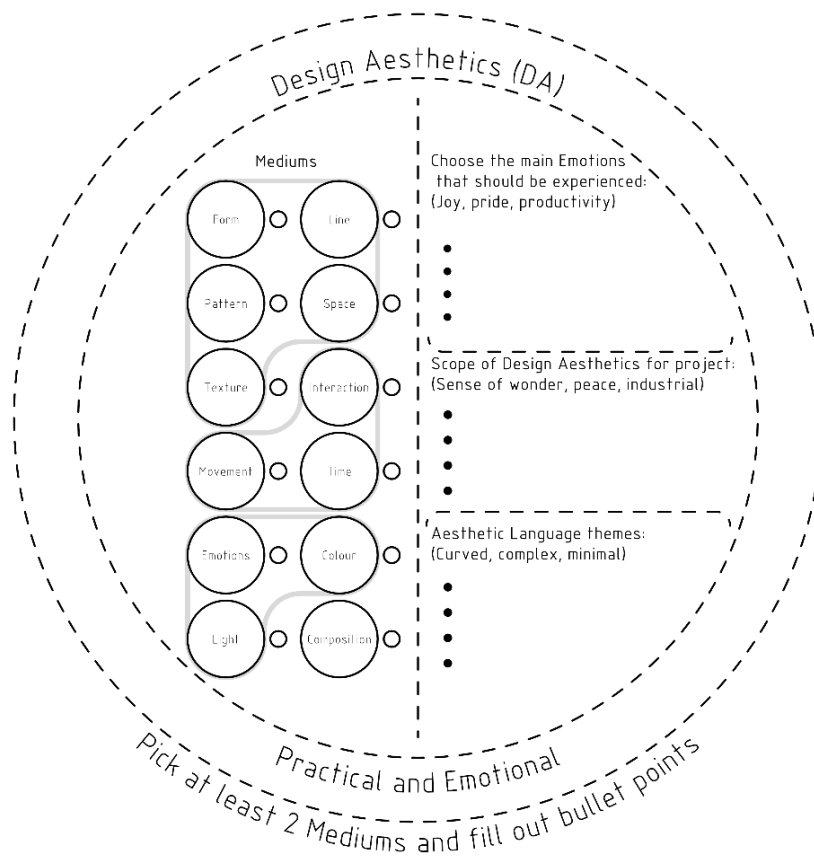


Figure 83 - Initial Medium Design Process - Design Aesthetics Bubble

Next the designer moves to Step 7 where the designer fills out the Robot Aesthetics conceptual bubble covering the morphological and behavioural considerations (Figure 84). This bubble helps define the morphology, styling and behavioural aesthetics of the robot. The RA bubble has 1 selection areas where the 6 morphologies and the 6 stylings are grouped together based on association. This helps form the major aesthetic and functional elements of the design. It also has 2 questions with prompts that are meant to generate focal terms for the development for the movement and behaviour. The morphologies and stylings are identical to the previous process and are grouped in the same manner as before. The 6 morphologies are: Anthropomorphism, Biomorphism, Functionism, Artismorphism, Amorphism, Neomorphism. The 6 stylings are: Mechanical – Angular, Natural – Curvature, Abstract – Iconographic, Realistic – Accurate, Familiar – Unity, Strange – Chaos. The first question is: How should the Movement of the robot feel? (Angular, optimised, sudden). This aim here is to generate aesthetic descriptions of how the movement should feel to the user.

The second question is: How should the behaviour feel? (Energetic, friendly, soft). This supports the generation of aesthetic descriptions of the more social aspect of the robot.

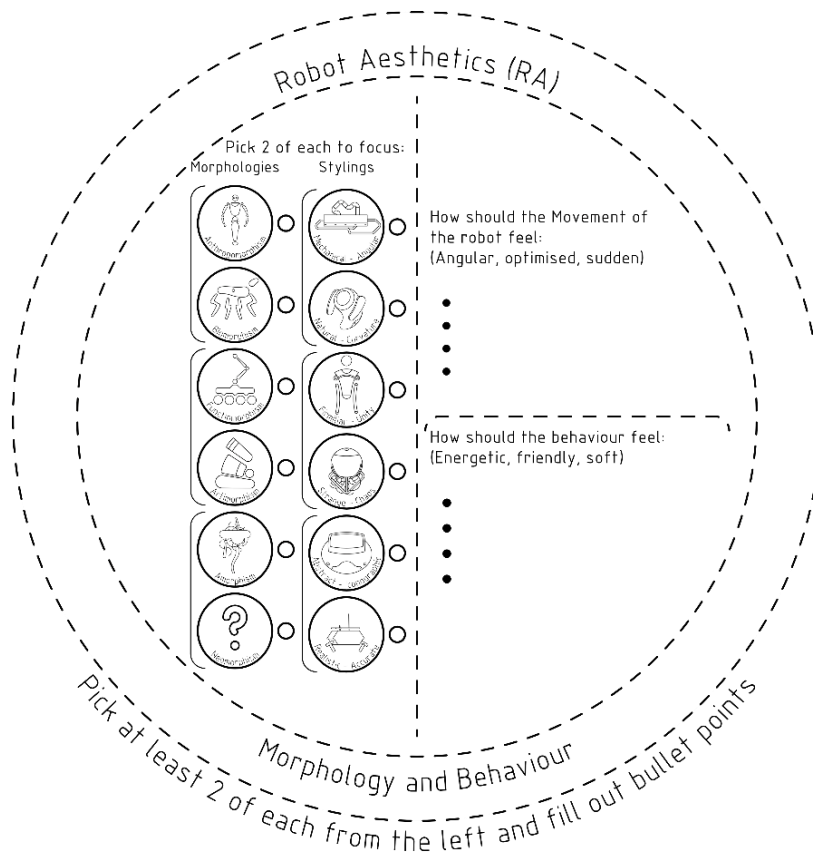


Figure 84 - Initial Medium Design Process - Robot Aesthetics Bubble

Next the designer moves to Step 8 where, after filling out the elements within the DA and RA bubbles, the designer uses them to develop 3 concepts, or more, each inspired by preferred Post-it notes. This is done by placing their designs on the spots identified to place their development drawings, after which they can evaluate the best ideas to take into prototyping. Next the designer moves to Step 9 where they identify ideas to prototype from their development concepts.

7.1.2.3. Prototyping

Once the Ideation and Development phase is complete the designer moves on to the Prototyping phase which has 3 main steps where the human and robot interactional elements are determined through the conceptual bubbles and then prototyping is undertaken, after which they can determine their findings to take into the next phase (Figure 85).

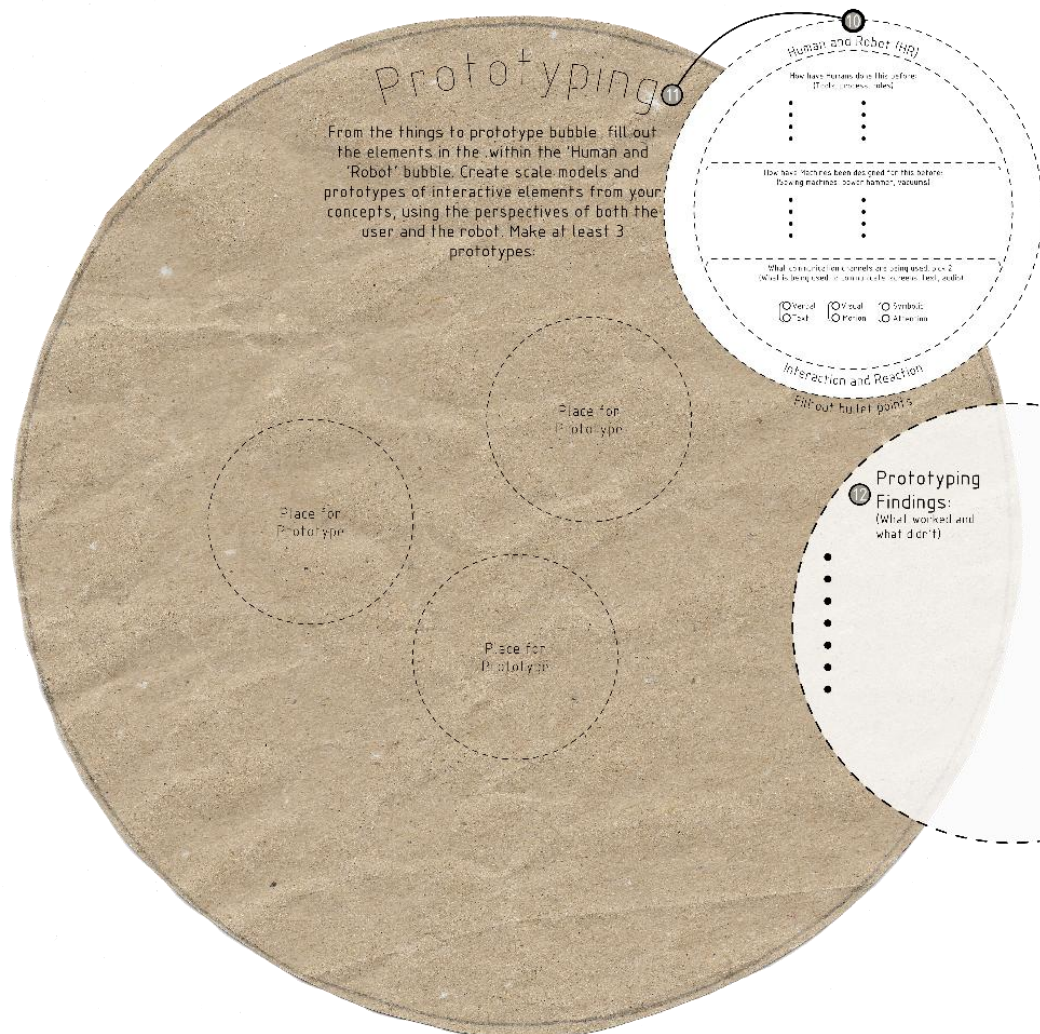


Figure 85 - Initial Medium Design Process - Prototyping

Next the designer moves to Step 10 where the designer fills out the Human and Robot conceptual bubble (Figure 86). This bubble helps define the needs of the human and robot and how they communicate. The HR bubble has 2 questions with prompts that are meant to generate examples of how humans and robots have dealt with the problem being prototyped in the past. It also has 1 selection area where there are 6 choices that have been grouped into 3 associations. They are all grouped in the same manner as before. The first question is: How have Humans done this before? (Tools, process, roles). The aim is to determine the human approach to the problem. The second question is: How have Machines been designed for this before? (Sewing machines, power hammer, vacuums). The aim here is to determine how machines have been designed to approach the problem. The 6 communication channels are: verbal and text, visual and motion, symbolic and attention. The designer picks what communication channels are being used which determines what communication channels are needed for the interaction.

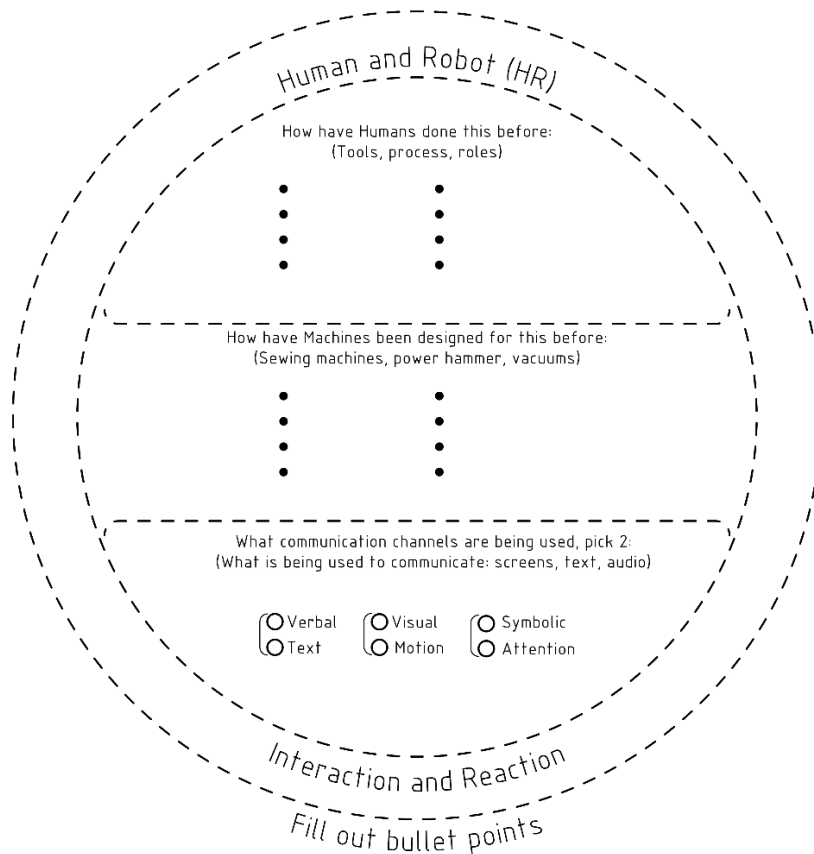


Figure 86 - Initial Medium Design Process - Human and Robot Bubble

Next the designer moves to Step 11 where the designer undertakes the prototyping process. From the things to prototype bubble and the HR bubble. The designer can create prototypes that are scale models, prototypes of interactive elements from the development concepts, using the perspectives of both the user and the robot. Then, the designer needs to make at least 3 prototypes. This helps the designer develop a better understanding of the issues with their design from the perspective of the user and robot.

Next the designer moves to Step 12 where the designer determines the findings from prototyping to capture what worked and what did not work for the prototypes. This helps determine what should be kept for the final phase.

7.1.2.4. Final

Once the Prototyping phase is complete the designer moves on to the Final phase which has 1 main step (Figure 87). Next the designer moves to Step 13. From the elements that have been determined through the activities from the development and the prototyping findings, the designer fills out morphology sketch (MS), working envelope (ME), and aesthetic icon (AI) of the final ideas first. Then the designer generates 2, or more, final concepts inspired by the development and prototyping.

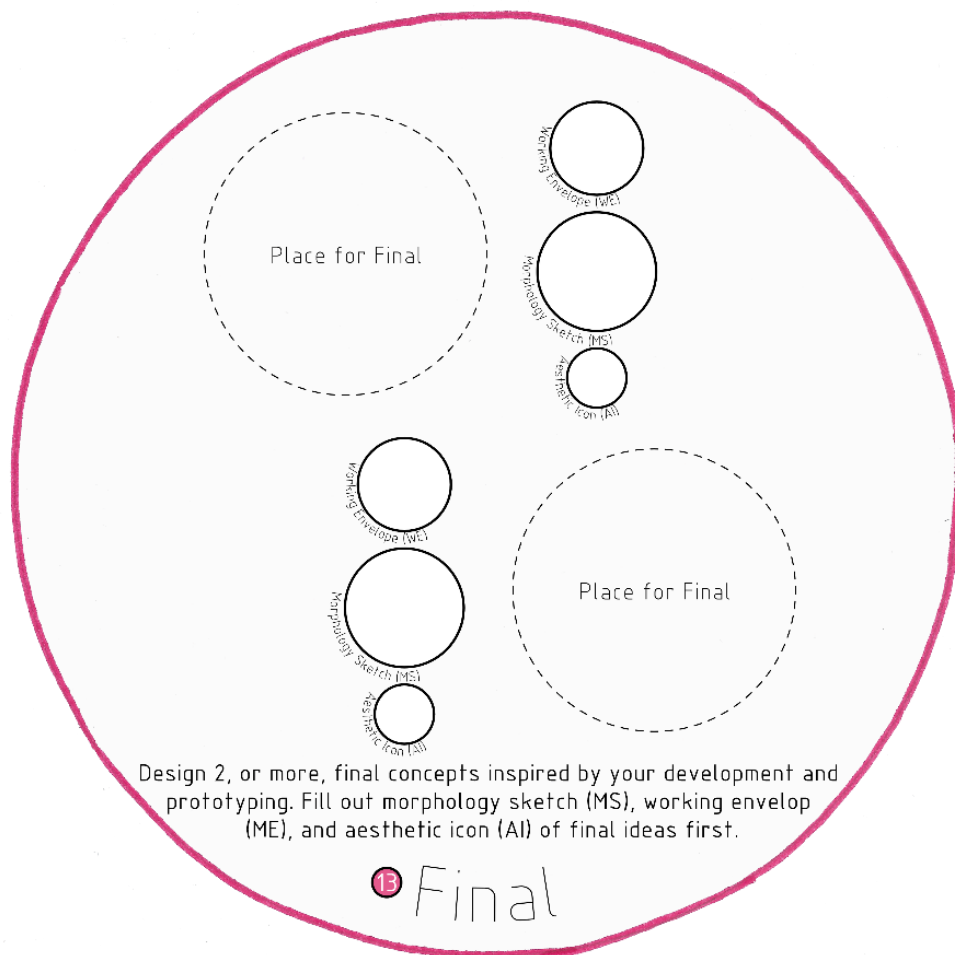


Figure 87 – Initial Medium Design Process - Final

7.1.3. Initial Long Design Process

The Initial long design process version was designed for those with substantial experience in design. It has been designed as a series of deep design activities (Figure 88), (Figure 89). The designer goes through 4 main phases; Define (green), Design (blue), Prototyping (brown), and Final (red). The designer fills out the sheet and conducts short internal and long external activities. The process is geared towards generating artefacts and design knowledge to inform the complex design decisions by generating multiple research output, design studies, developments and final designs. It is best used as an accompaniment to a long design project ideally geared towards generating highly novel designs and even new product typologies. Ideally printed as one poster print, as it is a long diagram that can be pinned to a board and design and research artefacts can be collected and pinned around it as the project moves forwards. Its width is A2 and has a height of four A1 sheets. The short internal activities act as ways of stimulating the creative process and avoiding stagnation and then conduct other external activities for the project. Although here the Step number resets to one for every phase as there are many more steps and the numerals became overly long for the diagram.

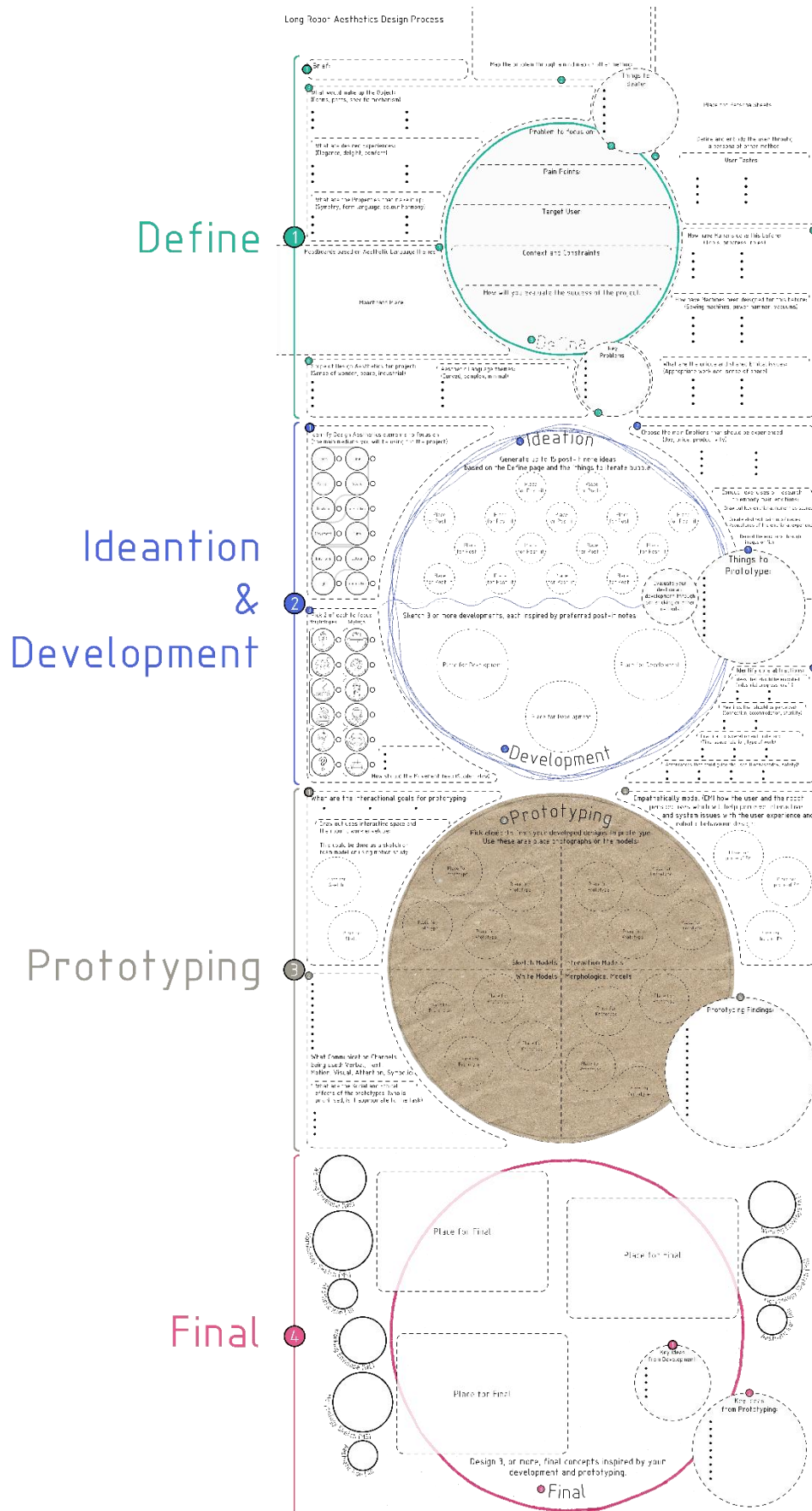


Figure 88 - Initial Long Design Process

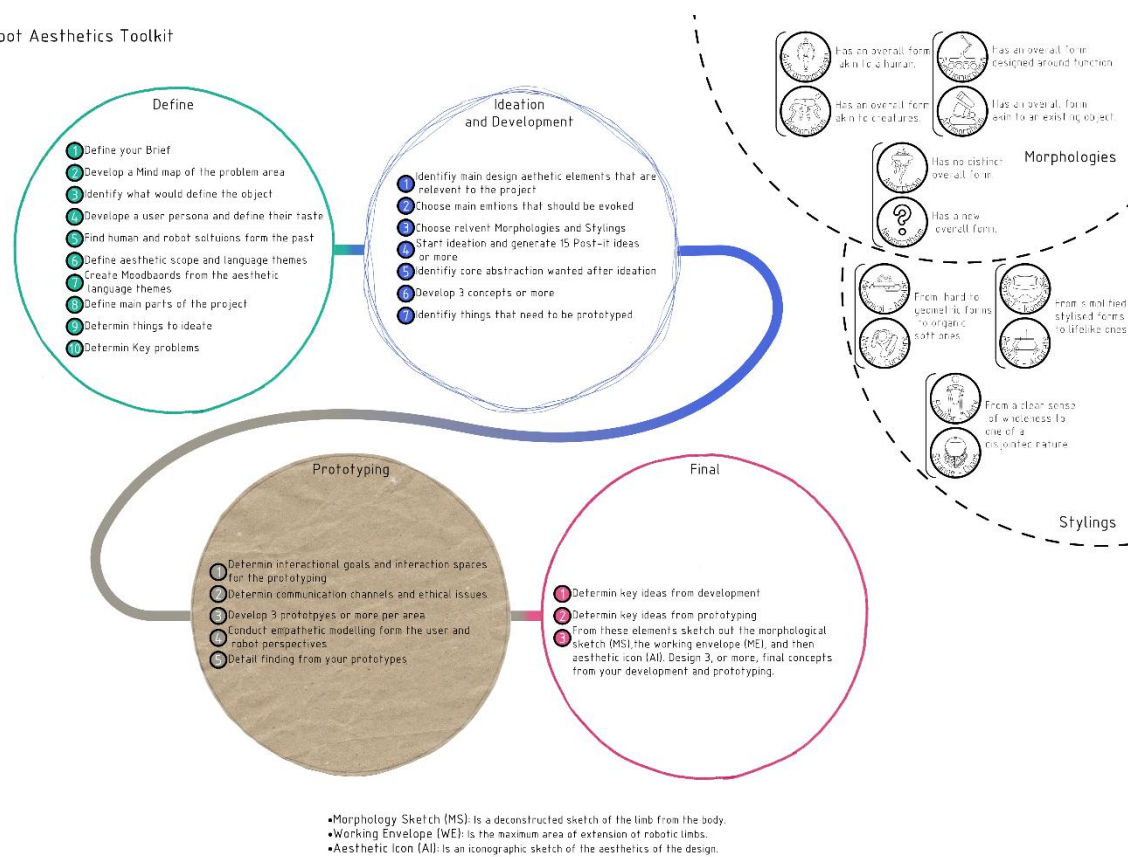


Figure 89 - Initial Long Design Process - Explanation Sheet

7.1.3.1. Define

The Define phase has 10 main steps where the designer explores the problem area (Figure 90). Step 1 is simple as the designer writes down their brief which has been predetermined by the designer beforehand.

Next the designer moves to Step 2 where a mind map of the problem is generated to focus the project further.

After, the designer moves to Step 3 which helps define the meaning and ideas for the project. This helps define the more abstract aesthetic elements that may make up the design and will help in ideas generation later. This step has 3 questions. The first question is: What would make up the Object? (Forms, parts, specific mechanisms). The aim here is to generate a loose set of parts that may make up the design. The second question is: What are desired Experiences? (Elegance, delight, comfort). The aim here is to generate a loose set of experiences that may be evoked by the design. The third question is: What are the Properties that make it up? (Symmetry, form language, colour harmony). The aim here is to generate a loose set of abstract and perceptual properties that result in the perception of the object.

Next the designer moves to Step 4 where the designer generates a persona for the problem. Here they are focusing on tastes that the persona might have. The aim here is to define the aesthetic limits and problem area from a human perspective.

Next the designer moves to Step 5 where they determine how humans and robots approached the problem before. This helps define the interactional and relational elements between humans and robots. This step has 3 questions. The first question is: How have Humans done this before? (Tools, processes, roles). The aim here is to determine the human approach the problem. The second question is? How have Machines been designed for this before? (Sewing machines, power hammer, vacuums). The aim here is to determine how machines have been designed to approach the problem. The third question is: What are the unique and shared ethical issues? (Appropriate workload, sense of space). The aim here is to determine what moral issues exist in previous attempts to develop a more appropriate solution and avoid common mistakes.

Next the designer moves to Step 6 where the designer defines linguistically what the aesthetics for the project will be. This step has 2 questions. The first question is: Scope of Design Aesthetics for project: (Sense of wonder, peace, industrial). The aim here is to generate a set of terms that form the aesthetic purpose of the development phase. The second questions are: Aesthetic Language themes: (Curved, complex, minimal). The aim here is to generate the grammar that results in the previous answers and selections.

Next the designer moves to Step 7 where the designer generates mood boards based on the terms picked in the previous step. The aim here is to find visual examples that can be used to embody the desired aesthetics.

Next the designer moves to Step 8 where the design defines the problem through 5 key questions. The first question is: Problem to focus on. The aim here is to generate a specific problem to continue the project with. The second question is: Pain Points. The aim here is to define issues for further investigation later. The third question is: Target User. The aim here is to create a quick summary from the persona. The fourth question is: Context and Constraints. The aim is to define the environment and industrial context of the problem. The fifth question is: How will you evaluate the success of the project. The aim here is the have referenceable points to determine the value of the work throughout and how well it fulfils the brief.

Next the designer moves the Step 9 where they determine ideas that could be ideated upon. The aim here is to start the creative process.

Next the designer moves to Step 10 where they determine key problems. The aim here is the have a set to focus on for ideation and development.

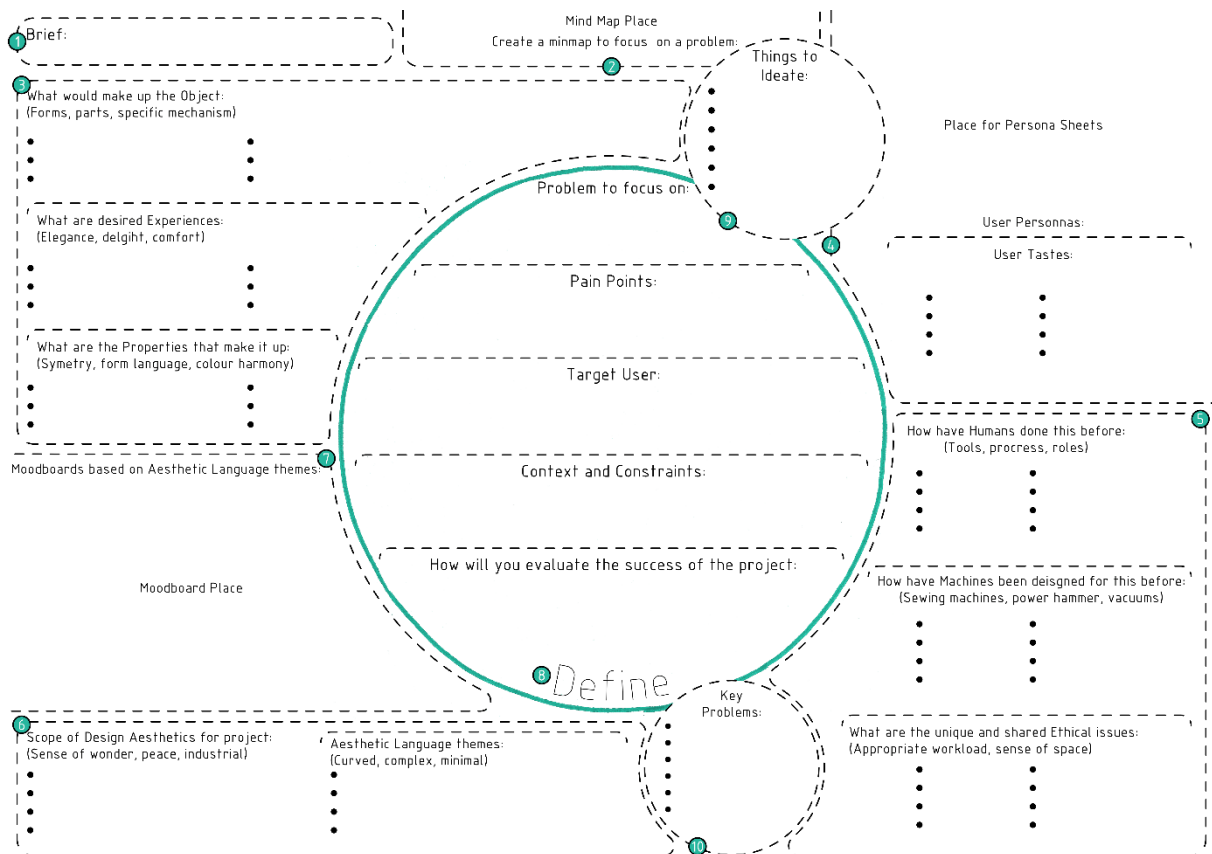


Figure 90 - Initial Long Design Process - Design

7.1.3.2. Ideation and Development

Once the Define phase is complete the designer moves on to the Ideation and Development phase which has 7 main steps to start creating concepts (Figure 91).

Next the designer moves to Step 1 where they need to identify Design Aesthetics elements to focus on which are the main mediums they will be using for the project. This helps define the more practical aesthetic elements that may make up the design and will help in generation during ideation and development designs. The mediums section has: Form, Line, Pattern, Space, Texture, Interaction, Movement, Time, Emotions, Colour, Light, and Composition. These were grouped in the same manner as the other toolkits.

Next the designer moves to Step 2 where they choose the main Emotions that should be experienced: (Joy, pride, productivity). They are informed that they should conduct exercises or research to embody main emotions. They can draw out key emotional moment as scenes, create abstract paintings/images/sculptures of the emotional experience, record the emotions through images or film. The aim here is to embody the emotions being designed through any appropriate methods. Preferably multiple methods.

Next the designer moves to Step 3 where they choose the main morphology and styling for ideation and development as well as one question. The morphologies and styles are the same as before. The 6 morphologies are: Anthropomorphism, Biomorphism, Functiomorphism: Artimorphism, Amorphism, Neomorphism. They are all grouped in the

same manner as before. The 6 stylings are: Mechanical – Angular, Natural – Curvature, Abstract – Iconographic, Realistic – Accurate, Familiar – Unity, Strange – Chaos. The question is: How should the Movement feel: (Sudden, slow). This aim here is the generate aesthetic descriptions for development of how the movement should feel to the user.

Next the designer moves to Step 4 where they start ideation inspired from the previous steps. Then the need to generate at least 15 Post-it note concepts to be placed on the sheet. After which they can evaluate the best ideas to take into development.

Next the designer moves to Step 5 where they identify the core abstractions where they need to answer 4 questions. The aim is to define a mix of philosophical ideas that can motivate the project forward as well as defining some HR theory constraints. The first question is: Ideas that should be embodied: (industrial progress, craft). The aim here is determining the ideas that need to be embodied by the design. The second question: Meanings that should be perceived: (Connection, accommodation, sterility). The aim here is to define association that should exist in the user towards the design. The third question is: Practical consideration and limitation: (Time-space relation, type of work). The aim here is defining some elements of HR theory that are most appropriate. The fourth question is: Affordances that could guide the user: (Form/shadow, safety). The aim here is to define how and what affordances will be used to communicate to the users.

Next the designer moves to Step 6 where they generate 3 development concepts, or more, each inspired by preferred Post-it notes and the previous work. Placing their designs on the spots identified. After which they can evaluate the best ideas to take into prototyping.

Next the designer moves to Step 7 where they determine the parts of the concepts that should be prototyped and explored further.

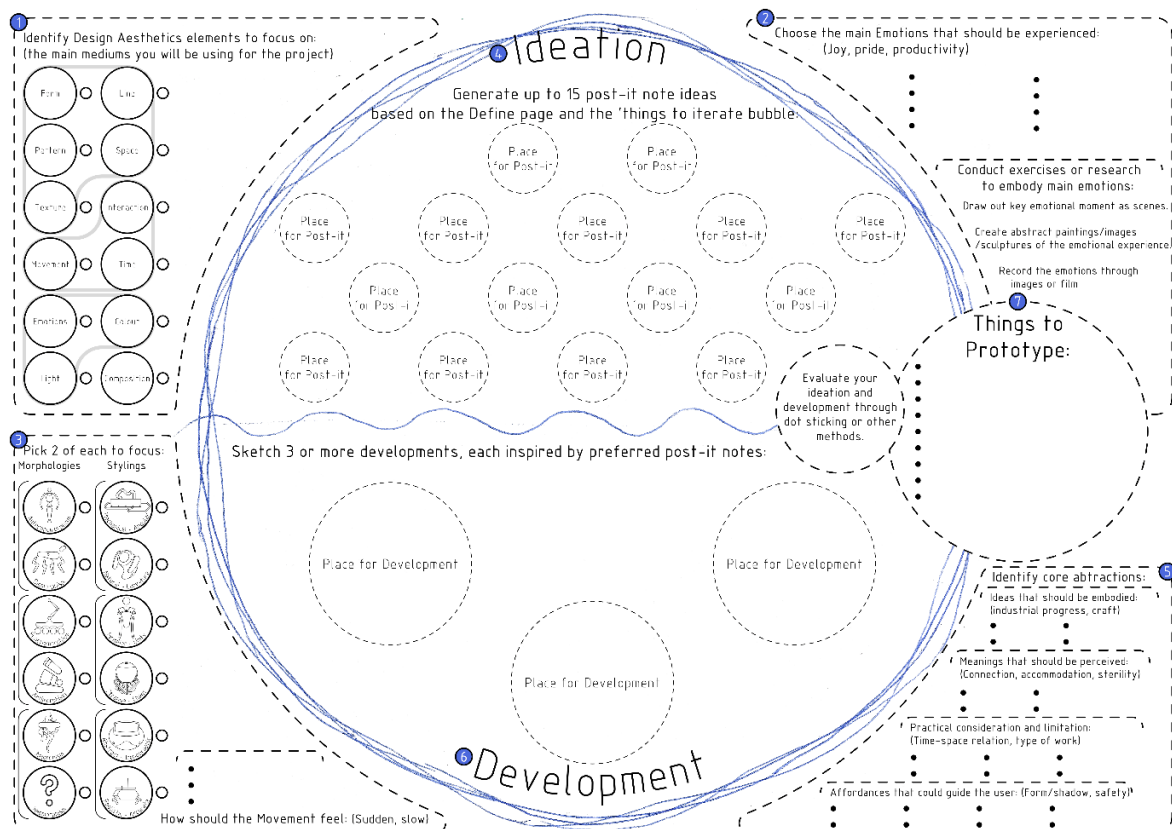


Figure 91 - Initial Long Design Process- Ideation and Development

7.1.3.3. Prototyping

Once the Ideation and Development phase is complete, they can move on to the Prototyping phase which has 5 main steps to experiment and prototype their concepts (Figure 92).

Next the designer moves to Step 1 where the designer define the interactional goals. Then they draw out the users' interactive space and the robotic work envelope: This could be done as a sketch or foam model or using a motion study. The aim here is to define the volume of space that might be used for interaction between the human and robot.

Next the designer moves to Step 2 where there are 2 questions. The first question is: What Communication channels are being used? Verbal, Text, Motion, Visual, Attention, Symbolic. The aim here is to define in what medium will the communication occur. The second question is: What are the Social and Ethical effects of the prototypes? (who is prioritised, is it appropriate to the task). The aim here is to determine what moral issues that are to be explored to then develop more appropriate solutions.

Next the designer moves to Step 3 where they pick elements from the developed designs to prototype. Using the identified areas, they can place photographs or models of the prototypes. The models can take 4 forms: Sketch Models, Interaction Models, White Models, Morphological Models. The aim here is to explore and prototype through different methods

and generate multiple prototyping artefacts.

Next the designer moves to Step 4 where the designer empathetically models (EM) from the user and the robot perspectives which will help them perceive interactive and system issues with the user experience and robotic behaviour design. Photographic evidence can be placed on the relevant area.

Next the designer moves to Step 5 where they determine the findings from prototyping to capture what worked and what did not work, which will help determine what should be kept for the final phase.

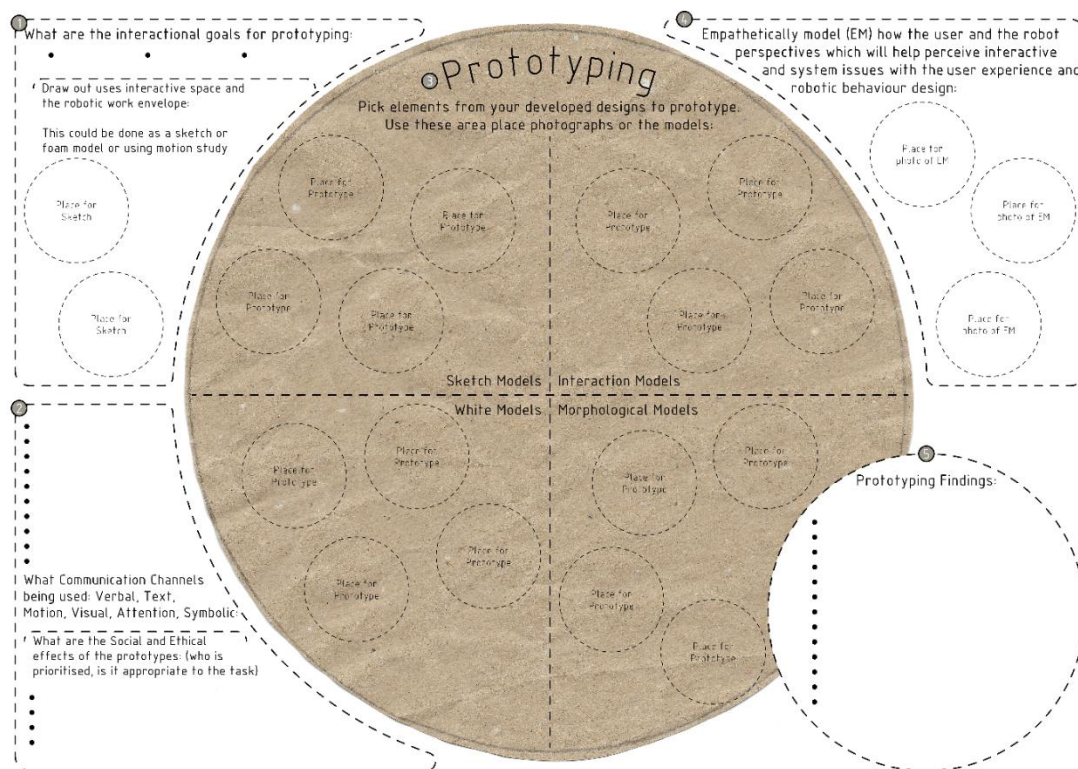


Figure 92 - Initial Long Design Process - Prototyping

7.1.3.4. Final

Once the Prototyping phase is complete the designer moves on to the Final phase which has 3 main steps (Figure 93).

Next the designer moves to Step 1 where they note the key ideas from development to have them as reference for the final designs.

Next the designer moves to Step 2 where they note key ideas from prototyping for the same purpose as Step 1.

Next the designer moves to Step 3. From the elements that have been determined through the activities from the development and the prototyping findings the designer fills out a morphology sketch (MS), working envelope (ME), and aesthetic icon (AI) for the final ideas first. Then the designer generates 3, or more, final concepts inspired by the development and prototyping.

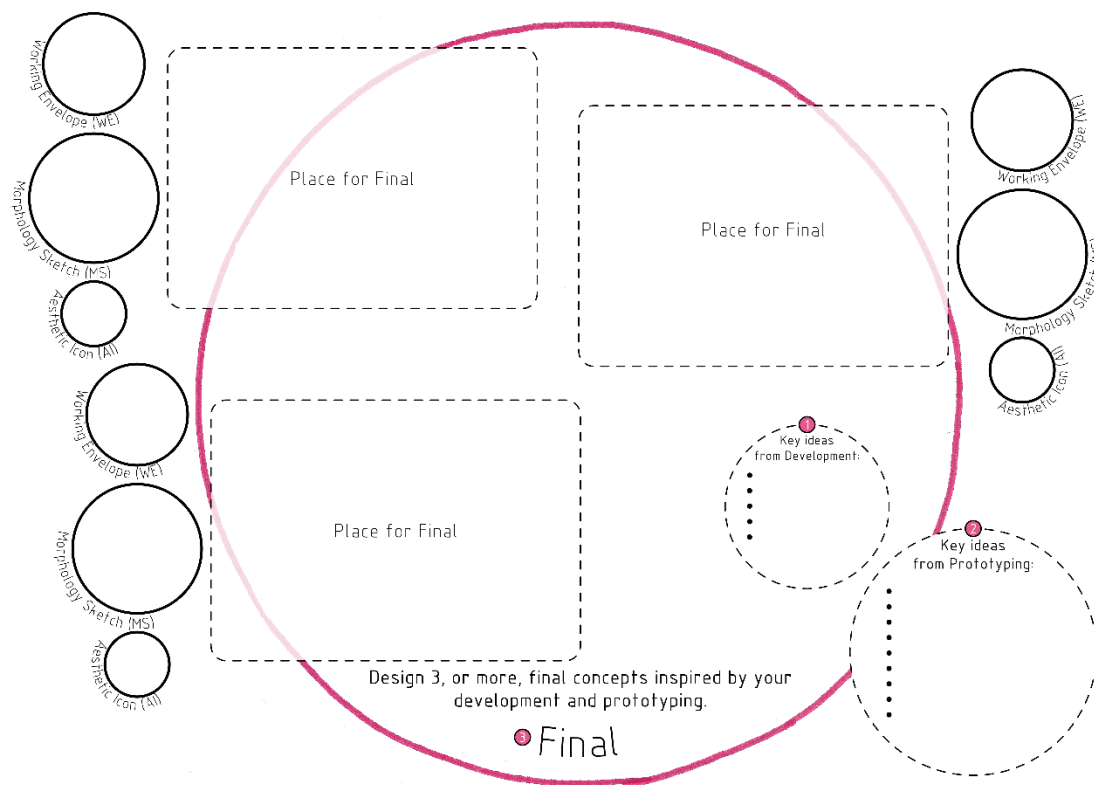


Figure 93 - Initial Long Design Process - Final

7.2. Interviews

Three interviews were undertaken to collect feedback on the final designs. During the interview the designer noted in a linear manner the key insights of each interviewee. The first interview was done with a roboticist, and they were shown the short design process version. The second interview was done with a design engineer, and they were shown the medium design process version. The third interview was done with a product designer, and they were shown the long design process skill version. The rationale for this separation was based on aesthetic fluency as the participant types are trained with different focuses. With the product designer being the ones that are generally directly trained to develop and understand aesthetics, design engineers being more balanced, and roboticists are more focused on the development of functional automation. As such the long version requires greater aesthetic fluency and was shown to the product designer. The medium design process is more balanced and shown to the designer engineer. The short design process is more guided and was shown to the roboticists. There were limits on maintaining the interest of the participant and considering their own time. As the interviews would have been overly long and repetitive if all three were shown to each participant. Although all the participant types can use any process they wish.

The interviews were open ended and asked 6 simple questions after the toolkit was explained to them:

1. Do you understand the toolkit?
2. Would you use it?
3. In what context would you use it?
4. What would you change?
5. Would you use it and it be useful in your work?

With an added 'extra' section at the bottom for other comments. See Appendix F – Expert Transcriptions.

7.2.1. Robotacist – Initial Short Design Process - Analysis

The robotacist understood all the steps and the terms and thought of applying it to their PhD level research. Although this version of the toolkit may need to be modified to space elements out a little to give the eye more room to travel between steps and phases. The process being seen as useful as a teaching aid and a project aid shows that the structure and the level of theory included is appropriate for a user with a low-level of design knowledge in relation to industrial/product design.

7.2.2. Design Engineer - Initial Medium Design Process - Analysis

There was a slight miscommunication about what the place for development and what the 9 and 12 were connected to. The fact that the icons for both morphology and stylings were seen as very useful to the participant here and in previous studies show that the distillation of the visual identity of these components through the hybrid method of sketch analysis autopsy and thematic icon grouping using the designs evaluated as dominant in participant evaluation was extremely successful. As such it should be used as a validated research method in design aesthetic research to define visual iconographic descriptions of ideas that are perceived and embodied through something. Moreover, the icons themselves as stated in previous chapters are research findings and associations seen in them are present in the perceptions of others. The participant also wanted to use the process cyclically rather than using once. This could be because the cyclical nature is present in the process and allow users to jump in and it can be applied to any brief. The participant wanted cleaner visual links between steps. The bubbles being seen as very intuitive is a positive outcome, as previously the participants needed help using them as the terms were too abstract and the design was too diagrammatical. The users wanted to adapt the bubbles to other areas of design as they were seen as very useful and attractive and could be an avenue of future work.

7.2.3. Product Designer – Initial Long Design Process - Analysis

The participant wanted to apply this across design fields and with different stake holders. As well as wanting to use it in teaching, research and consultancy. This version was seen more as a research tool to be used by teams to conduct external activities which was

the intended purpose. Flexibility and creativity were seen as being encouraged which is why it was design to be non-linear visually and structurally. The fact that given the length and complexity of this version was not confusing and the was exciting to the participant shows that the design of the toolkit is within the cognitive load abilities to the intended users.

7.2.4. Holistic Interpretation

The nonlinear design and circular nature of the toolkits was seen as beneficial during the studies and during the interviews as it caused users to circle back and not discount previous steps which encouraged creativity. All variations can be adapted to different design fields. All that would be required to do this is to conduct a literature review and develop a taxonomy diagram of the field in question and alter the relevant areas on the original toolkits.

7.3. Final Toolkit

The initial short design toolkit was modified to be on an A3 sheet instead of an A4. The medium skill toolkit was modified by increasing the size of the numbers for the first step in a phase. This was applied to the short process as well. Along with adding other options for mind mapping. The initial long design skill toolkit was modified by adding different options for mind mapping and persona as there were seen as restrictive compared to the freedom within the rest of the process. As well as adding primers at the start of the explanation sheets explaining the strengths of the process. The full Short, Medium, and Long Robot Aesthetic Design Process can be seen in the relevant appendix (See Appendix G – Robot Design Work). With the toolkit fully developed, it becomes necessary to synthesise the theoretical, empirical, and practical contributions of the thesis. The last chapter therefore brings these elements together, discussing their implications and reflecting on the research as a whole.

7.4. Designing Robots with the Toolkits

After the modifications were applied from the interview feedback the author of this thesis used the whole toolkit, which means all 3 processes (Short, Medium, and Long), for the same brief, although with different types of museums and galleries. Therefore, all three processes were used. The brief itself was identical to the one used by the participants in the second study:

How might we design a robot to improve engagement at museums or galleries. Bettering guidance, interaction and or understanding.

7.4.1. New Short Design Process – Art Gallery

The short design process was successful as it did manage to focus the attention down through the restrictive choices and deliver a relevant final concept. Although, two

different concepts were generated but the chandelier design was chosen as the final. See Figure 94 for outputs and Figure 111 for final concepts.

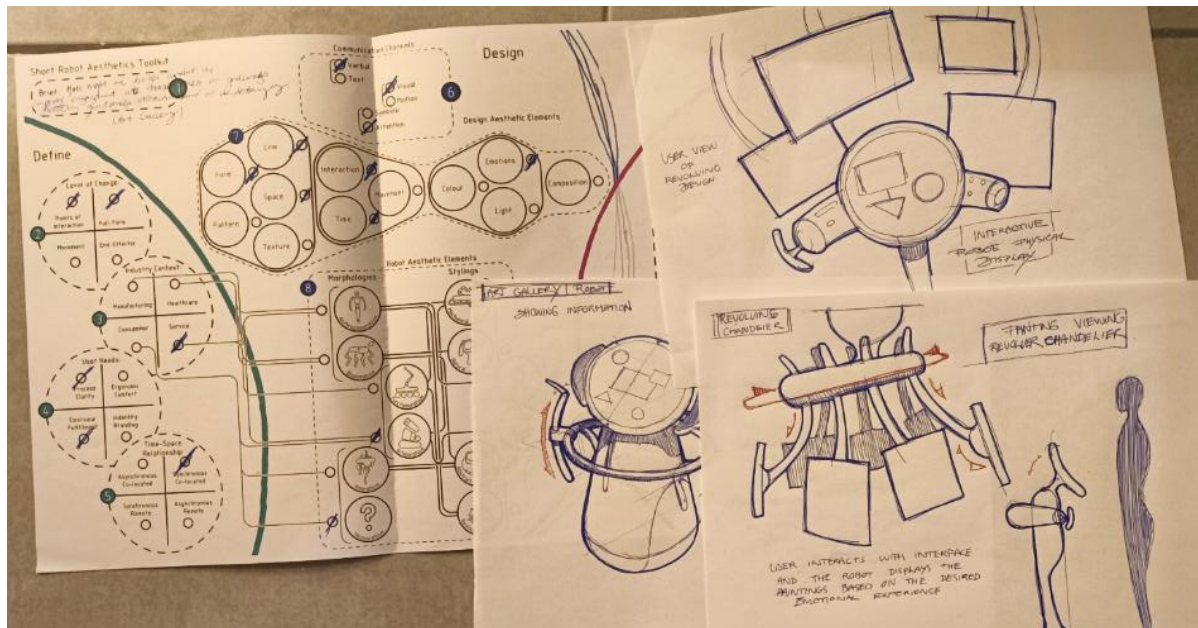


Figure 94 - Short Design Process Used

7.4.2. New Medium Design Process – Technology Museum

The medium design process was also successful, and the added lines and the sizing of the circles helped in guiding the eye through the process. The level of theory incorporated was fitting to the allotted time that it was designed for. The bubbles which are the areas with prompts where the designer notes terms down, works significantly better than in the previous versions. This is because the designer is guided through their own choices rather than restricting them with terms and conceptual diagram structures. See Figure 96 for outputs and Figure 114 for final concepts.

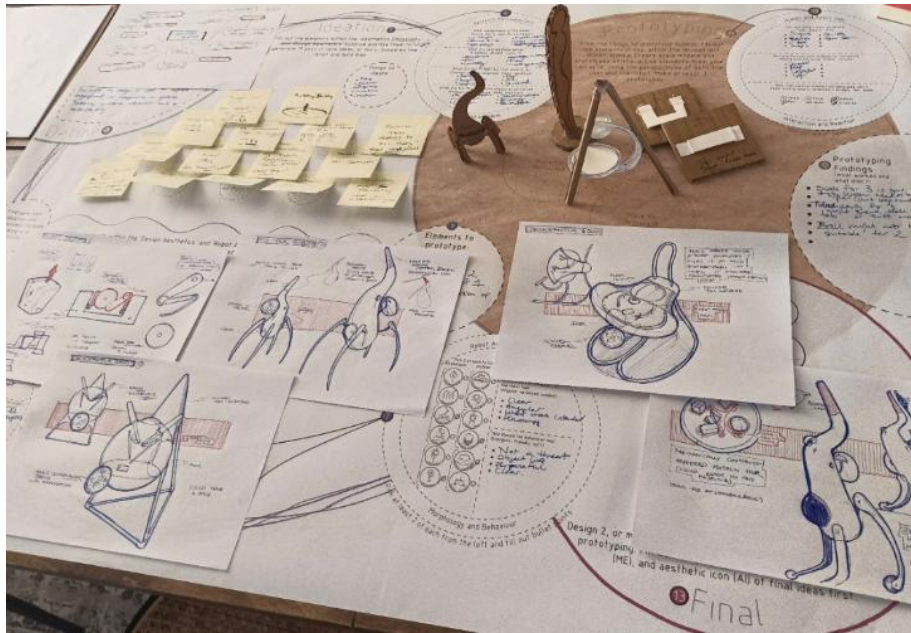


Figure 95 - Medium Design Process Used

7.4.3. New Long Design Process – Digital Physical Art Gallery

The long design process was very fruitful, and it could clearly be made longer with whole days spent on each phase. The detail that can be achieved through it and the varied ways in which the direction can be defined helps in generating more novel concepts. All three processes within the toolkit, are valuable to design robot aesthetics. Although, the idea of an adaptable toolkit could be explored further. See Figure 96 for outputs and Figure 117 for final concepts.



Figure 96 - Long Design Process Used

7.4.4. Conclusion on Designing Robots with the Toolkit

Out of the processes there were preferred designs from all of them (See Figure 97). The designs themselves feel new and creative in some ways. The top left chandelier design in the figure below was created using the short process and moves the painted pieces of art

that are on canvas is an interesting alteration of the traditional art viewing experiences. Where usually it is less personal and more navigational as you walk around and avoid another viewer. It echoes the medieval book wheel where scholar would use it to study multiple texts. In terms of the robotics, it would need sensors to determine the position of the users' head to then move the desired artwork at the appropriate viewing distance and different canvas sizes are used for different viewing distances. The design from the medium process which is more of a performance robot where rather than viewing pieces of technology in a cases. This design is a technological design that deconstructs technology and generated analysis of the object being disassembled in terms of how it works, how it was made, and its significance. Although it might be better to have simple items rather than someone's phone. The last design at the bottom was made with the long process and turn the wearer into part of the art exhibitions and experience for others as well as themselves. It communicates the users' reactions by displaying and broad casting them to other masks where this data is used by the masks to arrive at a consensus of the experience of the work of art.

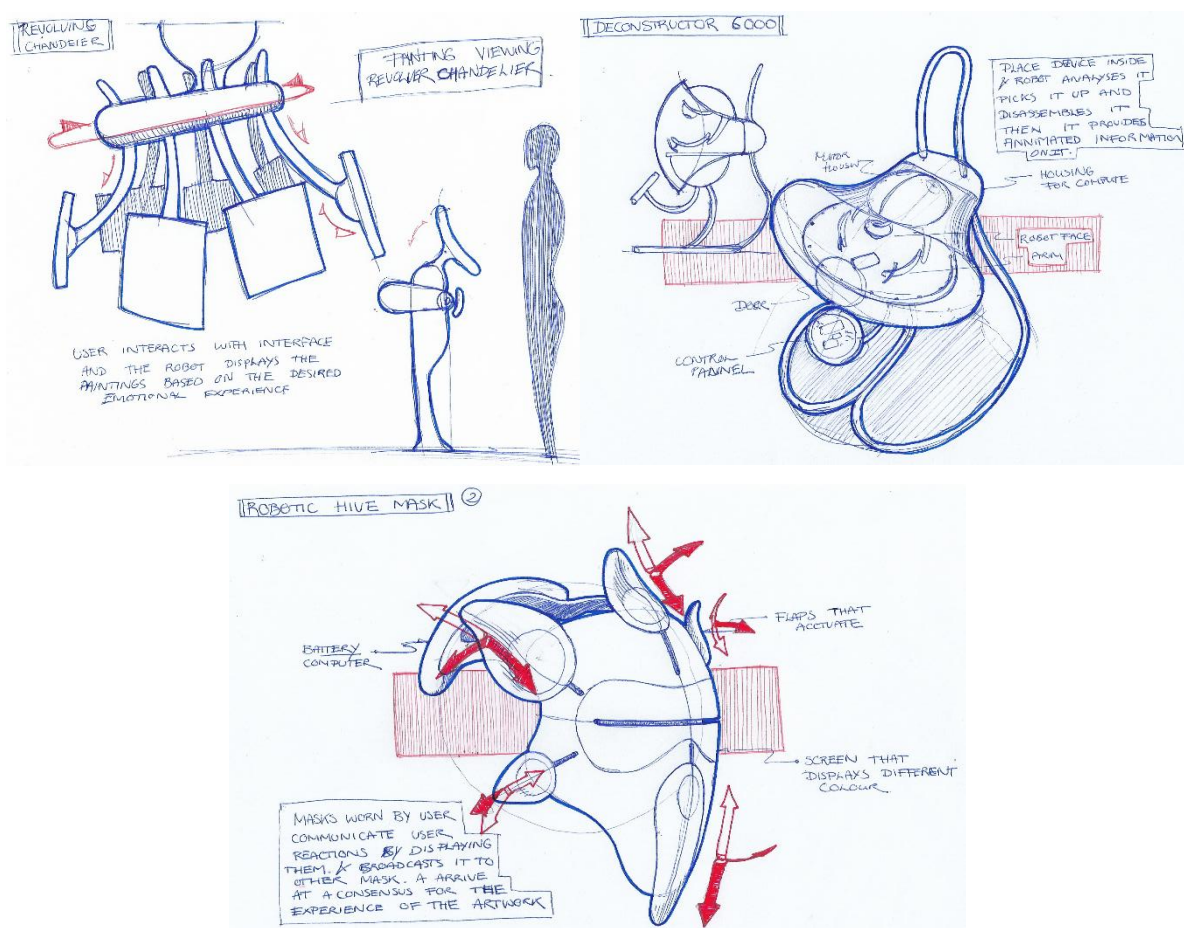


Figure 97 - Preferred Robot Designs

The design processes in the toolkit worked quite well, in terms of allowing for fluid and creative work whilst also giving structure and direction. The level of theory felt

appropriate in all three and seemed like distinct processes that were designed for different users and intents. As said previously the short, medium, and long processes are based off the level of design skill of low, medium, and high respectively. As well as being targeted at roboticists for the short process, design engineers for the medium process, and product designers for the long process. Given the authors' background in product design, design engineering, and robotics it seems appropriate to have the designer of the toolkit use all three processes. Along with this, the desired improvements from the participants in the second study, and the interview, were made to all three and not just the medium one. Although, there is more work that could be done to make a more adaptable and almost meta-design toolkit incorporating different fields and conforming to both the project and the designer. There is more detail of this in the future work section which follows later. This toolkit and the three processes are indeed useful to design robots and their aesthetics.

Chapter 8 – Synthesis, Discussion, Reflection, Contributions, Limitations, Future Work

This chapter synthesises the key insights from the taxonomies, empirical studies, design processes, and toolkit development. It evaluates these contributions in relation to robot aesthetics and human-centred design, and provides a broader discussion of their implications, alongside reflections on limitations and directions for future research. The thesis argues that robot aesthetics should be considered central to robot design practice, rather than a secondary or purely stylistic concern. By developing a taxonomy of robot morphologies and aesthetic categories and translating this into a practical toolkit validated with designers and roboticists, the research demonstrates that aesthetics function as communicative structures that are essential to perception, trust, and meaning making. The synthesis of philosophy, design history, and contemporary robotics shows that concepts such as beauty and the sublime are not merely abstract ideals but lived experiential qualities that shape human–robot interaction. The model of perception developed in this work, from visceral response to interpretive engagement and the reification of meaning, emphasises the layered and dynamic nature of aesthetic experience in robotics. Robots are understood here as cultural artefacts that must be designed not only to function effectively but also to enrich human experience in aesthetic and ethical terms. While this thesis focuses primarily on morphology and styling, future research could extend into areas such as computational design, relational aesthetics, and motion design, thereby broadening the scope of robot aesthetics.

Overall, this work establishes robot aesthetics as a fundamental component of robot design, on equal footing with function and interaction, by demonstrating how morphology, styling, and perceptual experience shape users' interpretation, trust, and acceptance of robots. It provides an integrated theoretical account through a framework of taxonomies, empirical validation, a model of aesthetic experience, and a human-centred design toolkit tested with professional designers and roboticists. Collectively, these contributions reposition robot aesthetics from a peripheral concern to a core determinant of meaningful, trustworthy, and culturally/contextually appropriate robotic designs.

8. Contributions

Contribution 1. A Multi-Domain Taxonomies from Aesthetics to Robot Aesthetics (Theoretical Contribution) (Primary): The framework of taxonomies links aesthetic philosophy, design aesthetics, HRI, and robot aesthetics into a coherent structure for robot design.

Contribution 2. Empirical Validation of Robot Morphologies and Aesthetic Dimensions (Empirical Contribution) (Primary): Empirical validation of six robot morphologies and three bipolar styling dimensions; demonstrates that morphology and styling are independent yet interacting layers.

Contribution 3. A Model of Robot Aesthetic Experience (Theoretical Contribution) (Primary): A model explaining how designers/users construct meaning from form visceral, to analogous (complex), to functional/contextual (settling/referential) reasoning.

Contribution 4. A Human-Centred Robot Aesthetic Design Toolkit (Practical Contribution) (Primary): A tested human-centred toolkit (with skill-level adaptations) that translate theory into method for ideation, exploration, and prototyping across morphologies.

Contribution 5. Establishing Aesthetics as Central to Human-Centred Robotics (Field-Level Contribution) (Secondary): Aesthetic design reframed as central to perception, trust, and acceptance, positioning robots as contextually appropriate artefacts that should enrich human life aesthetically and ethically.

Contribution 6. Methodological Innovation for Studying Robot Aesthetics (Methodological Contribution) (Primary): An integrated LTA-based, sketching analysis, iconic grouping and art-informed methodology for studying robot aesthetics and designer reasoning with replicable procedures.

8.1. Mapping Contributions to Research Questions

RQ1 – What are the taxonomies in the four aesthetic knowledge areas?

Addressed by C1 and C2. The related taxonomy (C1) and empirical validation of morphologies and dimensions (C2) answer RQ1 directly. Which also fulfil Aim 1 which was to identify various robot aesthetic morphologies, dimensions, aesthetic taxonomies in philosophy, design and human-robot interaction.

C1: New taxonomies for aesthetic philosophy, design aesthetics, human-robot relations, and robot aesthetics. Addresses the research question directly although given that these are all active areas of knowledge there is more that can be added to them. For this thesis the taxonomies have sufficient detail. This contribution fulfils all three objectives of creating taxonomical structures of the knowledge areas, create interrelated diagram, and a framework of the taxonomies.

C2: Definitions for morphologies: (six morphological categories) that are empirically proven categories. Is a more detailed answer of one of the taxonomies and given they are morphologies they are more inherently taxonomical. Definition for styling: (three bipolar

dimensions) that weakly couples styling to morphology and allows for greater contextual adaptation.

RQ2 – How do we perceive the aesthetic experience of robot morphologies and dimensions?

Addressed by C2 and C6. The studies validate perceptual categories, and the model explains how meaning is constructed from form. Here C6 contributes to C2 which fulfils Aim 2 of investigating how we perceive the aesthetic experience of the morphologies and dimensions in the context of robotics. As well as the third objective of designing a study to investigate the aesthetic characteristics of robots help achieve C2.

C6: Methodological innovations: LTA and the sketching analysis autopsy and thematic icon grouping for studying robot aesthetics and design aesthetics did not directly answer the research question but were needed to be able to answer it. This along with C2 both answer the research question as they are part of how the aesthetic experience of the robots were quantitatively and qualitatively investigated and then were modified to better represent the findings. This contribution also fulfils the first objective of creating a method of analysis for robot aesthetics and morphologies. As well as the second objective of using art-based methods to explore and extract aesthetics and ideas in the image set and participant results where sketching was a key process in the LTA approach.

RQ3 – How might we design a framework that incorporates these findings to design a robot?

Addressed by C4. The human-centred framework and toolkit use the taxonomy and model in design practice. C4 directly achieves Aim 3 of creating a process for robot aesthetics to aid designers when designing robots and explore their design concepts. As well as all three objectives of designing a process for designers to create new or modified robots, design the flow of its use and this process expressly using the results of the research.

C3: A new perception model: (visceral, to analogous(complex), to functional/cultural (settling/referential)) which shows possible interpretive pathways, was used as well as the other findings to develop the toolkit which is C4.

RQ4 – How do the model and toolkit help professionals design robots?

Addressed by C3 and C4. Toolkit testing with product designers, design engineers, and roboticists demonstrates utility and field-level impact. Where C4 also contributes to the second object of RQ3 to design a process.

C4: A new method (toolkit): which moves aesthetics to the start in the process with practical phases and steps. For C4 to be properly developed it was tested through key design activities and interviewing key participant groups. Apply modification and finalising the process

which are all respectively Aim 4 and all three objectives. C3 both contributed to the research question as they are the output and were apart of how it was evaluated.

With regards to C5 although it does not address a question directly the thesis does show the importance of aesthetics when applied to robot design and show that it should become more central, in particularly when designers are solving on human problems.

The contributions are scoped to form, styling, and perception rather than detailed mechatronics (e.g., joint design or kinematics), and most empirical work leverages image-based and art-based methods rather than extended in-situ robot deployments. These boundaries are acknowledged in the thesis and inform the recommendations for future work. Together, these contributions deliver conceptual clarity, empirical evidence, methodological tools, and practical guidance for designing robots whos' forms and behaviours are intelligible, trustworthy, and contextually situated, advancing the emerging field of robot aesthetics and supporting a truly human-centred robotics practice.

8.2. Synthesis

This section integrates the thesis's theoretical foundations, empirical findings, and design interventions into a single, of how and what was used to create the toolkit and the impact it had. It explains how the taxonomies motivate the studies, how the results refine the theory, and how the combined insights are used in the framework and toolkit. The goal was how to the better apply robot aesthetics, morphologies and styling into a design process to create more human centric robot designs. The literature synthesis established four complementary knowledge structures:

- **Aesthetic Philosophy:** Beauty, taste/judgement, aesthetic properties and experience (aesthetic object; affordances; Gestalt; affectivism vs. perceptualism). These define what can be experienced as aesthetic and how meaning is perceived.
- **Design Aesthetics:** Product semantics, interaction aesthetics, and the practical elements (form, movement, colour, texture, light, space, time, composition) through which ideas are embodied and communicated.
- **Humans and Robots:** Historical/cultural framing, collaboration modes, communication channels and cues, and the role of morphology in shared workspaces. These situate aesthetic judgement within real interaction contexts.
- **Robot Aesthetics:** The field-specific taxonomy that links morphology, styling themes, and kinetic/material cues to perception, emotion, and acceptance.

The synthesis of these pillars yields a multi-level structure for robot design: **Abstract** (conceptual/ethical grounds), **Analytical** (morphology and aesthetic dimensions), and

Practical (materials, motion, form giving elements). This structure is what later enabled the framework and toolkit to be designed and useful.

The empirical studies tested whether the proposed types of stylings and morphologies corresponded to what observers perceive:

- **Morphologies:** Participants converged on a set of aesthetic morphologies (e.g., anthropomorphism, biomorphism, functionism, artismorphism, amorphism; neomorphism).
- **Styling dimensions:** Perception of styling varied along three bipolar axes: Natural - Mechanical, Familiar - Strange, Abstract – Realistic.

The studies show that morphology functions as a semantic anchor, while styling acts as an independent, affective layer. This independence expands the design space as the same morphology can be styled differently to suit context and culture without losing identity. Across sessions, designers' reasoning followed a layered path from visceral reasoning to analogous(complex) reasoning, to functional/contextual (settling/referential) reasoning. This was formalised as a model of robot aesthetic experience. This model explains why professionals with different backgrounds can still reach stable interpretations and how aesthetic cues steer expectations of competence, intent, and safety. Perception broke down when motion cues contradicted appearance which was a source of uncanniness that was not related to an anthropomorphic face. Ensuring congruence between how a robot looks and how it moves is therefore a primary aesthetic principle in HRI contexts.

The synthesis positions aesthetics as central to human-centred robotics, as it directly shapes perception, trust, acceptance, and contextual appropriateness, factors that ultimately influence whether robots are adopted or ignored in real-world contexts. This reframing challenges the long-standing tendency to treat form as secondary to function, or to reduce design primarily to anthropomorphic imitation. Furthermore, the field's reliance on a limited set of dominant robot forms, particularly the repeated use of a single cobot morphology in research and practice, has contributed to both theoretical and morphological stagnation. This thesis seeks to interrupt that cycle by introducing validated alternatives and actionable stylistic variables, enabling design exploration beyond the prevailing "UR arm" paradigm. The framework and toolkit translate the abstract–analytical–practical structure, along with the model of aesthetic experience, into repeatable design actions across the stages of definition, ideation, development, prototyping, and finalisation. Adaptations for different skill levels (low, medium, and high) ensure accessibility for product designers, design engineers, and roboticists.

The toolkit enables:

- **Intentional morphology and styling pairing**, where designers select a morphology and then systematically adjust styling along key dimensions to suit context, culture, and use case.
- **Contextually sensitive outcomes**, since styling operates independently, allowing a single robotic concept to be adapted for different markets without redesigning its core form.
- **A shared language for design reasoning**, as the taxonomy and aesthetic dimensions provide a common vocabulary for cross-disciplinary teams to communicate, evaluate, and iterate more effectively.

Together, these resolve the central problem identified in the introduction where robot design has prioritized function and anthropomorphism while lacking a human-centred account of aesthetic meaning and practical means to design it. The implications of this are for research, future HRI studies should manipulate both morphology and styling systematically and evaluate movement and form congruence as a variable alongside task performance and safety. For practice, teams can treat morphology as a semantic frame and styling as an affective medium, enabling variety without re-engineering core systems. For education, the taxonomy and toolkit offer a shared foundation for teaching robot design as a distinct specialism in industrial design.

This thesis synthesises aesthetic theory, design practice, and HRI into a single toolkit that: structures robot aesthetics (taxonomies, and their framework), validates its perceptual components (morphologies and dimensions), explains meaning-making (experience model), and uses them in design (toolkit). In doing so, it establishes aesthetics as a core element of human-centred robotics and how to achieve it.

8.3. Discussion of Contributions

Contribution 1. A Multi-Domain Taxonomies from Aesthetics to Robot Aesthetics (Theoretical Contribution): The thesis synthesises four domains, Aesthetic Philosophy, Design Aesthetics, Human–Robot Relations, and Robot Aesthetics, into a coherent, layered taxonomy that explains how aesthetic properties emerge, are perceived, and can be intentionally shaped within robotic artefacts. This structure links conceptual foundations (such as beauty, taste, and experience), analytical perspectives (including product semantics and interaction aesthetics), and practical design elements (such as form, movement, colour, texture, light, space, time, and composition) to concrete robot design decisions. Its significance lies in bridging philosophical, design, and human–robot interaction perspectives to provide a shared framework for understanding robot aesthetics. In doing so, it enables researchers and practitioners to reason about robot form and meaning in a more structured

way, moving beyond ad hoc interpretations and purely anthropomorphic assumptions. Theoretically, the development of the taxonomies contributes to design research by clarifying the abstract structure of the different domains involved in the study. It helps to formalise how concepts within these fields are organised and related. Practically, the continued usefulness and evolution of these taxonomies depend on the establishment of a shared taxonomical visual framework across the respective fields. This also highlights the need for a clearer and more consistent visual language to communicate the relationships represented within these diagrams. Methodologically, the taxonomies were developed through a systematic mapping of the relevant literature, grouping sources according to conceptual relationships. This produced map-based structures that reflect the underlying organisation of ideas within each field, rather than imposing an externally defined or arbitrary framework.

However, to ensure long-term relevance, these taxonomies should be understood as dynamic theory maps rather than fixed representations. A peer-review mechanism could be introduced to allow researchers to submit new contributions for evaluation and potential integration. In this way, the taxonomies could evolve alongside the field, with periodic updates informed by ongoing literature and research developments.

Contribution 2. Empirical Validation of Robot Morphologies and Aesthetic

Dimensions (Empirical Contribution): Through a multimethod programme, image-sorting studies, art-based sketching, and a combined Linkographic + Thematic Analysis (LTA), that the thesis empirically validates:

- **Six aesthetic morphologies** (e.g., anthropomorphism, biomorphism, functiomorphism, artiomorphism, amorphism; with neomorphism)
- **Three bipolar styling dimensions** (Natural - Mechanical, Familiar - Strange, Abstract - Realistic).

This contributions tests and integrated the various categories published by authors such as DiSalvo and Gemperle (2003), Hanson (2006), Bartneck and Forlizzi (2004), Fong et al. (2003). Where now the different categories are well defined and have less conceptual ambiguity. With the findings answering Hanson's (2006) question of developing aesthetics principles of robot aesthesis. The key findings are that morphology and styling are weakly coupled but interacting layers: morphology provides a semantic anchor while styling modulates affect, expanding design flexibility. Theoretically, the empirical validation of the morphologies and stylings appears robust, supported by the large number of robot images used and the careful, incremental refinement of morphological categories. These categories were tested in relation to one another rather than in isolation, demonstrating that they are meaningfully represented in participants' perceptual responses. Practically, image-based

evaluation was the only feasible method for testing approximately 100 designs within a reasonable timeframe, and it aligns with established approaches in similar studies. However, images are inherently less immersive than real-world objects and therefore tend to elicit less vivid or embodied responses. This raises the question of whether alternative methods, such as virtual reality, Wizard-of-Oz techniques, or simple animatronic prototypes, could serve as more effective and cost-efficient surrogates for evaluating robotic perception in more realistic conditions. Methodologically, the controlled study design was appropriate and introduced useful innovations, such as the use of a grounding shape behind each robot and a black matte background to focus attention on the stimulus. Nevertheless, the influence of environmental context and the potential value of more structured aesthetic control mechanisms to guide visual attention remain underexplored areas in aesthetic robotics research.

Contribution 3. A Model of Robot Aesthetic Experience (Theoretical

Contribution): The thesis proposes a model of aesthetic experience that explains how designers (and by extension, users) construct meaning from robotic form via a layered process of visceral reasoning, to analogous (complex) reasoning, to functional/contextual (settling/referential) reasoning. This model clarifies why different stakeholders converge or diverge in their interpretations and how aesthetic cues guide expectations of capability and intent. Theoretically, this contribution is less substantial than the previous two, as it broadly aligns with Norman's (2003) model. Along with Lehar (2003) view of reification although in this sense it is a reification of meaning instead of a visual one. However, the findings offer slightly differentiated insights due to the inherently ambiguous nature of robots at first perception. It is possible that this perceptual pattern is particularly relevant in contexts where users encounter novel, unfamiliar, or poorly defined artefacts. Practically, this suggests a need for further research to clarify how perceptual experiences vary across different object typologies. While Norman's model provides a general framework, more specific models have yet to be developed for distinct design categories, perceptual states, or interaction experiences. Understanding these differences may help refine how users interpret emerging technologies such as robots. Methodologically, this stage enabled the interpretation of participant "moves" and decision patterns across the dataset, providing a structure that can now be empirically replicated and further validated in future studies.

Contribution 4. A Human-Centred Robot Aesthetic Design Framework and

Toolkit (Practical Contribution): Building on the taxonomy and model, the thesis develops a practical framework and toolkit that translates theory into repeatable methods for ideation, exploration, and prototyping. The toolkit was tested with product designers, design engineers, and roboticists, and includes skill adaptation, enabling teams with diverse expertise to work coherently with morphology and styling choices. The outcomes here are

that the toolkit helps teams: Firstly, make intentional morphology and styling decisions early. Secondly, maintains movement and form congruence to avoid uncanny cues. Thirdly, achieve contextually sensitive, aesthetically coherent robot outcomes within varied briefs. Theoretically, the integration of the underlying theory into the toolkit was successful, and the resulting structure appears sufficiently robust to be adapted for use in other domains. Practically, post-interview refinements were relatively straightforward, further indicating that the toolkit can be transferred beyond robotics. However, such adaptation would still need to be supported by a corresponding taxonomical framework and an appropriate literature review to ensure domain relevance and validity. Methodologically, the structure of the project supports greater flexibility and encourages methodological creativity. Its modular design makes it relatively easy to adapt, while also promoting engagement in external exploratory activities by designers as part of the process.

Contribution 5. Establishing Aesthetics as Central to Human-Centred Robotics

(Field-Level Contribution): The thesis reframes aesthetics as central to perception, trust, and acceptance in robotics, arguing that robots should be designed as cultural artefacts that enrich human life aesthetically and ethically, not merely as functional machines. This re-positioning is supported theoretically and applied through the framework and toolkit. Theoretically, this position is less commonly adopted in robot aesthetics research, as studies such as Green et al. (2008) often assume anthropomorphic forms as the primary or most appropriate basis for evaluation. This tendency may stem from practical constraints within experimental design. However, adopting a broader aesthetic perspective moves beyond the default assumption of anthropomorphism and enables a wider range of designs, research approaches, and investigative questions. Practically, this shift encourages more exploratory and creative approaches to robot design and evaluation, rather than relying predominantly on cognitive science frameworks or anthropocentric assumptions. Methodologically, it suggests a need for greater involvement of creatively oriented researchers in the design of studies and research artefacts. Increased sensitivity to design and aesthetic considerations can enhance both the quality and variety of insights generated, leading to more varied and meaningful contributions to knowledge.

Contribution 6. Methodological Innovation for Studying Robot Aesthetics

(Methodological Contribution): The research adapts and combines Linkography with Thematic Analysis (LTA), integrated with image-sorting with sketch analysis autopsy and thematic icon grouping and art-based methods, and complements qualitative interpretation with structured coding and ICA, offering a replicable pathway to study aesthetic judgement and designer reasoning in robotics. Theoretically, the novel methodology is a rather eclectic combination of approaches to the research questions and does provide a few new methods

that evolve and augment the research. Practically, the approaches are rigorous enough to be repeated by other researchers, and the sketching method is a rigorous way of developing visual icons which are derived from quantitative participant data. Methodologically, the sketching method, LTA, and the first study are the clearest methodological contribution, as they are novel methods that both add new approaches to qualitative and quantitative data collections and analysis.

8.4. Reflections

There appears to be a significant opportunity to apply more creative design methods and innovation within design research. While the reliance on social science methods is understandable, industrial and product design inherently focus on developing new objects and technological artefacts. It seems remiss not to create novel tools specifically for designers and design researchers. In other research fields, scholars often develop or sell specialised equipment to facilitate experimentation and data collection. In contrast, design training emphasises invention, innovation, and creativity, suggesting that design researchers could maintain libraries of unconventional objects to explore research questions, gather data, and enable new approaches to design.

Although researchers often work with their own prototypes, academic departments and publications rarely focus on building object libraries or developing novel artefacts solely for research purposes. While this thesis contributes new knowledge and methods, as is the expectation for a PhD, designing new objects could also constitute a valid avenue for evaluation within a Design PhD. By creating an object based on deep, complex understanding, and should be considered as challenging and legitimate as developing new knowledge from prior work. The use of a multimethodology approach resulted in the generation of useful knowledge from the qualitative and quantitative methods used. These were image sorting, sketching, LTA, interviews, and design study. The strengths are that the studies use multiple methods to capture many avenues of data, which in part managed to capture the complexity of the phenomena and support the theories concerning them.

Although the sample size is sufficient for all aspects, it would have been more useful to have more volunteers for the second study and the interviews. Although this was simply determined by how many responded. Unfortunately, individuals who were part of research institutes and robotic companies did not respond to requests for interview. Only practicing designers responded which does limit the interview to an individual's perception instead of someone who has to contemplate whether or not this should be integrated into an organisation. The author aimed to maintain an unbiased stance during data interpretation, driven primarily by curiosity about the subject matter. The focus was on the broader, abstract structures emerging from the literature and studies, rather than on the fine-grained detail of

individual participant responses. In designing the toolkit, creativity and flexibility were prioritising. Robot design is often a technically demanding field, and this can introduce pressure that constrains creative thinking. From authors' experience in robot design and system integration, the author observed that designers who feel uncertain, whether due to limited technical or design expertise, tend to default to familiar or "safe" solutions in order to reduce cognitive load and avoid stress when working in unfamiliar contexts.

For this reason, the toolkit was intentionally designed to feel engaging, fluid, and non-linear, encouraging experimentation and exploratory thinking rather than rigid procedural execution. The intention was to create space for designers to "play" with ideas and explore alternatives more freely. This approach was intended to improve the design experience and, in turn, support better outcomes, including more effective solutions to design problems, stronger alignment with user needs and desires, and the potential for more innovative robotic designs. During the toolkit development, the authors' familiarity with industrial and product design made it feel natural to build physical scale models of the process pages and to prototype the system iteratively. This hands-on approach supported ideation and refinement and helped avoid becoming overly focused on digital refinements that might ultimately have been discarded. The toolkit and associated studies evolved through repeated cycles of iteration, informal testing, and more structured evaluation, gradually converging on a more robust final design. This process also enabled the collection of data about both the toolkit itself and the broader research aims. The final version effectively integrates robot theory into a practical design process, supporting designers in producing more aesthetically informed solutions.

However, in the second study the author initially assumed that the simplified taxonomies, represented as "bubbles", would be intuitive and easily understood by other designers. This proved not to be the case, which required them to be reinterpreted into clearer questions, prompts, and selection structures. The assumption that visual simplification and reduced terminology would aid comprehension was incorrect, and participants instead found the format unfamiliar or unclear. This revealed a mismatch between my own familiarity with the more nuanced aesthetic, design, HRI, and robotics terminology, developed through the literature review and taxonomy construction, and the perspective of other designers. The author was also reluctant to oversimplify the "bubbles," as this felt like a loss of fidelity to the underlying work. Now that the process is complete, the author feels more capable of engaging with complex, ambitious, or ambiguous design problems. The author has developed a clearer understanding of how knowledge is structured and how it can be translated into pathways for generating new knowledge, which has strengthened the authors' design ability through undertaking this PhD-level research. In

reflecting on automation design as a field, it appears to be emerging from industrial design in response to industrial, social, and technological pressures that are collectively driving significant change. This creates an important opportunity for both design practice and research. It has also encouraged the author to pursue more distinctive design research methods and perspectives, rather than relying heavily on approaches borrowed from other disciplines, which can dilute the specific contribution of design research.

Going forward, the author will approach similar research projects with a stronger emphasis on creative exploration, while still maintaining clear methods for evaluating outcomes. Also structuring future work more explicitly as a design-led research process, rather than treating it primarily as a conventional long-term academic study, as this one initially was.

8.5. Implications

From Philosophy to Practice: By integrating foundations from aesthetic philosophy (beauty, taste, aesthetic experience), design aesthetics (product semantics, interaction aesthetics, emotional design), and HRI (communication channels, social cues, workspace relations), the taxonomies yield a structure that is simultaneously abstract, analytical, and practical. This enables designers to navigate from high-level ideas to concrete decisions about form, movement, material, and interaction. The implications are that the structure discourages defaulting to humanoid mimicry and instead supports context appropriate morphologies and stylings that better align with user needs, and context.

Weak Coupling Morphology and Styling: The empirical finding that morphology and styling are decoupled yet interacting unlocks design bandwidth as teams can anchor a concept in a robust morphology while exploring alternative stylings (e.g., natural vs mechanical; abstract vs realistic) to tune perception, trust, and clarity without undermining meaning. This counters the assumption that morphology dictates a narrow set of permissible stylings.

A Model for Interpreting Aesthetic Judgement: The proposed model organises aesthetic judgement as a layered process: visceral, to analogous(complex), to functional/contextual (settling/referential). providing a vocabulary to analyse why different stakeholders “read” the same robot differently and how to design for convergence where needed (e.g., in safety-critical co-bot contexts).

A Toolkit for Robot Aesthetic Design: The toolkit uses the taxonomy and model in workshop-ready methods and prompts, adaptable to low/medium/high skill levels, and validated with product designers, design engineers, and roboticists. Designers reported that

it supports shared understanding, earlier aesthetic reflection, and better movement and form congruence, reducing the risk of uncanny or misleading cues.

Reframing the Field towards Automation Design: By placing aesthetics at the centre of human-centred robotics, the thesis argues for robots that embody beauty, meaning, and ethical presence, not ornamental attachments but integrated aesthetic and functional artefacts. This shift aligns with broader human-centred trajectories in Industry 5.0 and positions robot aesthetics as a strategic lever for adoption. Along with adding to a growing body of knowledge that is forming into a new field from industrial design to become a separate one that could be termed automation design. This is akin to how automotive design emerged from industrial due to industrial, social, and technological pressures.

Ethical Implications: A few ethical concerns emerge from the possible application of the framework in industry. The first concern is that rapid iteration of robot design could create a desire to develop ‘fast robots’ akin to ‘fast fashion’. As the framework is to help in the facilitating the robot design process could make designers develop robots that seek to profit off short term trends. Where the robot is designed to only last as long as the trend will last. The second concern is that there is a lack of cultural analysis in the framework. Although, it does consider the context and the effect of the object and the user. From this, cultural elements can be inferred from, but there is no explicit process of immersion or bracketing. Such processes would help in identifying biases and allow for the open exploration of the culture the object would be in, as well as help during the reflective processes. Yet, these more anthropological and philosophical methods are generally less common in design practice.

8.6. Limitations

The studies were conducted using images and design-based processes, which means that responses to fully embodied physical robots, as well as the practical challenges of implementing aesthetically driven robot designs, could not be fully captured. Methodologically, the reliance on images and simulated design activities limited the ability to examine real-world interaction, including movement, behaviour, and tactile qualities, all of which are important aspects of robot aesthetics. While the toolkit enabled participants to engage with form, style, and conceptual aspects of aesthetics, the absence of physical robots restricted understanding of how these designs would be experienced in real environments. Theoretically, the research focuses primarily on morphology, styling, and aesthetic categorisation. This necessarily narrows the scope of the conclusions to visual and conceptual dimensions of robot design. As a result, aspects such as motion, behaviour, and relational aesthetics fall outside the study’s scope, which may limit the extent to which the findings can be generalised to full human–robot interaction contexts. Practically, it was not

feasible to present participants with a large number of physical robot prototypes. Although evaluating 100 physical robots in a controlled environment would have been ideal, logistical constraints and participant fatigue made this approach impractical. Using image-based cards was therefore the most viable solution. This approach also supported focused evaluation, aided by design choices such as grounding shapes behind each robot and a dark matte surface, which helped visually isolate each design and improve clarity during assessment.

8.7. Future Work

This section explores the possibilities now made clearer due to the work in this thesis. Firstly, the work that other researchers could conduct will be outlined and discussed and then the author.

For future work for other researchers, more detailed research is needed into each morphology, as well as into each end of the bipolar styling dimensions. Both morphologies and styling dimensions likely contain definable sub-categories, which together could form a highly differentiated and “kaleidoscopic” set of relationships between aesthetic types. This also highlights the importance of understanding transition states, how one morphology shifts into another, as well as how movement occurs along bipolar styling dimensions and between different stylistic axes. Although movement was not included in the studies, there is a clear need to develop a qualitative taxonomy of robotic motion. Since movement is embedded in the three design processes used in this research, it would be valuable to be able to describe, analyse, and communicate robotic movement in both technical and aesthetic terms. There is also a need for methods that allow movement to be explored and prototyped quickly and creatively. One potential direction is to build on Gemeinboeck (2021), who combined card-based design methods with dance-based exploration. Current research into human–robot interaction often focuses on forms of interaction that resemble human–human communication. However, interaction styles that are unique to human–robot relationships appear to be less well explored. This may be due to the dominance of anthropomorphic assumptions and the tendency to design robots that mimic human behaviour. As a result, similarities have been prioritised over differences, even though these differences may offer more significant opportunities for design, engineering, and research innovation. There has also been a strong research focus on the “uncanny valley,” particularly in terms of avoiding negative responses. However, deliberately designing for discomfort, repulsion, or strangeness, as well as attraction or beauty, may offer valuable insights into how aesthetic responses are formed. In this sense, intentionally creating repulsive or unsettling artefacts could be more informative than simply analysing existing unpleasant examples. The same principle can be extended to attractive and beautiful forms. More broadly, these concepts could be further developed by examining repulsive and attractive qualities as abstract

aesthetic dimensions rather than fixed categories. The term “uncanny valley” is a form of meaning incongruence between design elements and some being beautiful is a form of congruence. Therefore, it might be more fruitful to term these phenomena in a broad sense as ‘congruence’ and ‘incongruence’ as it would enable their identification in different phenomenon.

For future work for the author, the toolkit could involve the development of software that generates a tailored design process based on user input. Designers could specify their level of experience, project brief, and available time, after which the system would assemble a customised sequence of toolkit components suited to their skill level and working preferences. This output could be printed or used digitally as required. The system could also adapt to different cognitive or working styles, helping to avoid situations where designers are required to follow a process that is misaligned with their strengths. This could be implemented through modular, attachable digital components with defined functions, enabling a system to generate an integrated workflow based on user parameters. In addition, if taxonomies for other domains were developed, the toolkit could potentially be extended to support design beyond robotics. A related direction for future research is the development of dedicated design software that enables rapid exploration of robot morphologies, conceptually similar to the game *Spore*. Such a tool would allow designers to quickly construct and iterate different robot forms by selecting and arranging mechanisms, while simultaneously visualising the resulting functional and aesthetic consequences. For example, robot movement could automatically update based on limb configuration, end-effector placement, and overall morphology, enabling real-time evaluation of both aesthetic and functional outcomes. This would significantly accelerate the design process by allowing rapid generation of multiple variants, reducing reliance on slow physical prototyping cycles. Further work is also needed to improve tools for analysing sketching processes, particularly by refining approaches such as Sketching Analysis Autopsy and Thematic Icon Grouping. These methods could be developed further to better capture sketching not only as an ideation tool, but also as a form of reasoning, explanation, and communication. The findings from the sketching study suggest that current methods may interfere with natural creative flow, as requiring participants to structure or categorise their ideas during generation can introduce cognitive disruption and reduce exploratory thinking.

Within robot aesthetic research more broadly, there is also a lack of clearly defined experimental controls when investigating specific aspects of human–robot interaction. Establishing aesthetic baselines for robot studies could help address this issue by ensuring that participants are responding to comparable and well-defined stimuli. While the diversity of existing designs and experimental approaches is valuable and should be preserved,

introducing more consistent controls would help clarify findings and enable more fine-grained investigation of specific research questions.

Another promising avenue for future work is the integration of computational design tools that optimise aesthetic properties while maintaining or enhancing mechanical performance. Such systems could be embedded within robot design software to support the automatic generation of compliant mechanisms, such as joints, directly from morphological inputs. For instance, Xu et al. (2018) (Figure 98) demonstrate a method for computing joint designs for animatronic morphologies and kinetic wire structures, producing elastically deforming wire forms fabricated via CNC wire-forming processes. In their approach, motion was derived from designer-defined keyframes and then optimised computationally to achieve the desired kinetic outcomes, illustrating how aesthetic and functional design can be jointly resolved through computational methods.



Figure 98 – Computational Wire Joint Designs (Xu et al., 2018)

Similarly, Megaro et al. (2017) developed a computational design tool for compliant mechanisms where conventional joint designs were automatically replaced with parameterised flexures (Figure 99). Motion animation can also be optimised for wire joints, eliminating unwanted vibrations while preserving the intended motion, as demonstrated by Hoshyari et al. (2019).



Figure 99 – Parameterized Flexible Joints (Hoshyari et al., 2019)

Computational design can also extend to modular robotic devices, where high-level motion specifications combined with libraries of actuators, mounting brackets, and connectors can generate diverse morphologies (Ha et al., 2018) (Figure 100).



Figure 100 - Computational Morphologies (Ha et al., 2018)

Even sheet materials can be mechanically characterised computationally, enabling exploration within an aesthetic–mechanical design space (Schumacher et al., 2018) (Figure 101). These examples demonstrate how computational tools can support aesthetic and functional design simultaneously, enabling rapid generation of complex, novel robotic forms. By integrating libraries of technical components that can be fabricated with 3D printing or CNC machines, such approaches could expand robot design, making it more accessible to individual designers and small teams, rather than limiting innovation to large corporations or standardised morphologies.

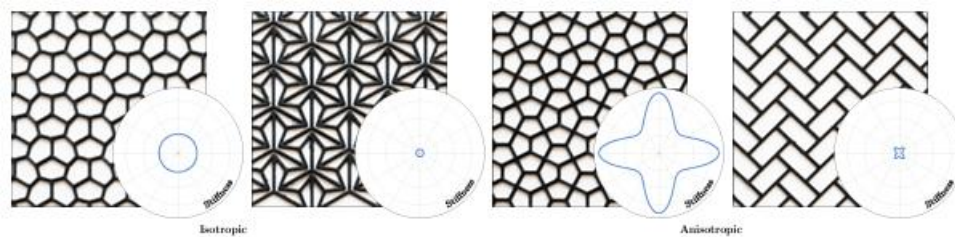


Figure 101 - Computational Aesthetic and Mechanical Characterization (Schumacher et al., 2018)

Another promising avenue for future work is the implementation of art-based and relational design tools. While robot design necessarily involves technical constraints, there is considerable creative potential in techniques such as the Wizard of Oz method, motion prototyping, and relational design exercises using simple materials like cards or wood. This approach encourages thinking about robots in the spirit of early cybernetics and the “mangle” of practice described by Ross Ashby (Pickering, 2002), prioritizing experimentation with strange and unconventional devices rather than aiming for polished, anthropomorphic forms like those depicted in films such as *I, Robot*. Such practices enable designers to explore the abstract human and relational dimensions of robotic systems, not just technical aspects like path planning or control. At the conceptual level, aesthetic principles can function as guiding frameworks for achieving coherence and perceptual quality in technological design. This includes considerations such as composition, unity, and the embodiment of core design intent, without relying on overly rigid or prescriptive systems that might constrain creativity in the manner of classical interpretations of Platonic aesthetics.

Simple, low-cost methods such as compositional sketch analysis, where major forms and key structural lines are identified through tracing or selective blurring, can be used early in the design process to quickly evaluate form and proportion. Similarly, rapid sculptural approaches using foam, clay, or kit-bashed components allow designers to explore morphological ideas directly in three dimensions. These methods emphasise immediacy, experimentation, and creative freedom, temporarily setting aside detailed technical constraints in favour of exploratory thinking. Such approaches are inexpensive, accessible, and highly iterative. Foam and clay prototypes can reveal spatial relationships, affordances, and visual dynamics that are difficult to perceive in two-dimensional sketches. Kit-bashing, which involves assembling components from diverse sources, encourages unexpected combinations and the emergence of novel morphologies, aligning with experimental traditions in cybernetics and speculative design. By embedding aesthetic reflection into early-stage prototyping, these methods ensure that considerations of beauty, meaning, and human experience are integrated alongside functional requirements. When combined with sketching and reflective design journaling, they could provide a strong complement to more formalised robotics design processes. Future work could also revisit the taxonomy diagrams developed in this thesis. One possibility is the creation of a dynamic, peer-reviewed taxonomy system that allows users to “zoom in” on specific elements, revealing increasingly detailed sub-diagrams. This would create a fractal or Mandelbrot-like structure capable of mapping complex relationships within design knowledge. Such a system could help consolidate dispersed knowledge, represent contested areas of theory, and visualise different philosophical positions or evidential bases. In this sense, the taxonomy would function as an interactive research map, making the complexity of design research both navigable and explorable.

These directions, morphology-focused generative software, art-based rapid prototyping methods, and interactive fractal taxonomies, could collectively support a more strongly aesthetic-driven approach to robotics. Computational tools would enable rapid iteration of complete robotic forms, while art-based methods would accelerate exploration of motion, interaction, and material expression. A fractal taxonomy of design knowledge could integrate research insights, highlight gaps, and reveal areas of creative opportunity. Collectively, these developments could help establish robot design as a distinct subfield of industrial design, comparable to automotive design, where artistic, technical, and human values converge. In this vision, robots are understood as cultural artefacts that contribute to everyday life through aesthetic quality, meaning, and ethical presence. Achieving this trajectory would likely require a comprehensive synthesis of robot design principles, methods, and values, which would consolidate the field and reinforcing its status as a mature and distinct area of design practice.

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Appendix A – Pilot Study Iteration

9. Study V1

- Image Set Evaluation Only.
- Defined Categories.
- One Set. (Set 1)
- Researcher does Analysis of Set.

9.1. Notes on study structure:

This study applied the theory comprehensively, resulting in a more controlled setup for interpreting participant responses (Figure 102). Participant 1 spent considerable time deliberating on card placement within the morphological categories and interpreting the meaning of the terms, rather than developing an intuitive sense of them. In contrast, Participant 2 was more comfortable with the terminology, likely due to prior experience with robotics. Differences in how participants marked the cards, along with some hesitation or confusion over the morphological categories, highlighted the need for clearer guidance in future iterations.

Using the theoretical framework facilitated the creation of an intensity map of aesthetic and morphological evaluations. When combined with researcher notes, this allowed for integration of quantitative and qualitative results. However, the lack of space for participants to annotate or sketch on the cards limited the capture of their visual thinking. Evaluating 25 images within 30 minutes proved feasible, though slightly more time per participant might improve depth of analysis. Enlarging the theory diagrams would also aid comprehension. Pre-analysing the image set using the theory provided a useful primer and helped contrast my thinking with that of participants, although doing so for all 25 images felt somewhat redundant.

9.2. Notes on study results:

- Chaos and abstract were often linked, as participants associated these categories with ambiguity in the design's function, clarity, morphology, or overall complexity.
- The use of morphological categories and dimensions offered a clearer understanding of which aesthetic and morphological elements led to particular interpretations.
- Familiarity was interpreted subjectively, reflecting participants' personal experiences rather than objective similarity to known designs.
- Participant 2 demonstrated the clearest understanding of the neomorphic category compared to others, suggesting prior exposure or familiarity with robotic terminology influenced comprehension.

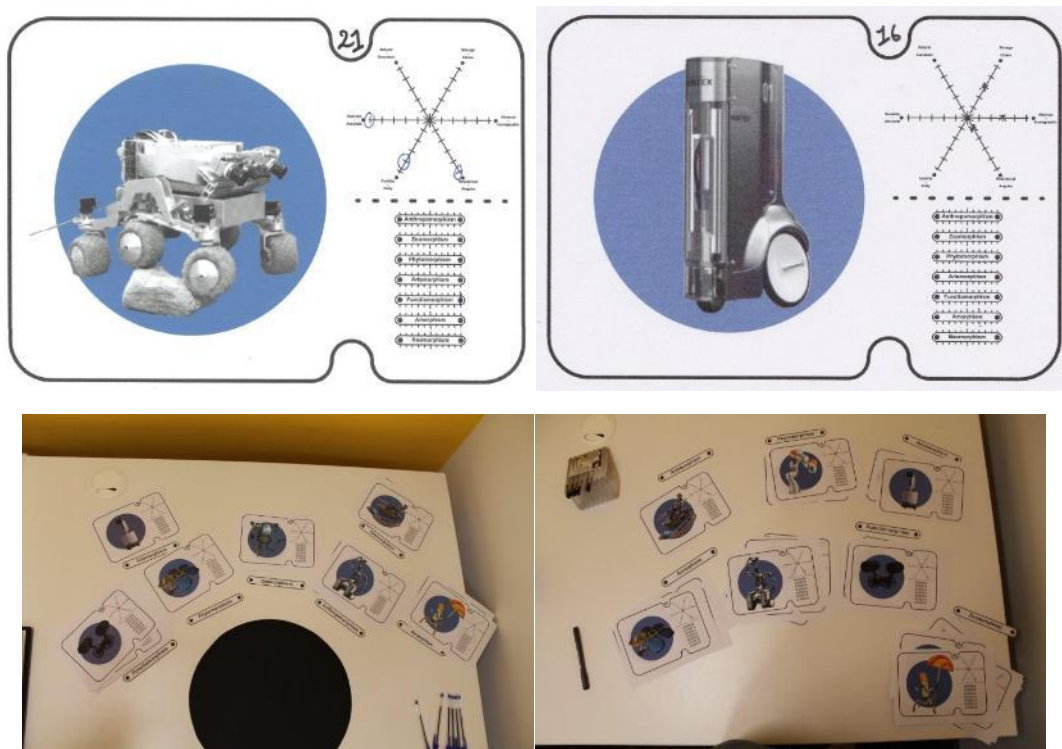


Figure 102 - V1 Results

10. Study V2

- Analysis by Participant.
- Participant Created Categories.
- Multiple Sets. (Set 2 and 3)
- Researcher does Aesthetic Analysis of Participant Analysis.

10.1. Notes on study structure:

The looser structure of the study proved extremely valuable, as it allowed participants to annotate the cards with their visual reasoning and highlight specific parts of the robot designs (Figure 103). This approach enabled a deeper and more detailed analysis of each image. However, the extended engagement required meant that 30 minutes was insufficient for participants to complete the task comfortably.

The use of image sets 2 and 3 helped to cover a broader range of designs. Increasing the number of participants reviewing these sets, for example, 10 participants per set, would provide more robust data. However, using different sets carries the risk of potentially missing key insights or “golden nuggets” from designs not evaluated by all participants.

The analysis of participant worksheets proved limited, largely due to the absence of participant drawings or visual annotations. This highlights that the theoretical framework is most effective when applied to the analysis of the robots themselves, rather than interpretations of their aesthetics.

10.2. Notes on study results:

The sorting into morphological categories became more closely aligned with emotional terms and thematic associations rather than strict morphological distinctions. This was particularly interesting, as participants' emotional and thematic associations were actively recorded during the process. Over the course of the study, the line between aesthetic and morphological analysis became blurred.

Participant 1 tended to use a mix of emotional, symbolic, and some morphological terms when categorizing the robots. Participant 2, on the other hand, organized the robots along a spectrum, where the categories reflected associations and emotions rather than strict morphological characteristics.

Interestingly, the inclusion of more sketched robot designs influenced participants' perceptions: these designs felt less real and, as a result, were perceived as more engaging and imaginative rather than threatening, even when the robot depicted was a war machine.

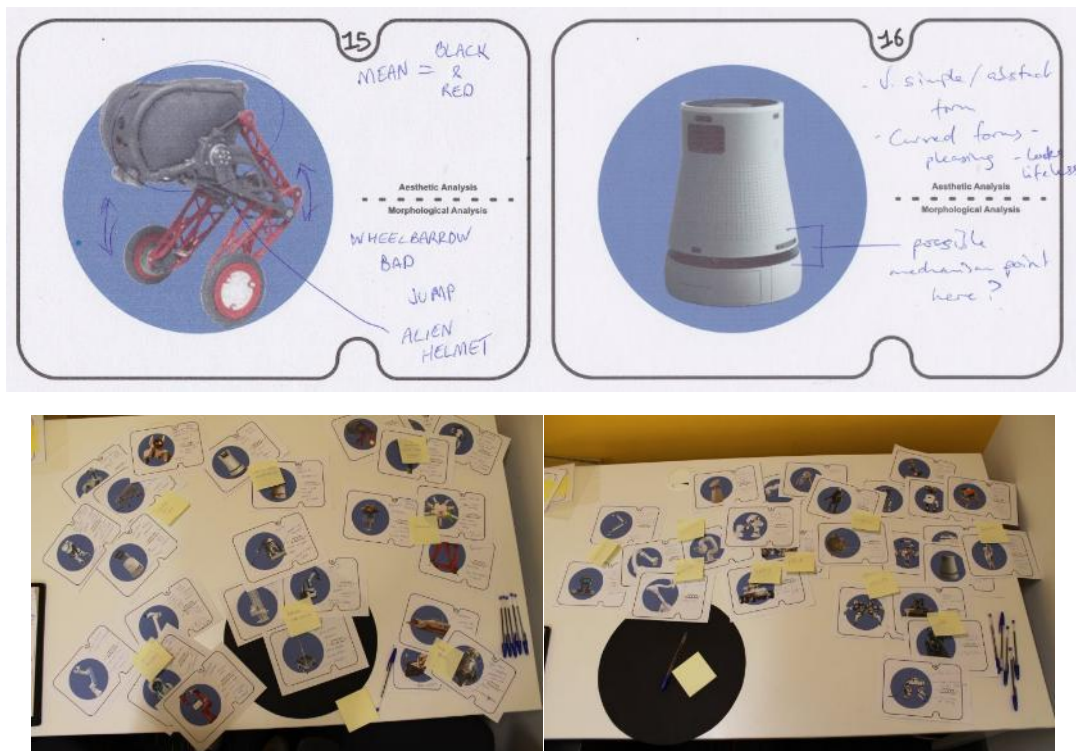


Figure 103 - V2 Results

11. Study V3

- Image set Evaluation Only.
- Participant Created Categories.
- Multiple Sets. (Set 2 and 3)
- Researcher Does Analysis of Set.

11.1. Notes on study structure:

This looser structure also required more time to complete (Figure 104). Over the course of the analysis, the morphological evaluation increasingly became a record of the visceral emotions elicited by the images. The use of aesthetic dimensions helped guide participants in conducting an aesthetic analysis; however, both participants initially made notes in the morphological analysis space before considering the aesthetic dimensions. Overall, the utility of this research analysis did not differ significantly from Version 1.

11.2. Notes on study results:

The interpretation of “opposite” morphologies and aesthetics was considered unsettling by Participant 1 (e.g., mechanical versus zoomorphic designs). The absence of predefined morphological categories required additional analysis after the aesthetic evaluation was completed. For Participant 1 reviewing Set 2, the resulting groups were organised around aesthetic themes rather than morphological categories. Similarly, for Participant 2 reviewing Set 3, the groups reflected emotional responses and aesthetic themes rather than formal morphologies.

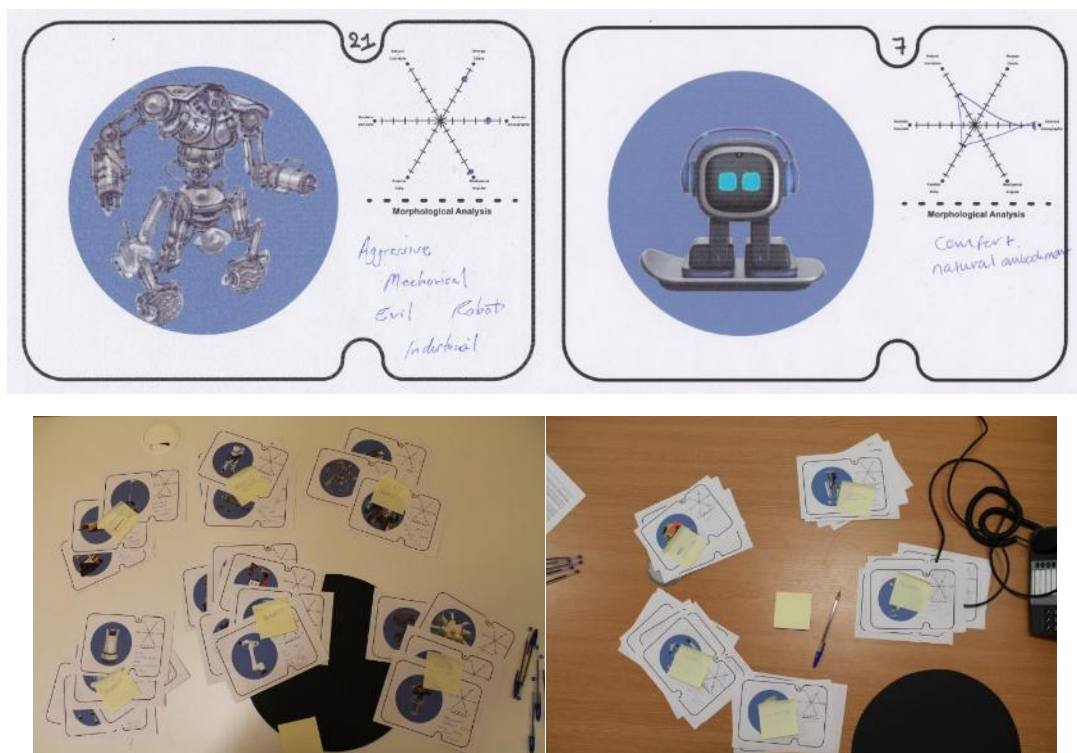


Figure 104 - V3 Results

12. Study V4

- Analysis by Participant.
- Defined Categories.
- One Set. (Set 1)
- Researcher does Aesthetic Analysis of Participant Analysis.

12.1. Notes on study structure:

Some of the aesthetic analysis shifted into morphological analysis (Figure 105). The blank areas on the images were treated as free space rather than regions with a specific function. Overall, the utility of this analysis did not differ from Version 2.

12.2. Notes on study results:

The results of the card sorting differed between participants, but their justifications remained consistent. Participant 1 tended to determine the robot's aesthetic from the extremities first, suggesting that an example card could have helped clarify the task. Participant 2 approached the analysis by first considering morphologies and then aesthetics, often using analogies. Terms like amorphism and neomorphism were unclear to Participant 2.

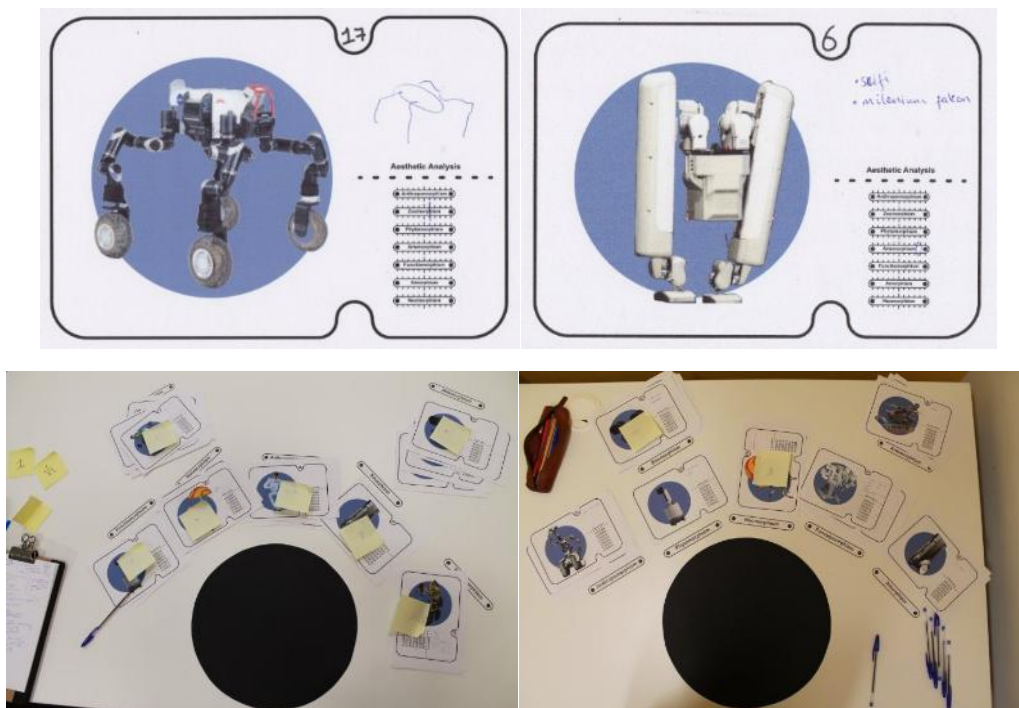
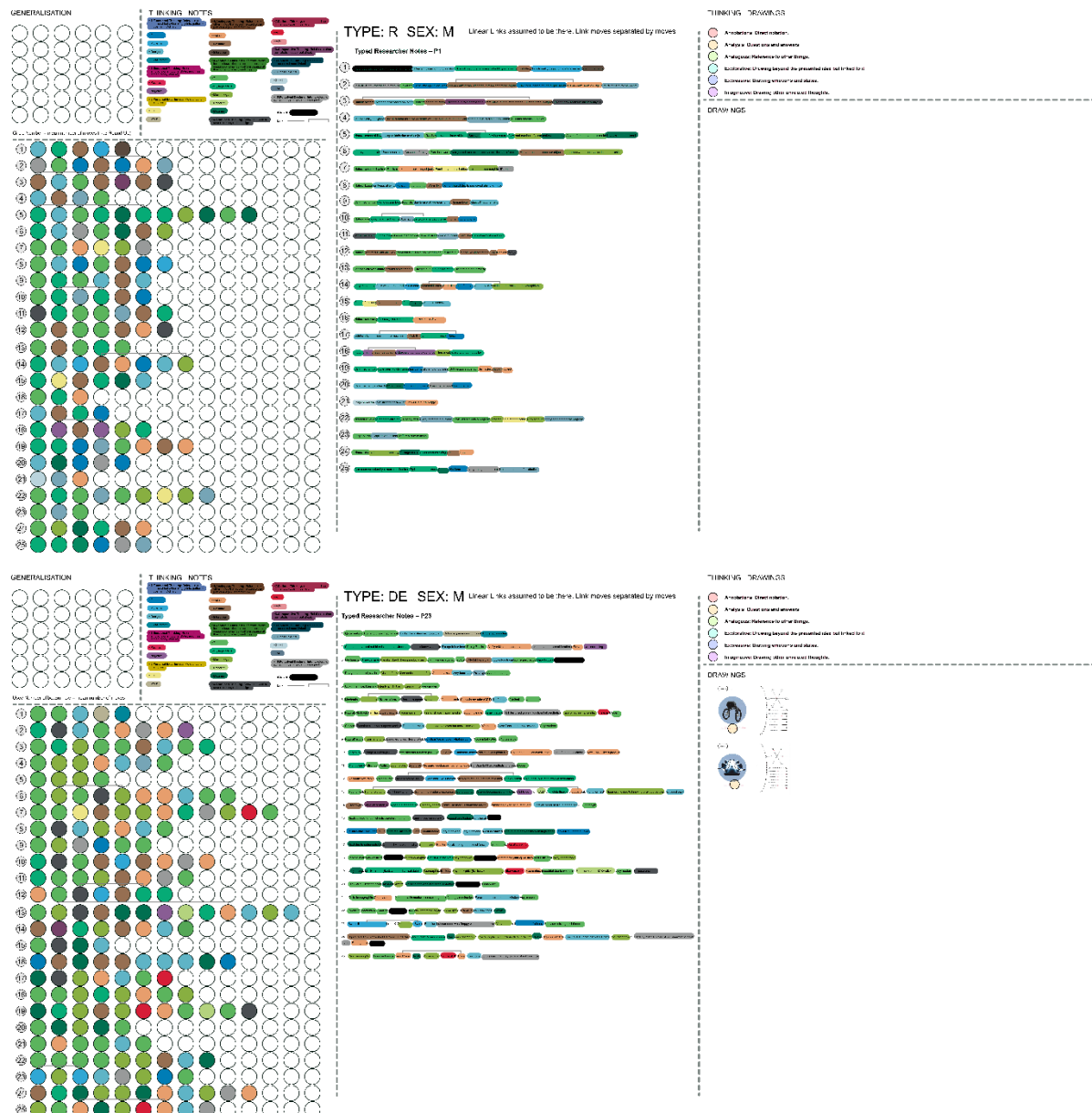


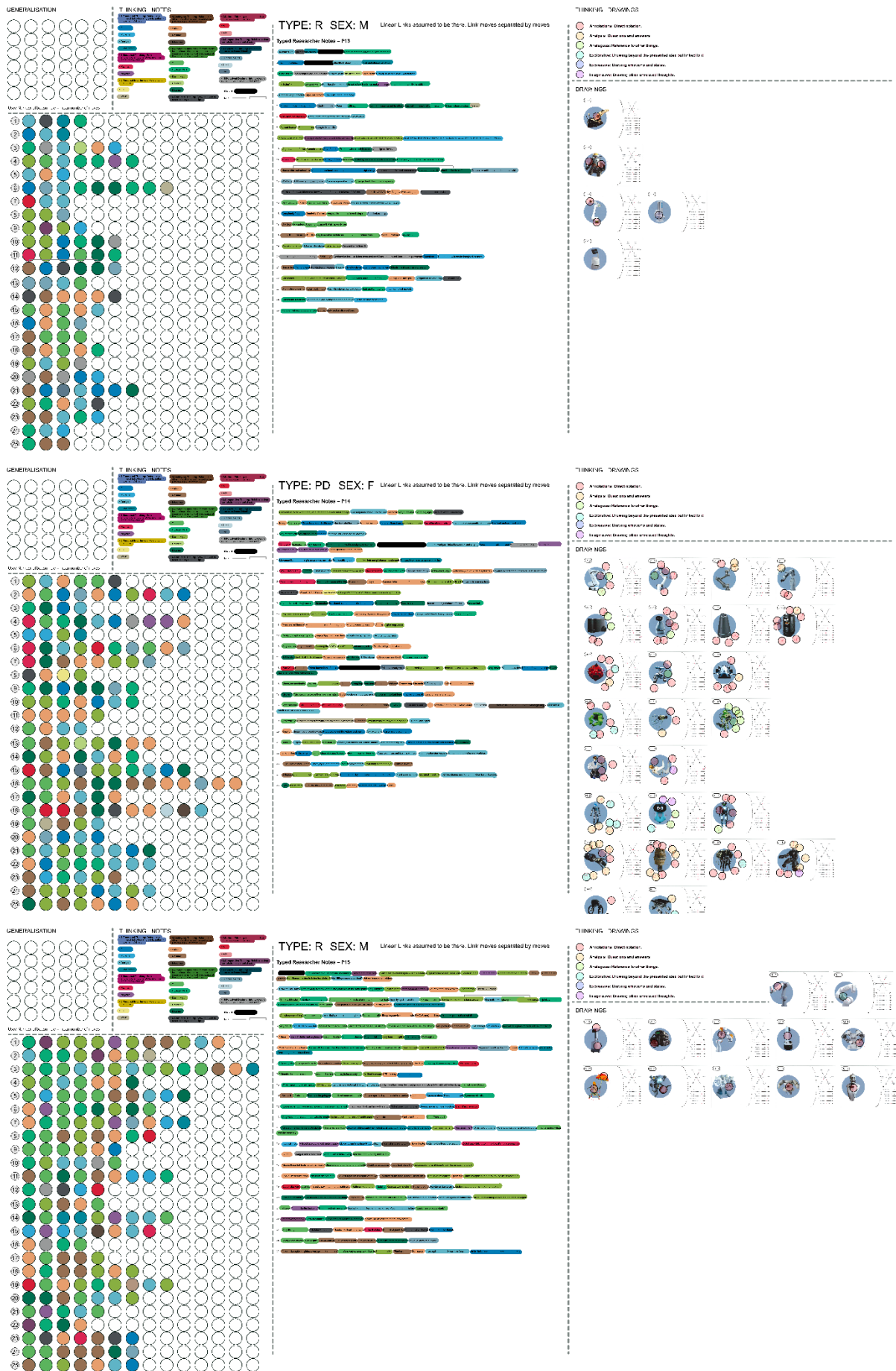
Figure 105 - V4 Results

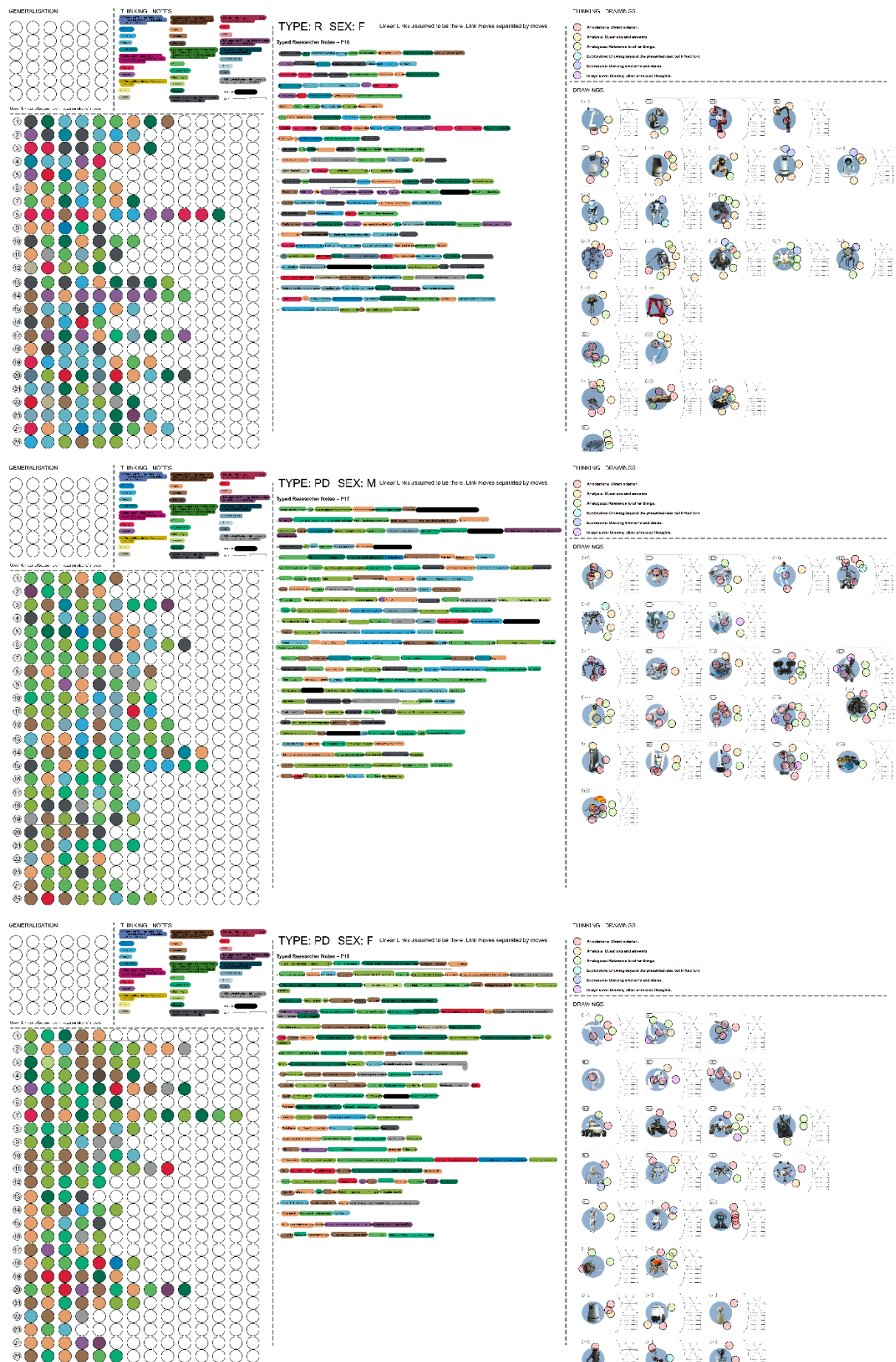
Appendix B – Researcher Coding Data

R1









GENERALISATION

THINKING NOTES

TYPE: PD SEX: M

Linear L-its assumed to be there. Link moves separated by moves

Typical Researcher Notes - P17

THINKING DRAWINGS

GENERALISATION

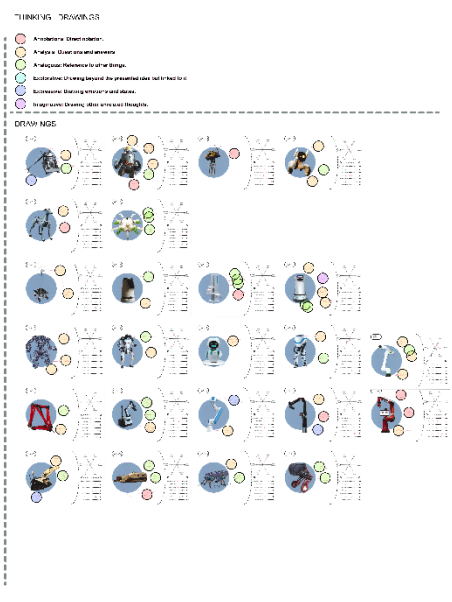
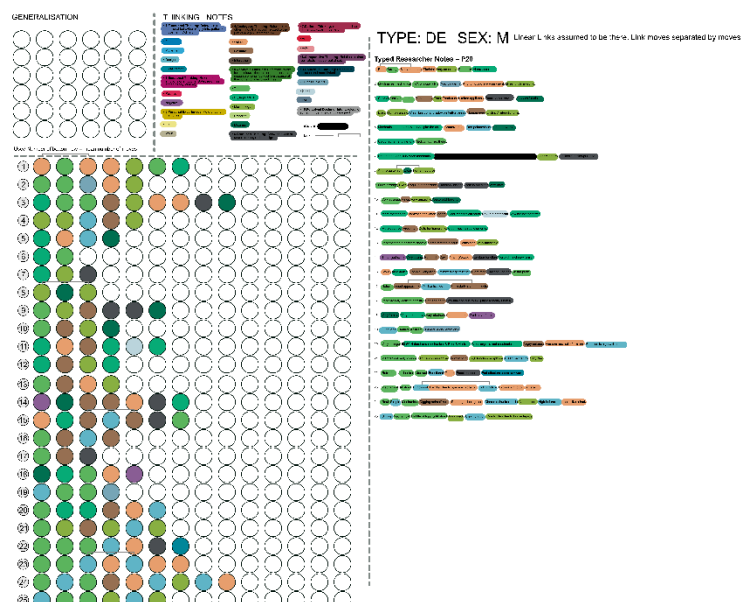
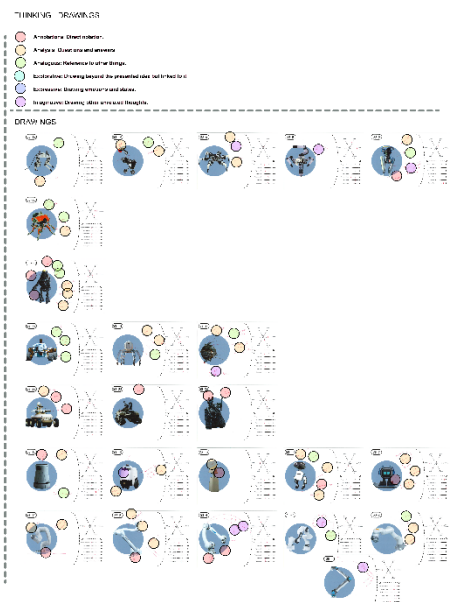
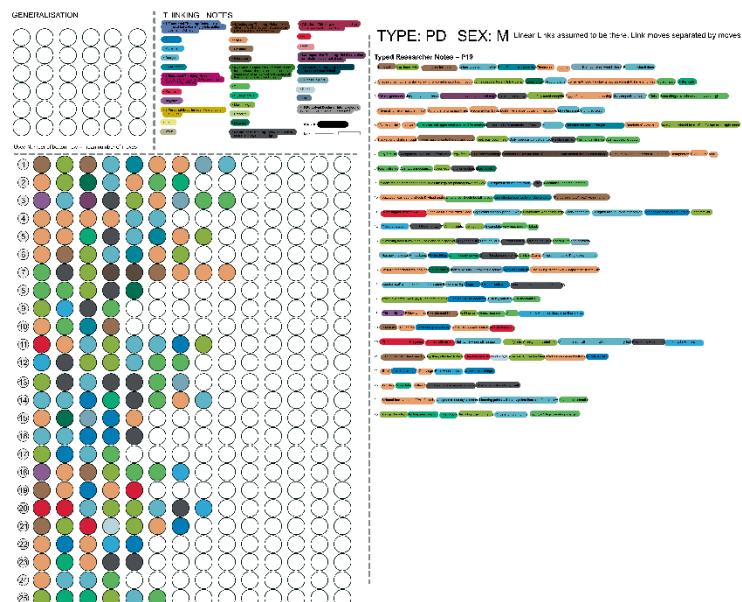
THINKING NOTES

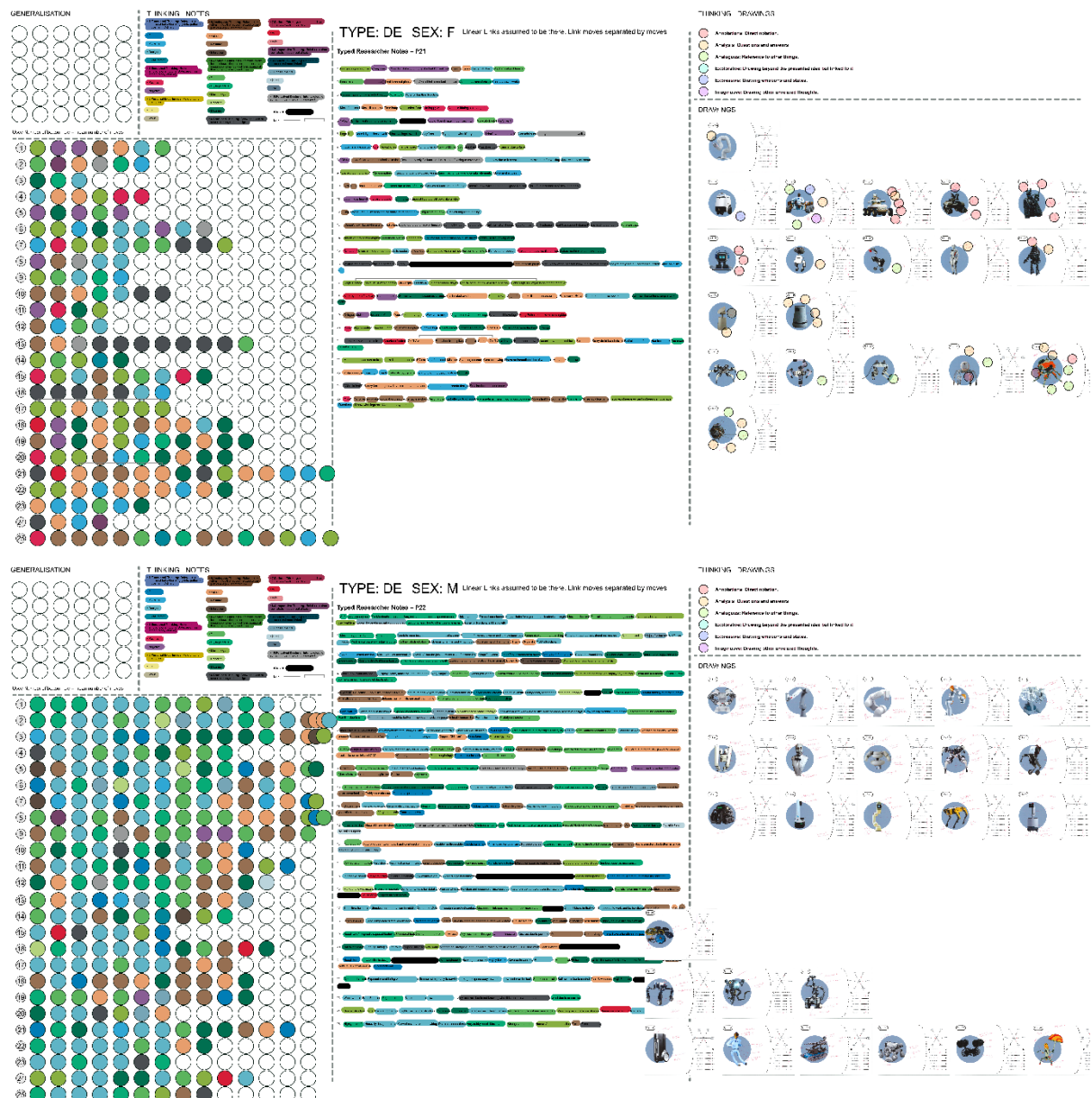
TYPE: PD SEX: F

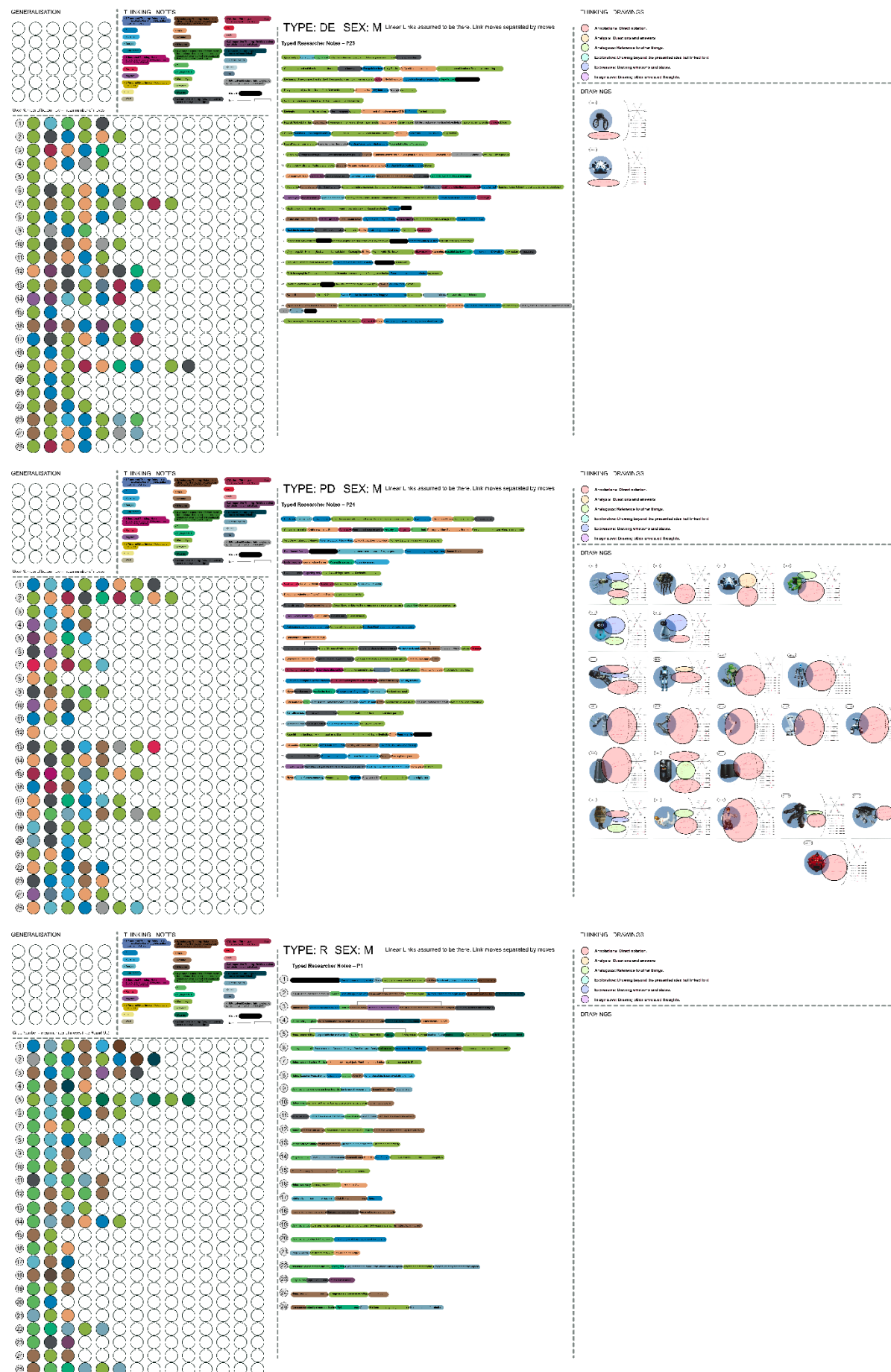
Linear L-its assumed to be there. Link moves separated by moves

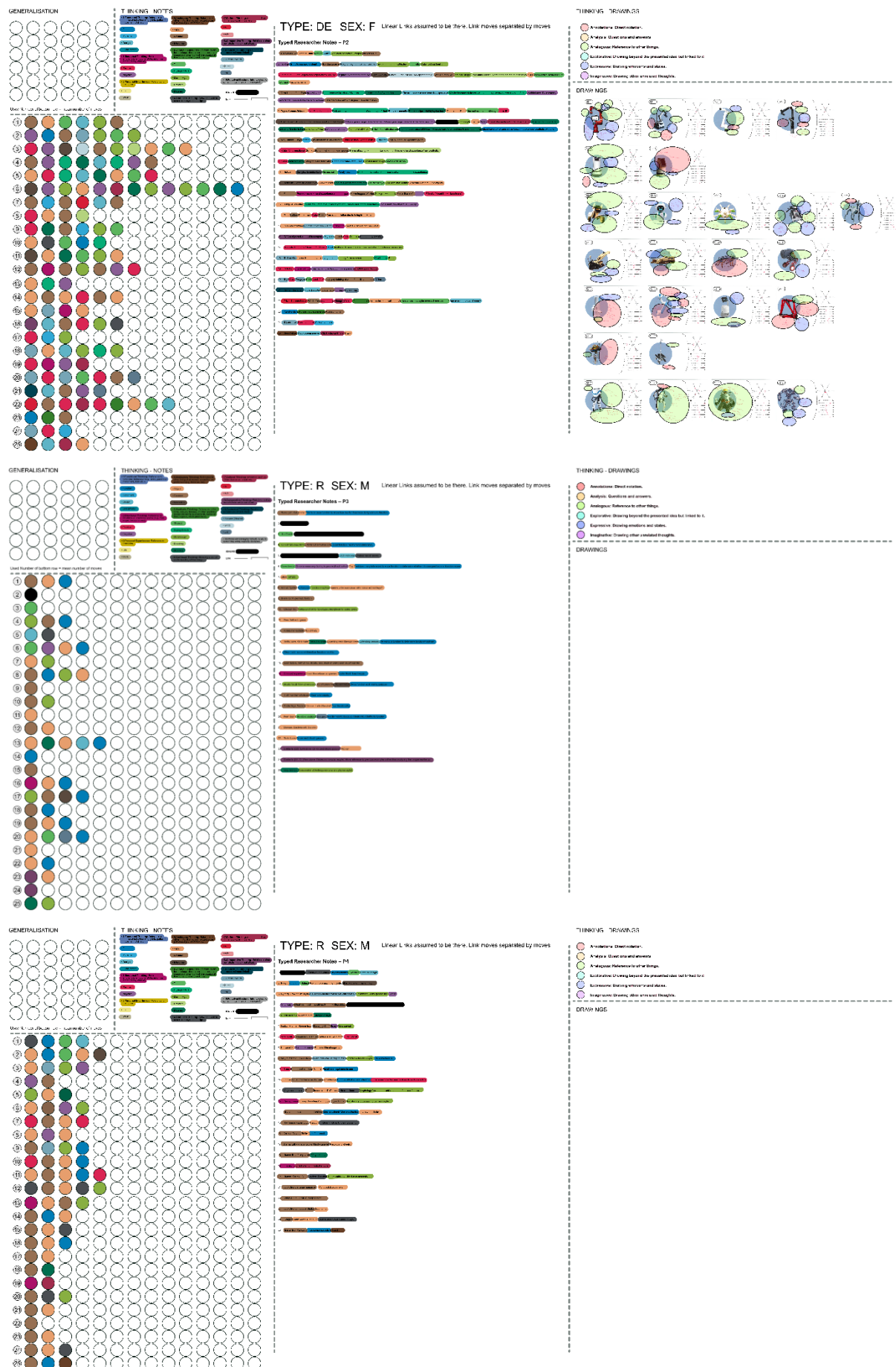
Typical Researcher Notes - P18

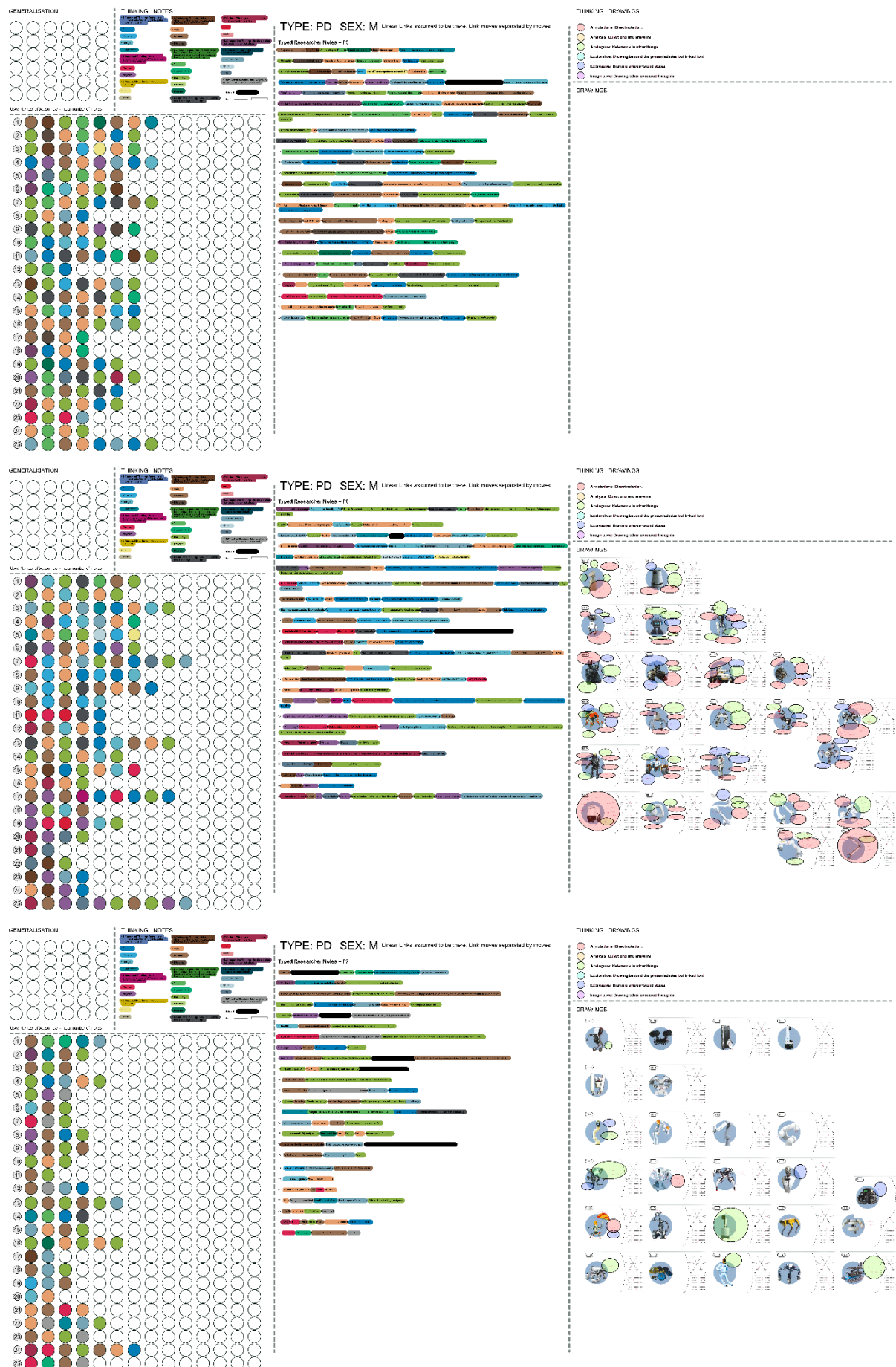
THINKING DRAWINGS

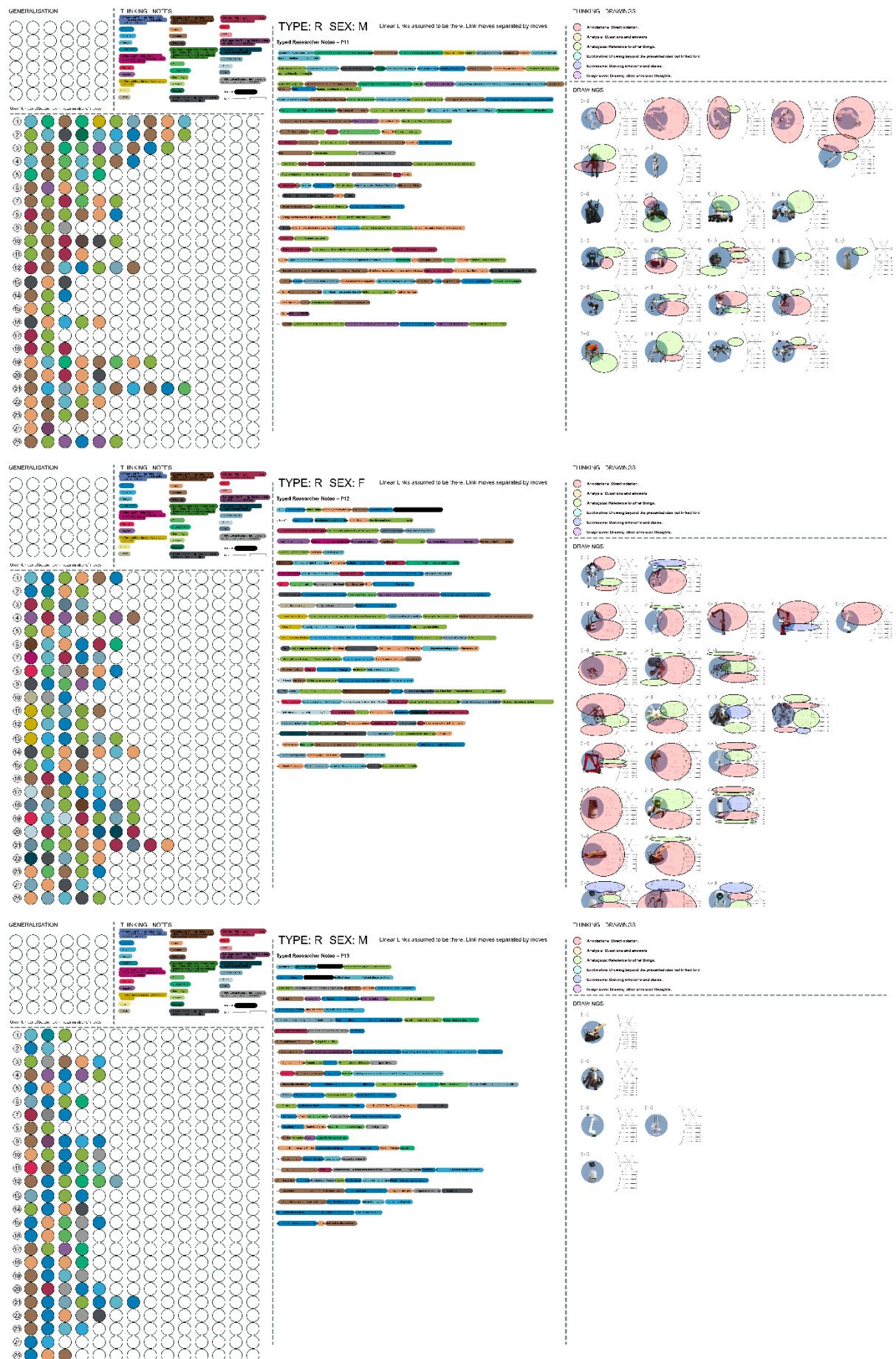


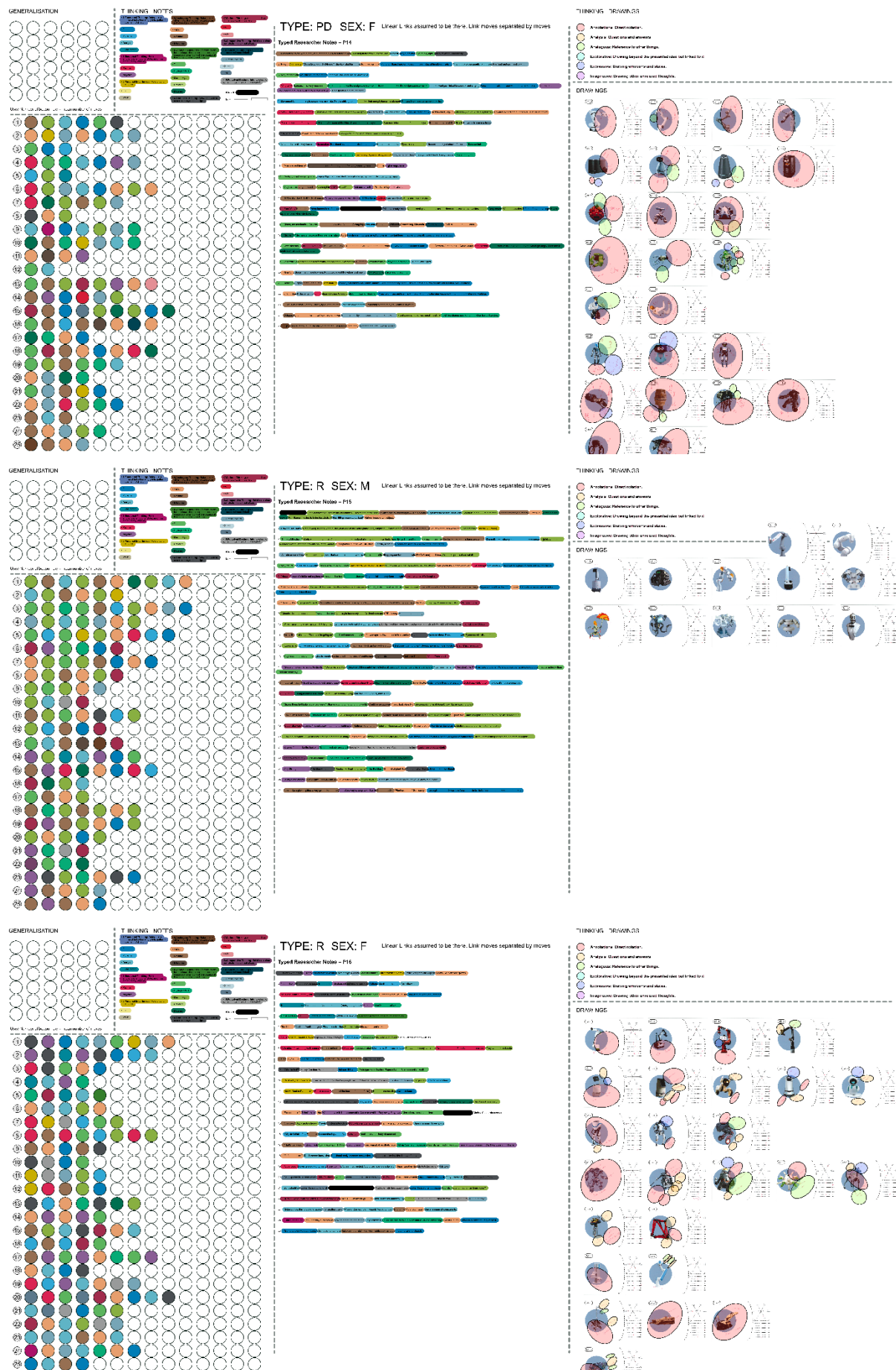


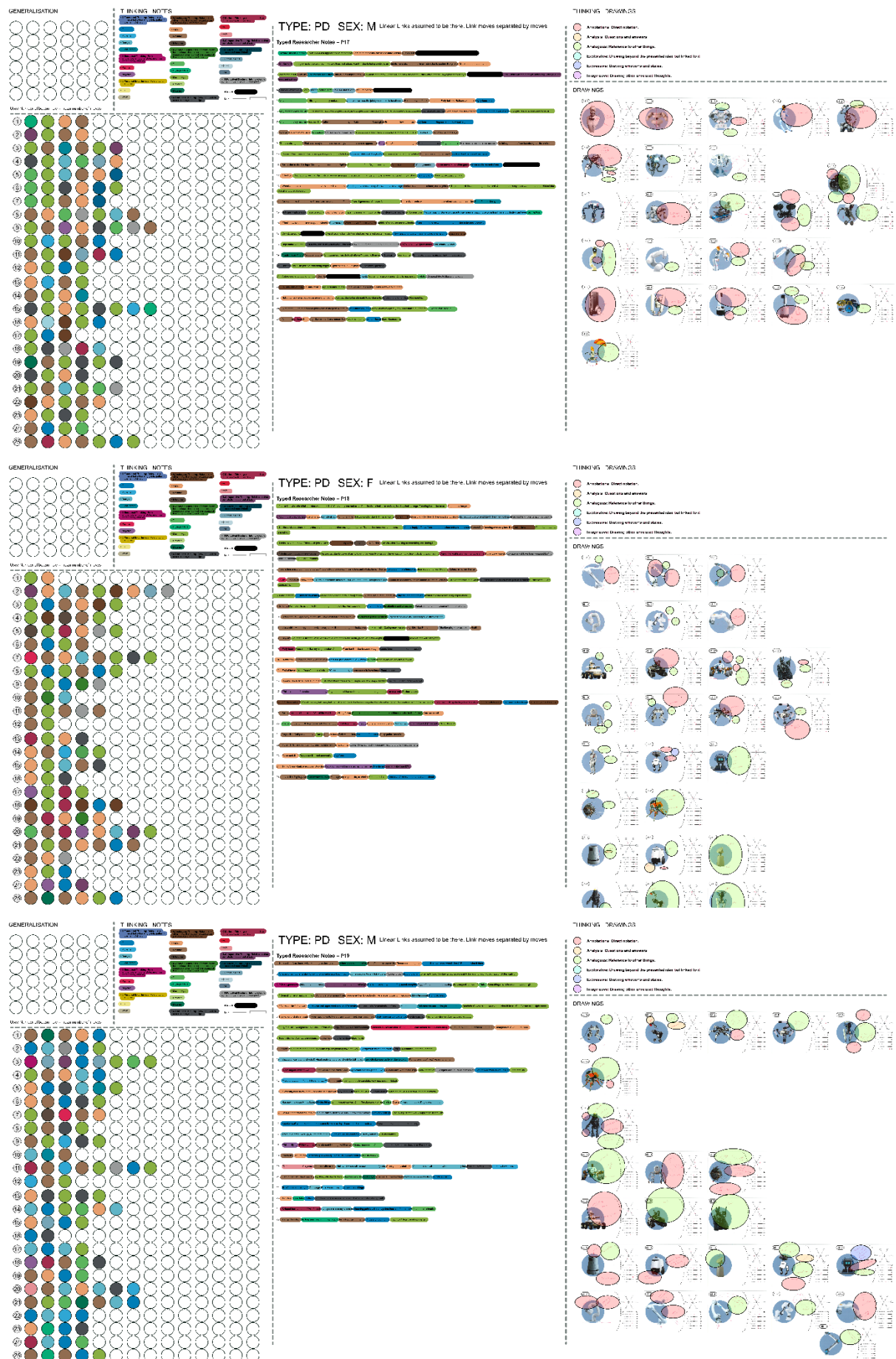


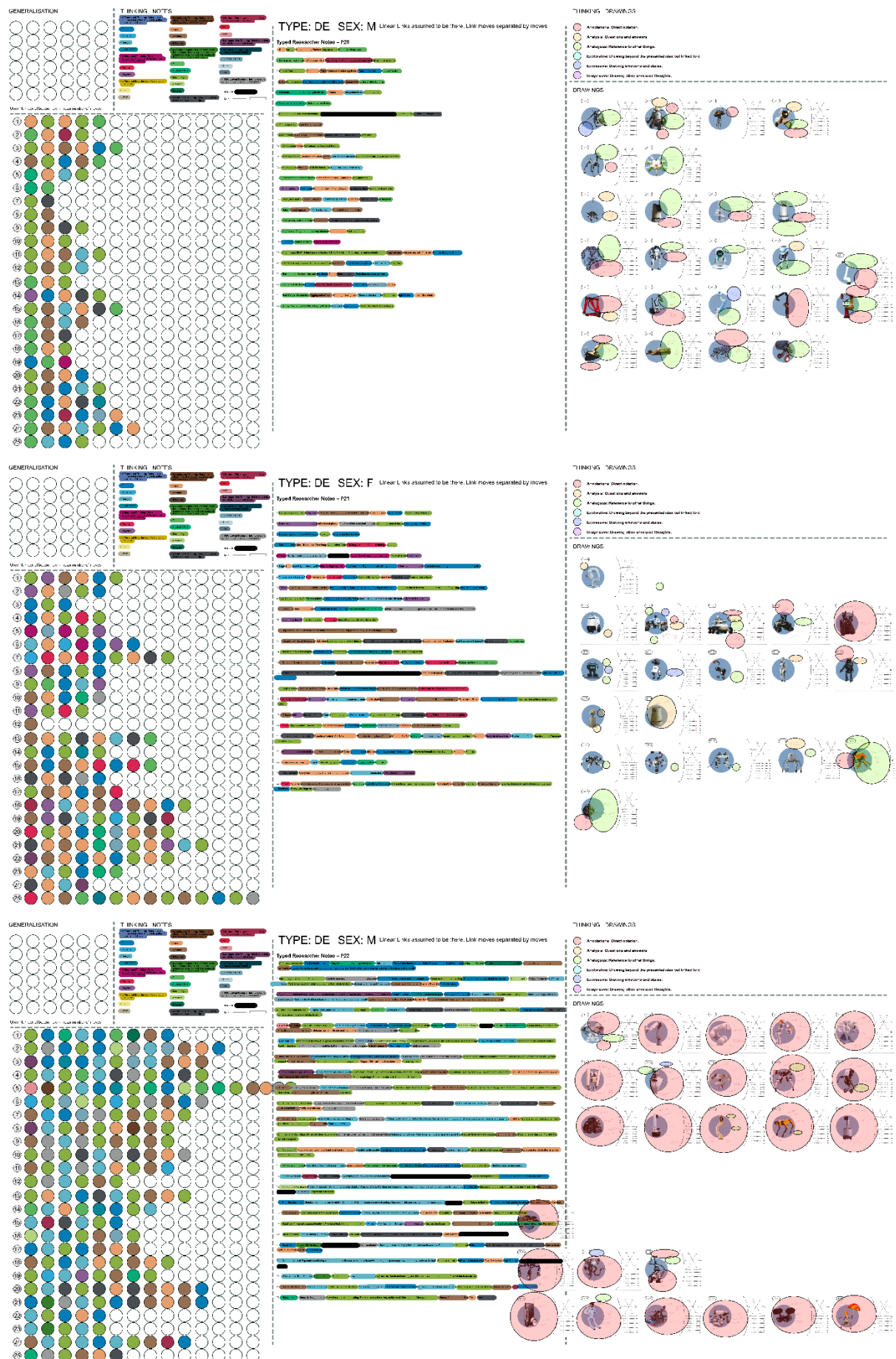






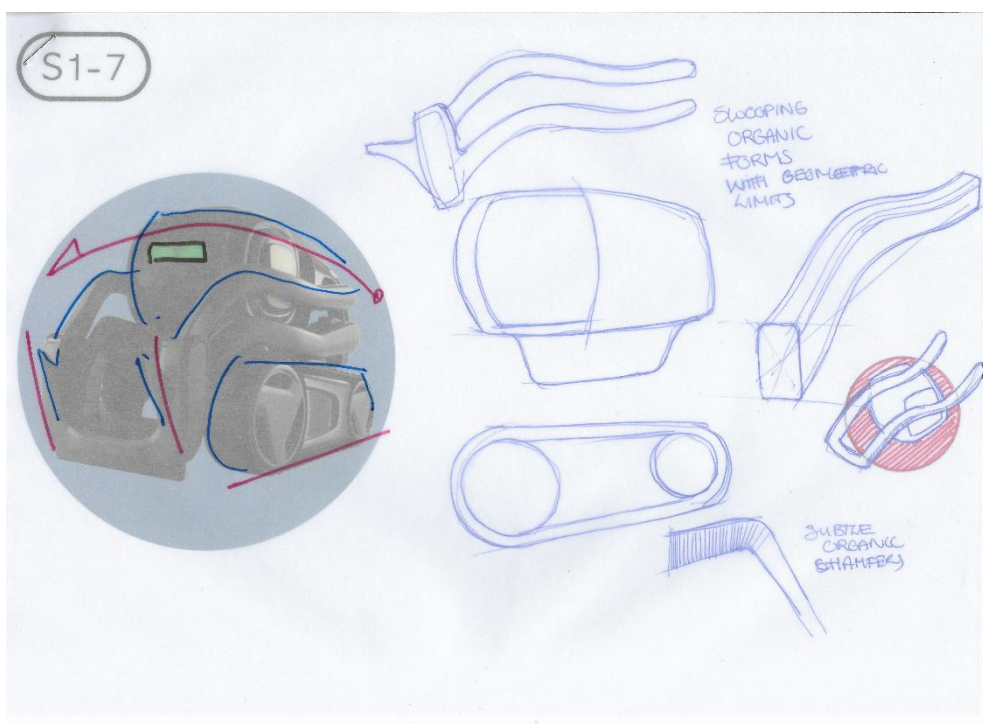
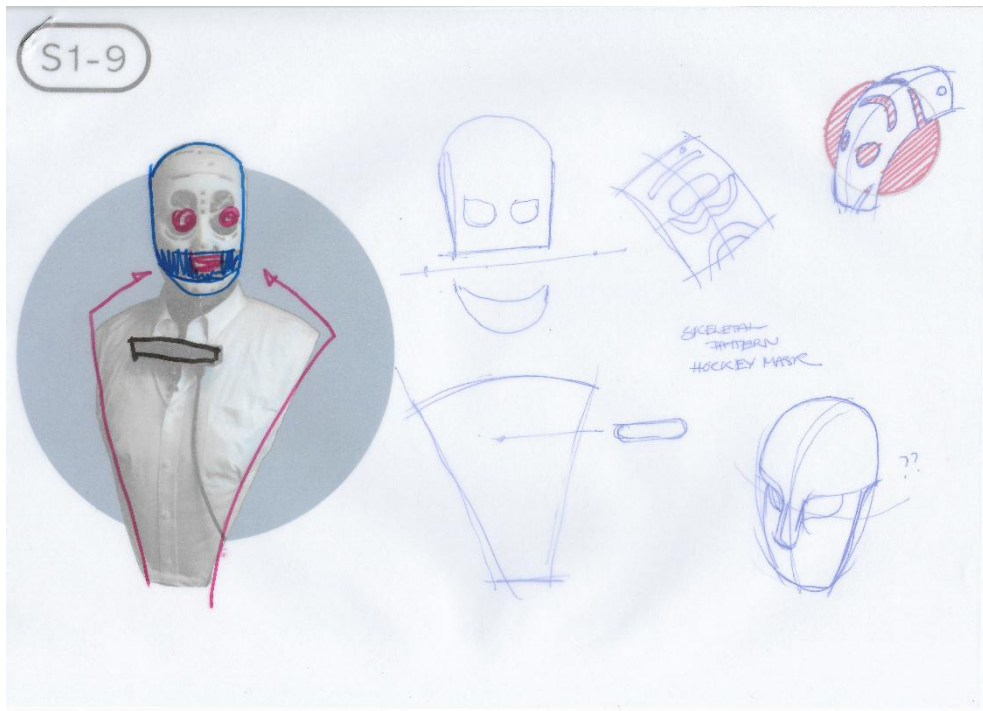


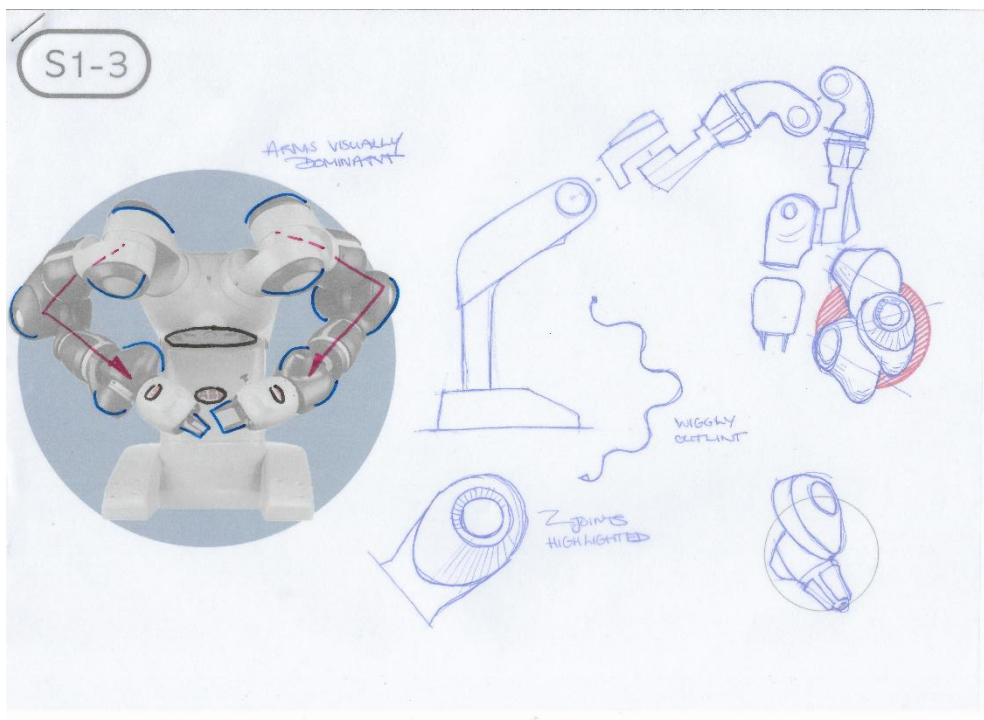
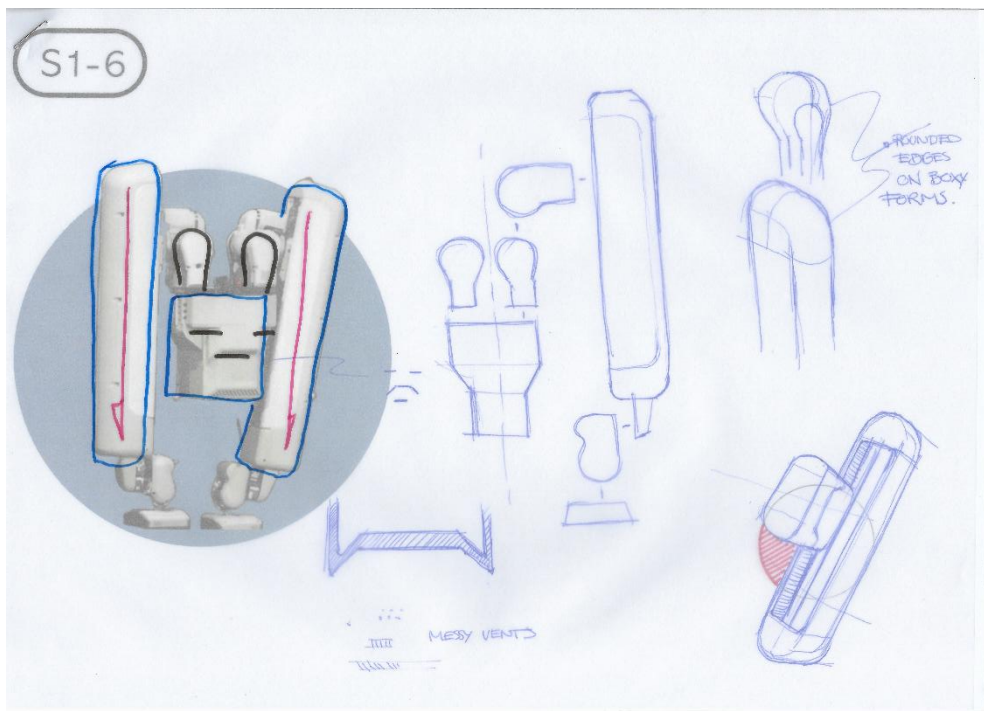


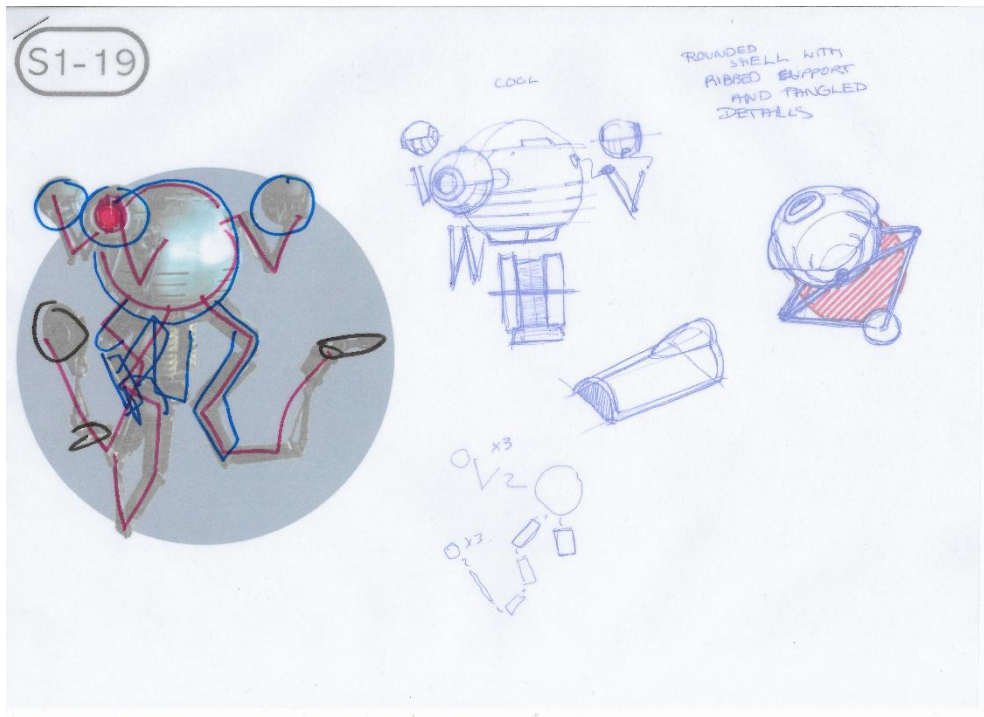
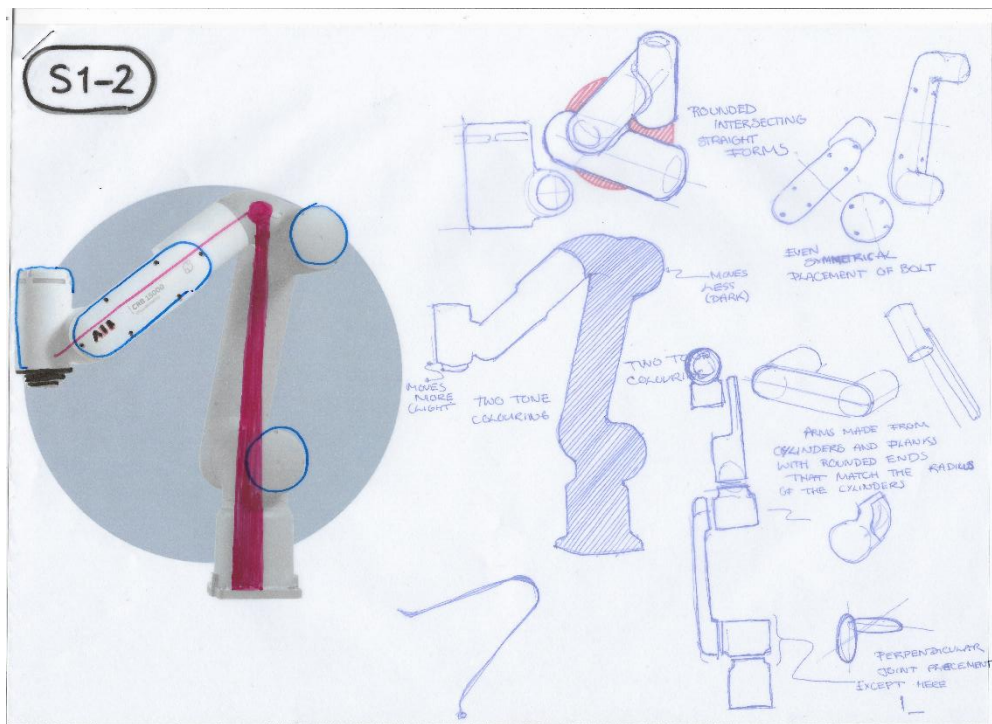


Appendix C – Sketching Autopsy Analysis Data

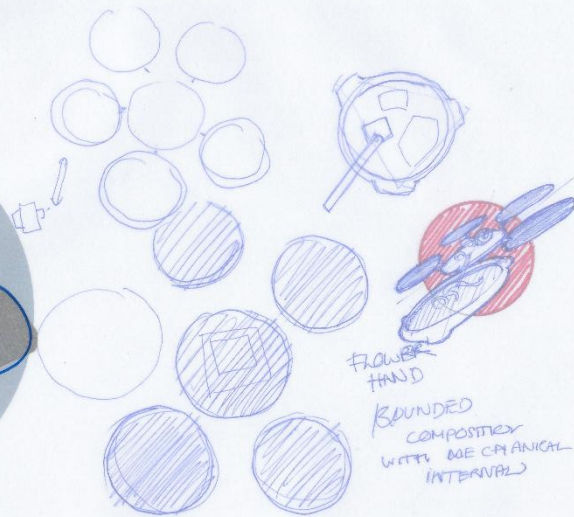
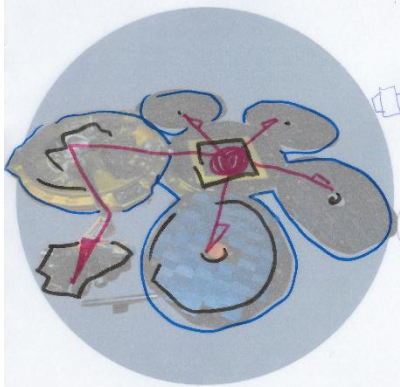
13. Dominant Design from Set 1





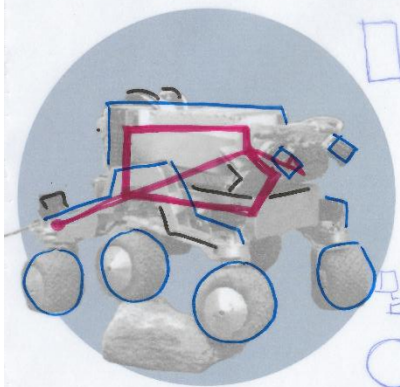


S1-20

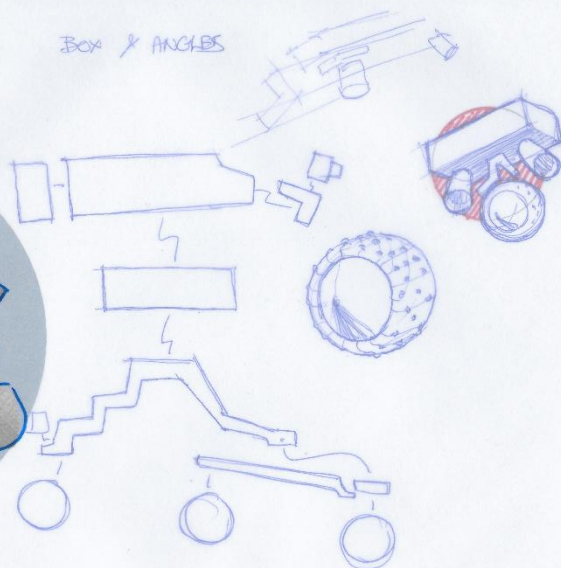


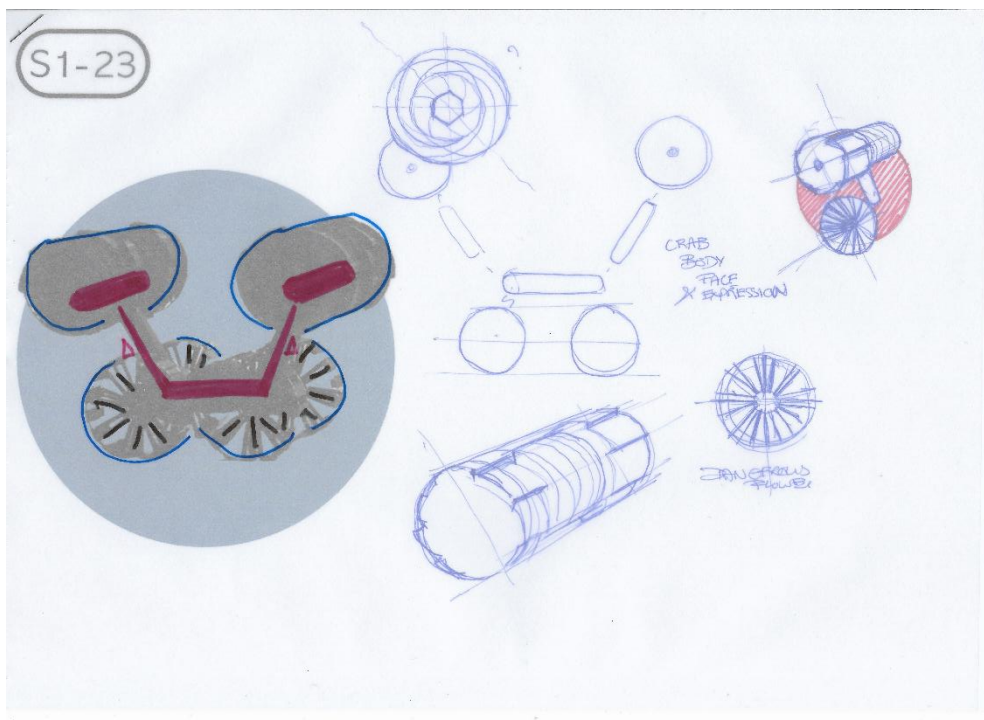
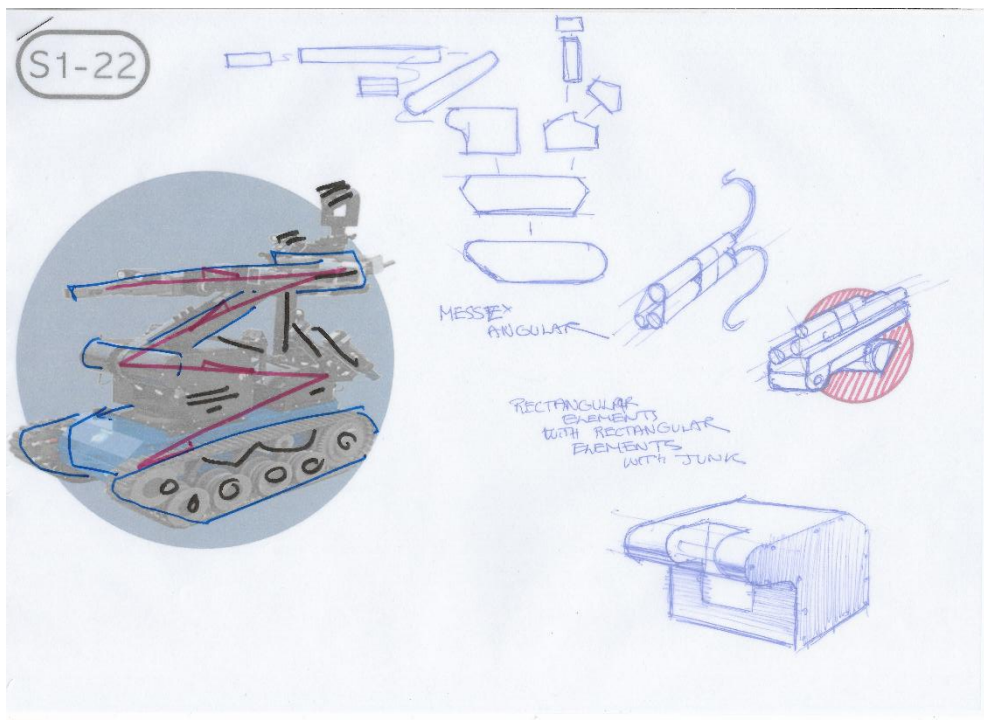
FLOWER
HAND
BOUNDED
COMPOSITELY
WITH MECHANICAL
INTERNAL

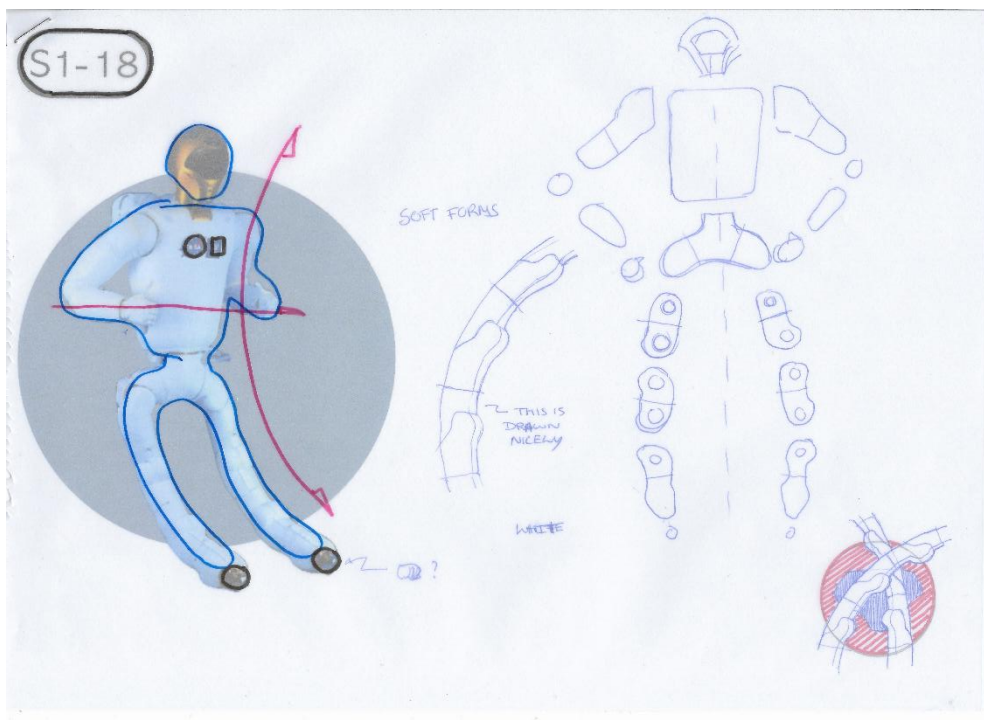
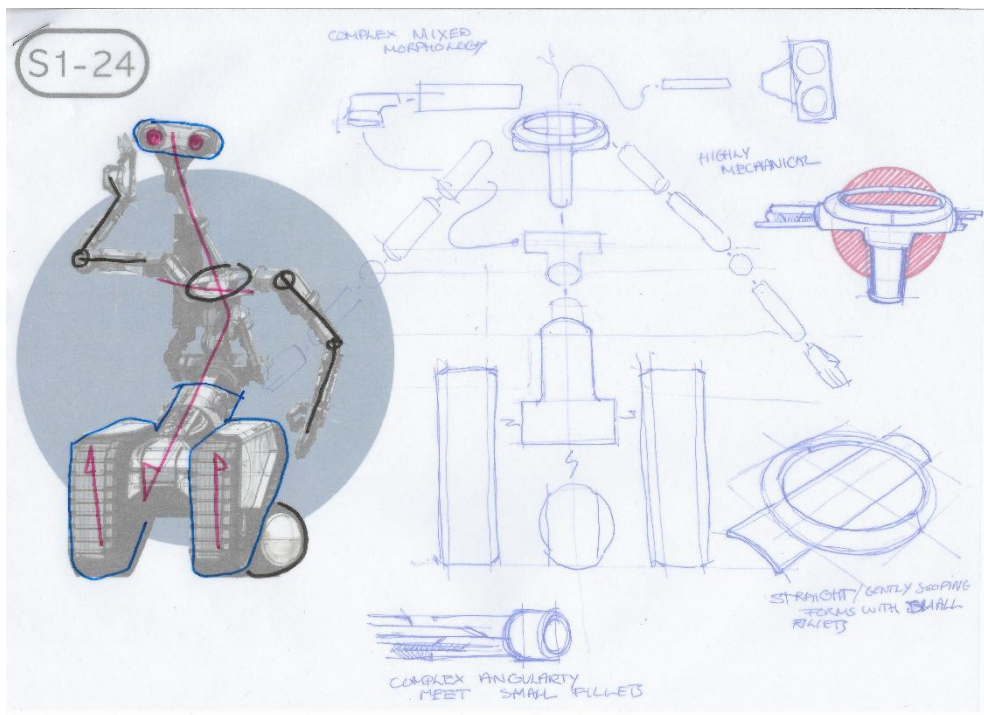
S1-21

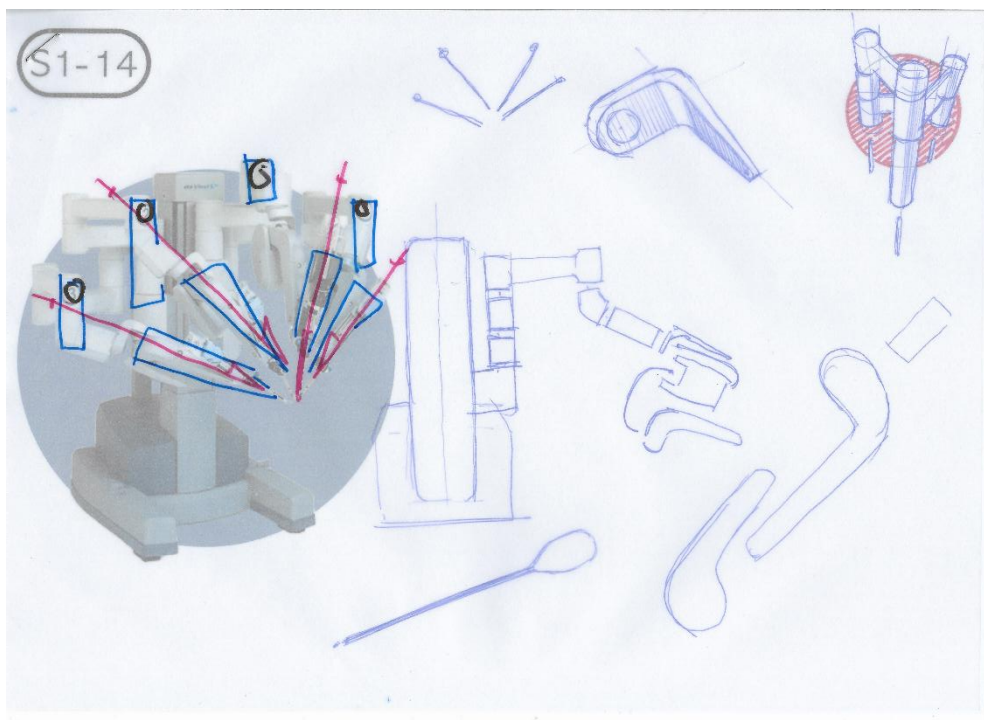
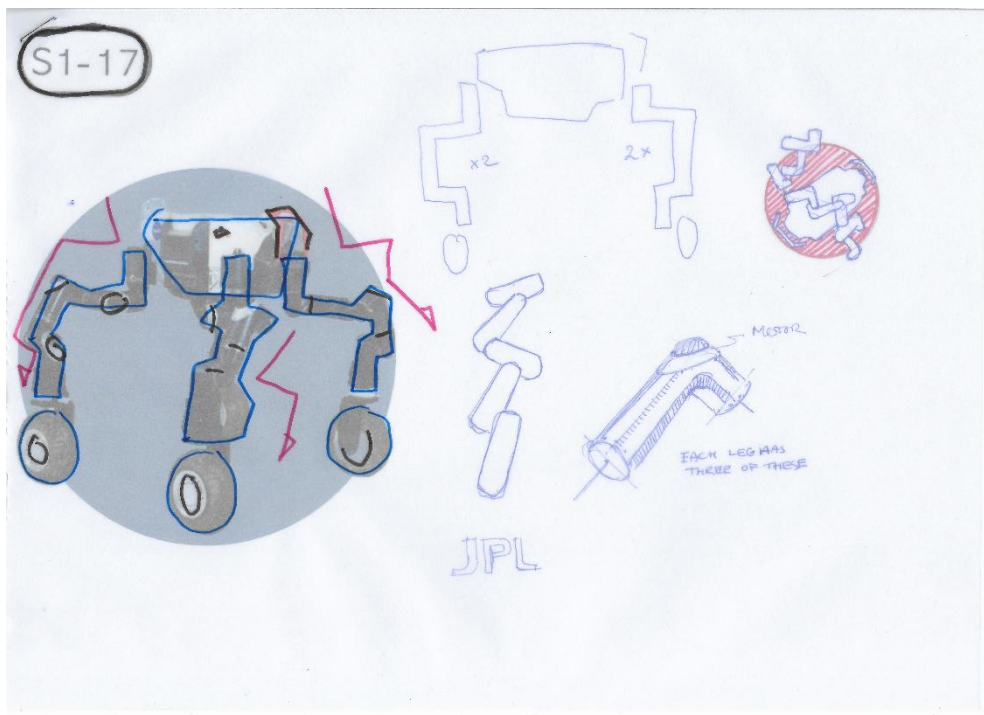


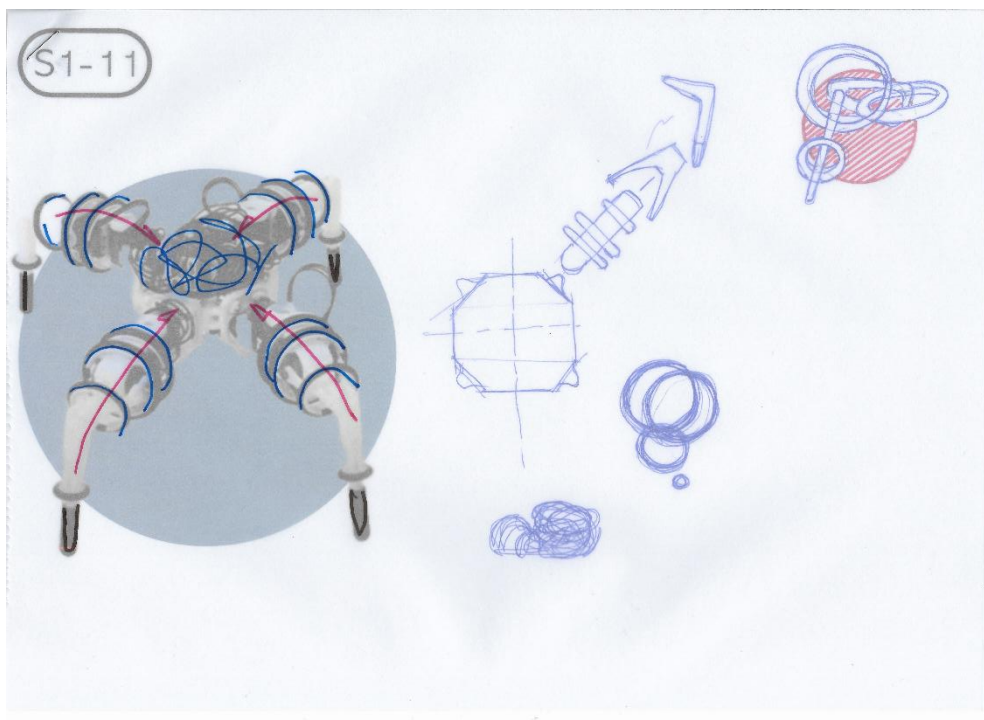
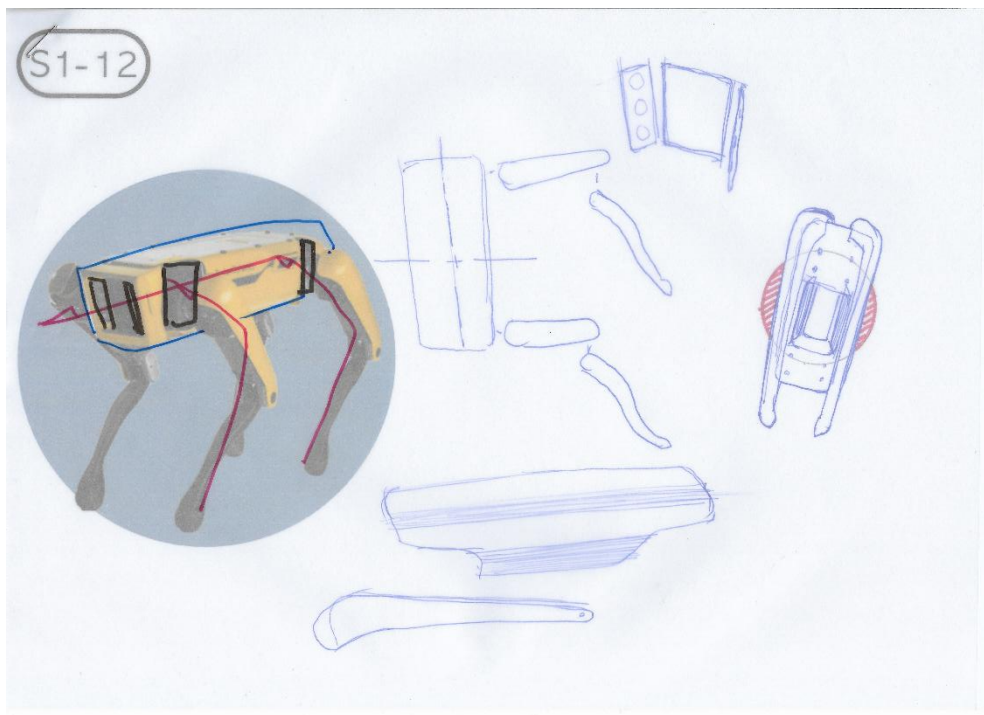
BOX / ANGLES



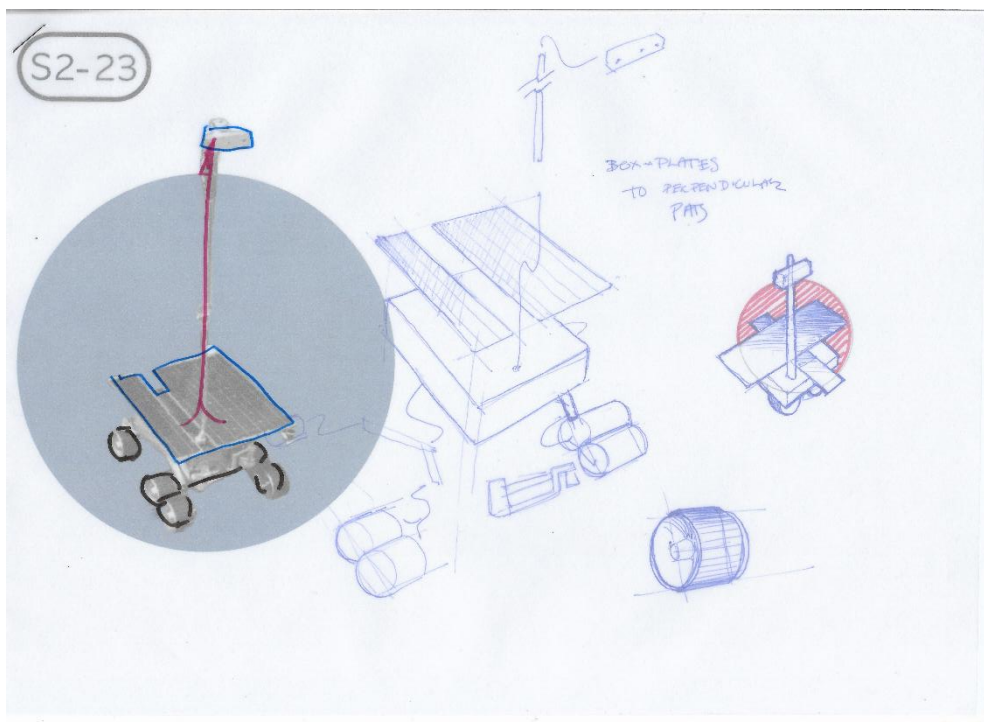
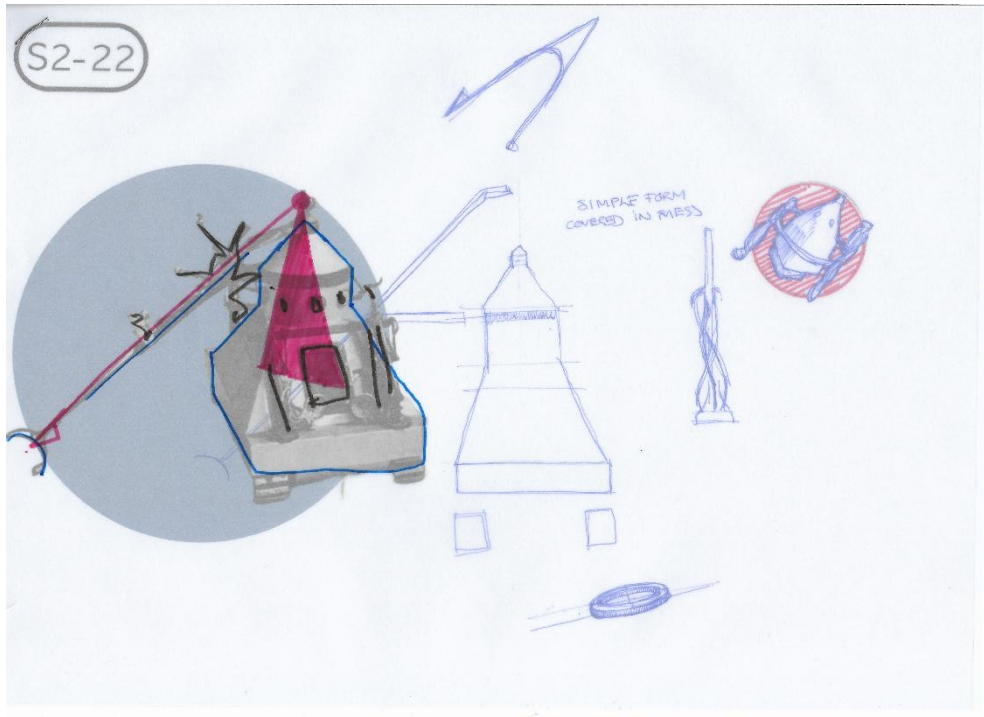




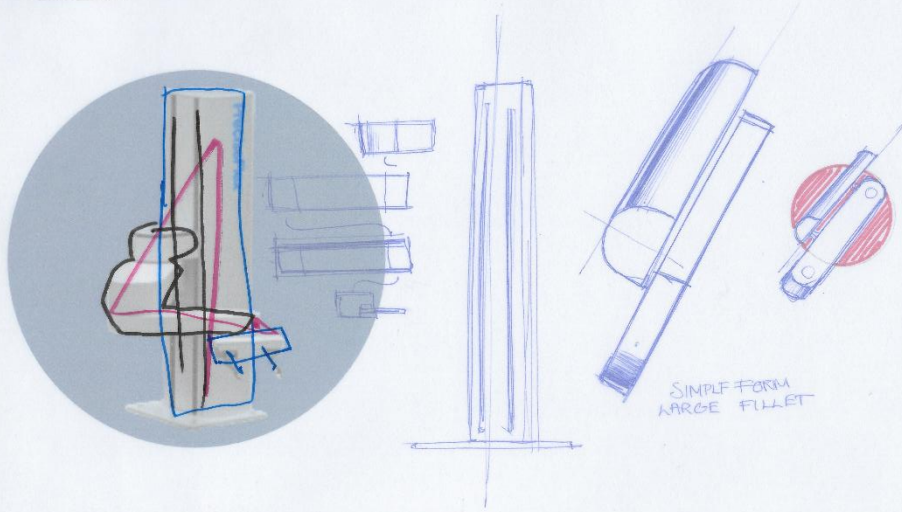




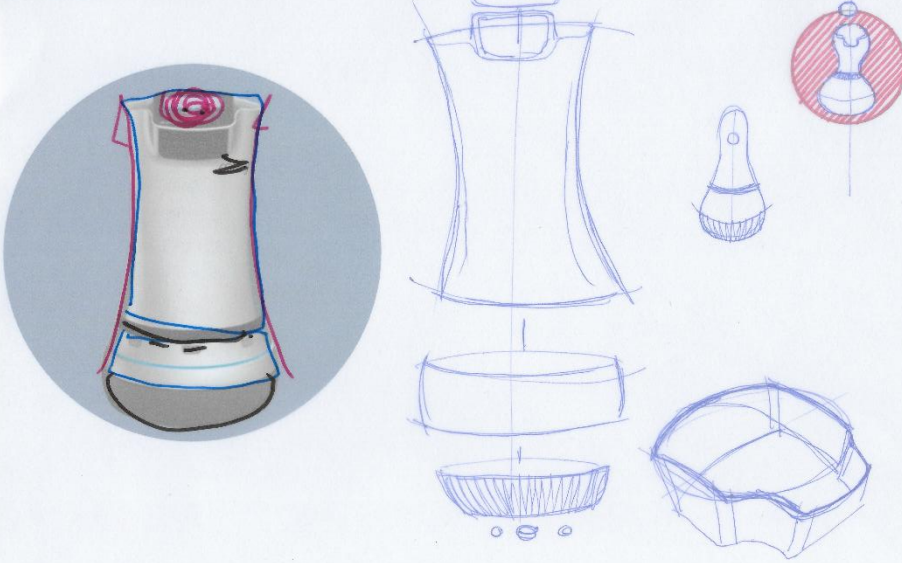
14. Dominant Design from Set 2



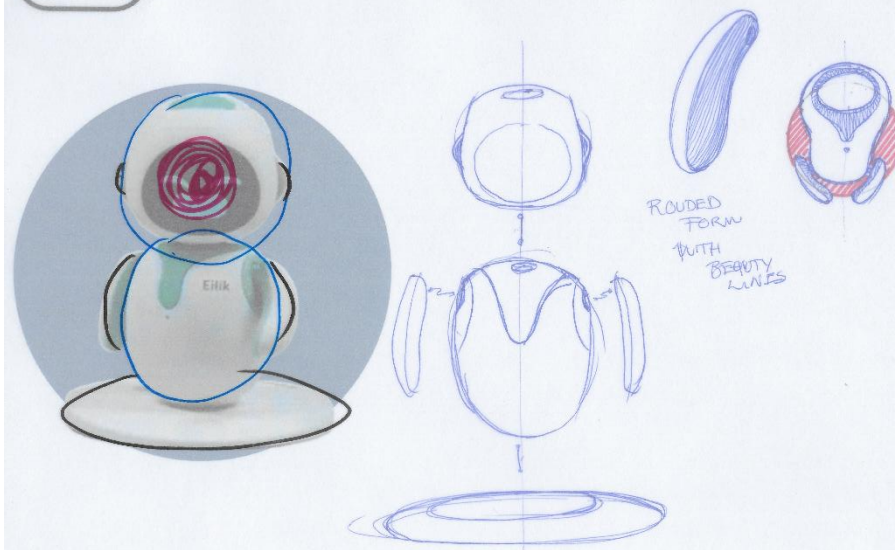
S2-2



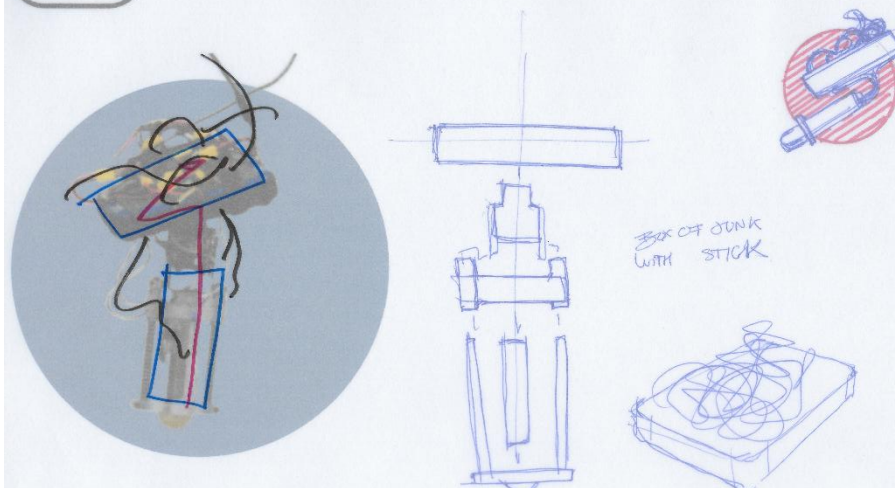
S2-3



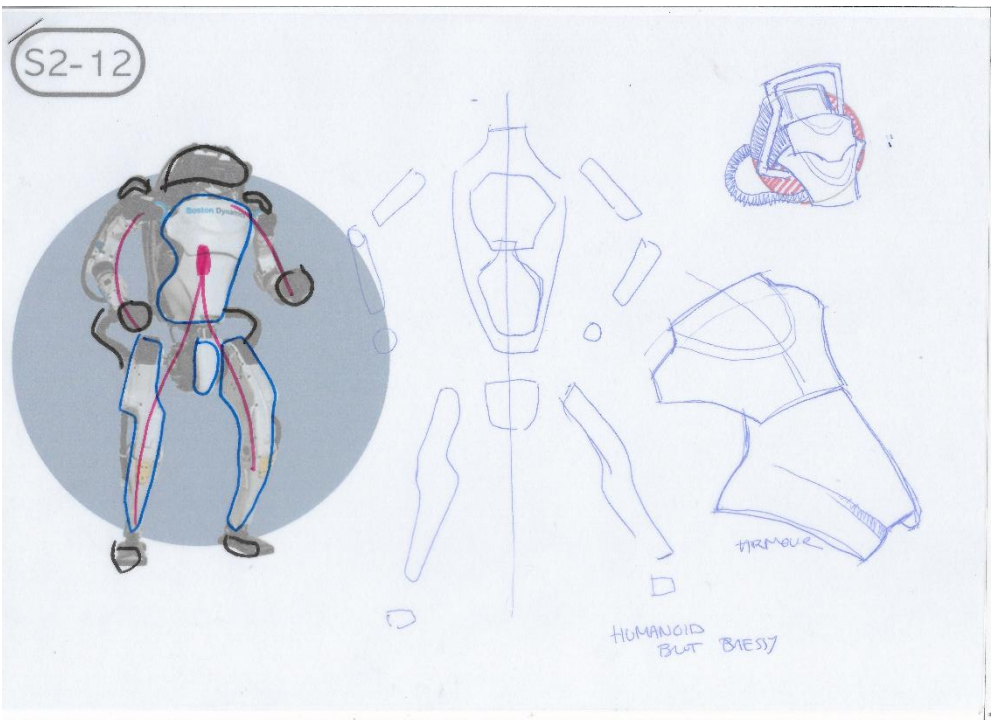
S2-8



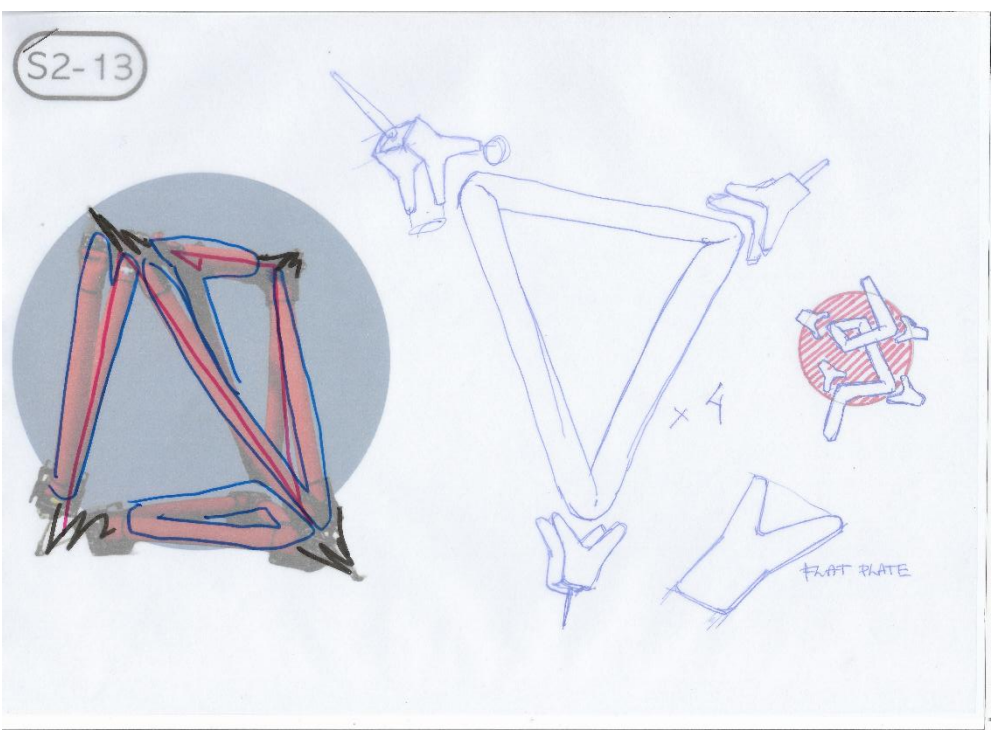
S2-10



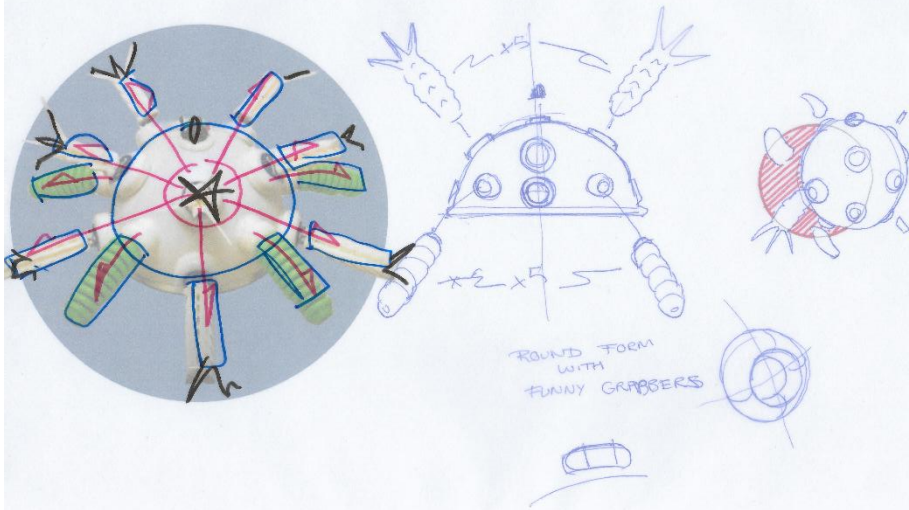
S2-12



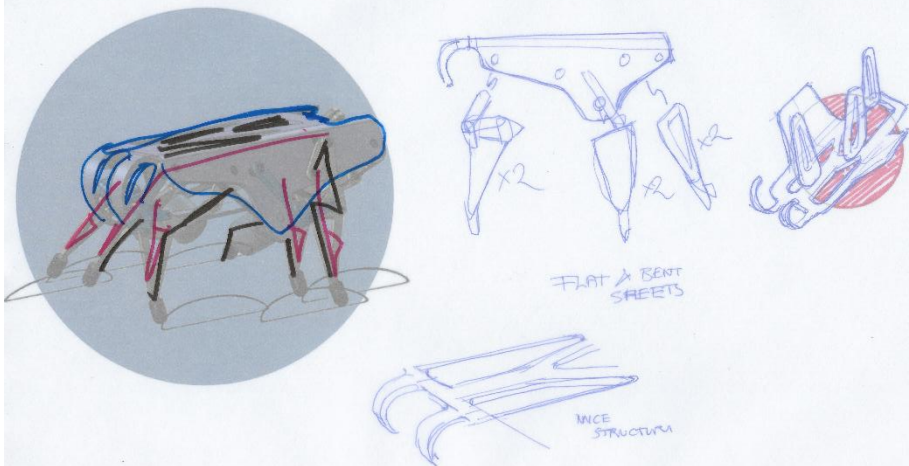
S2-13



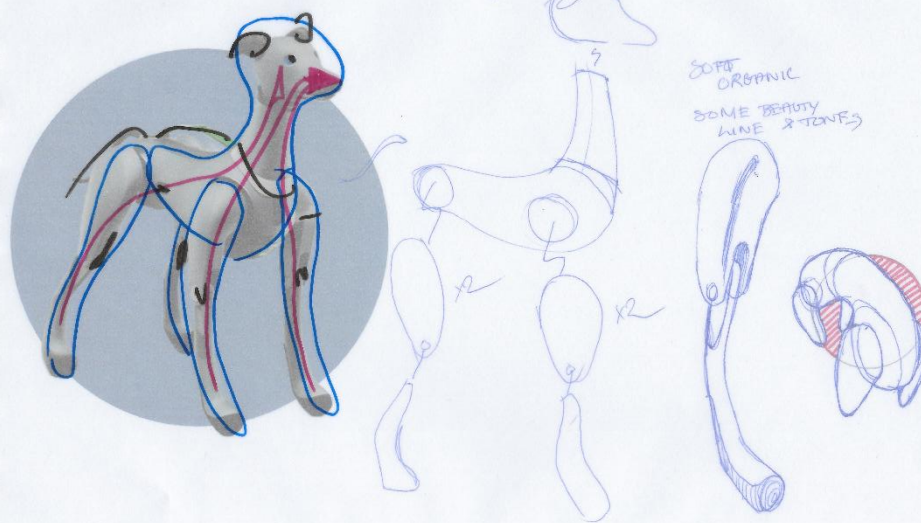
S2-14



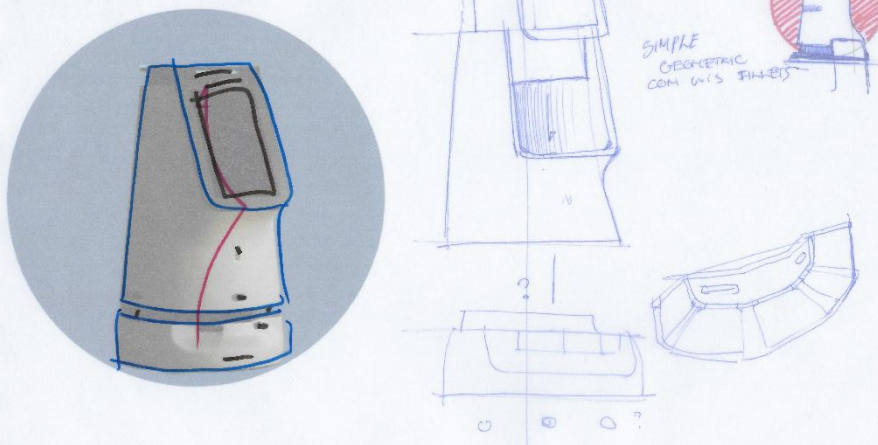
S2-16



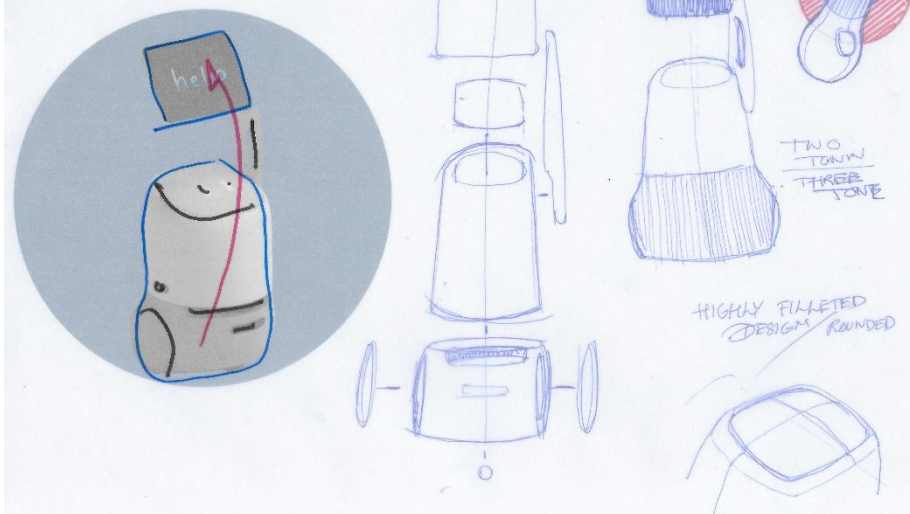
S2-17



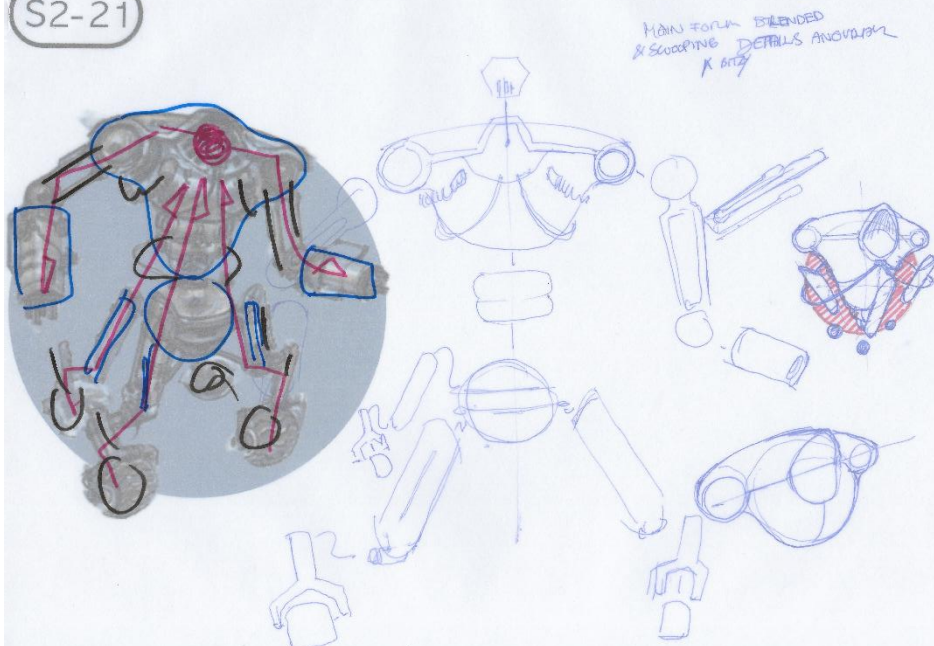
S2-18



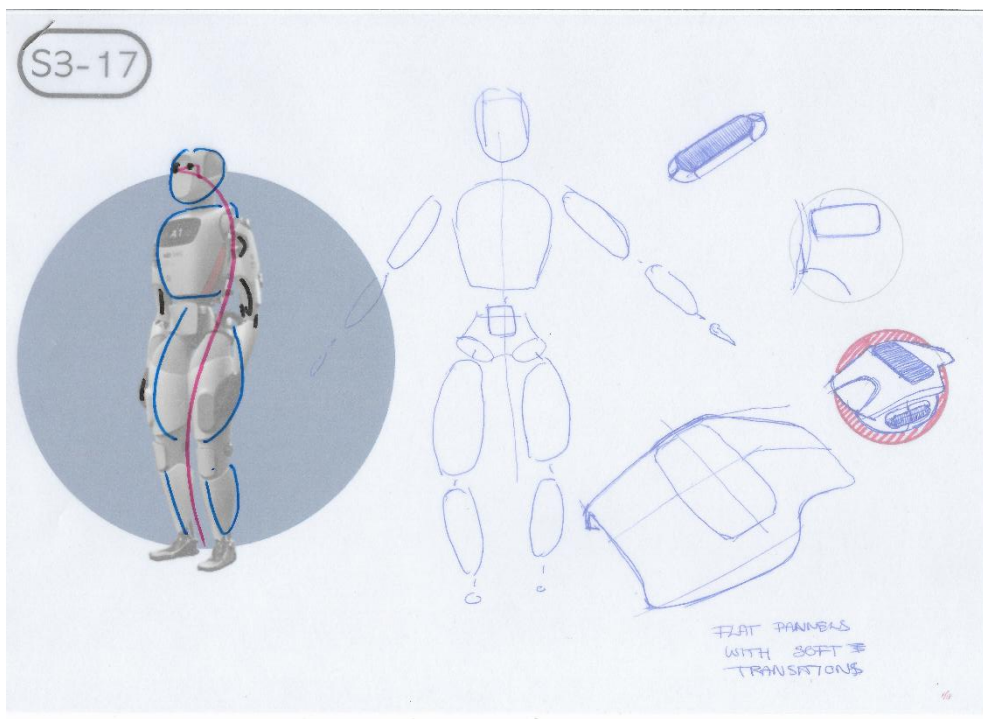
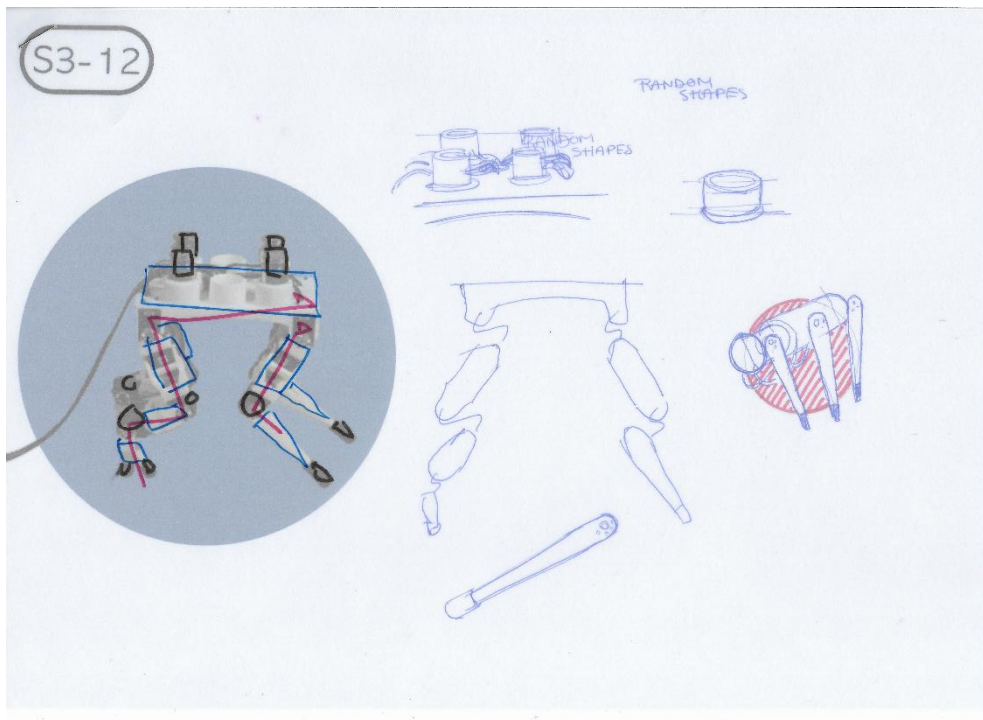
S2-19



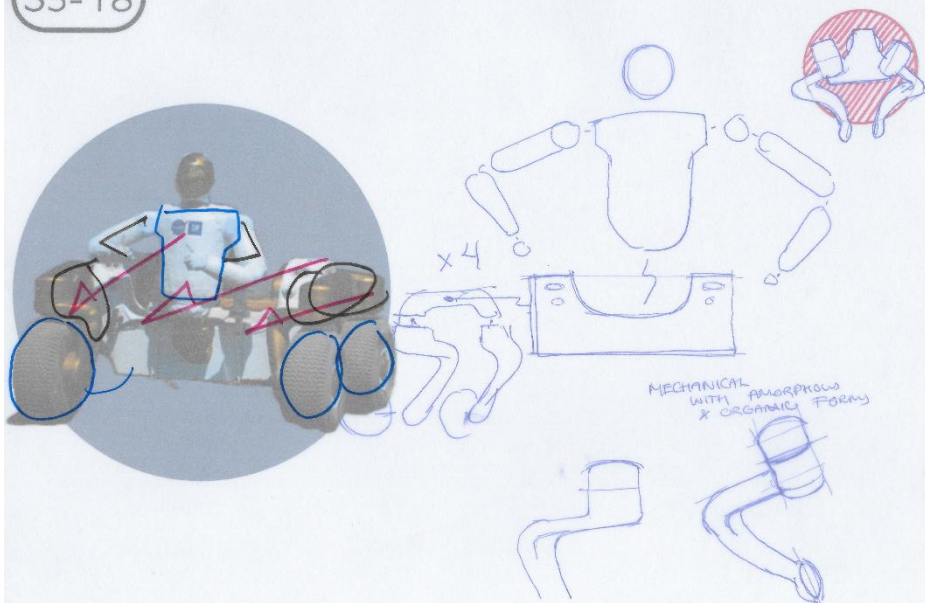
S2-21



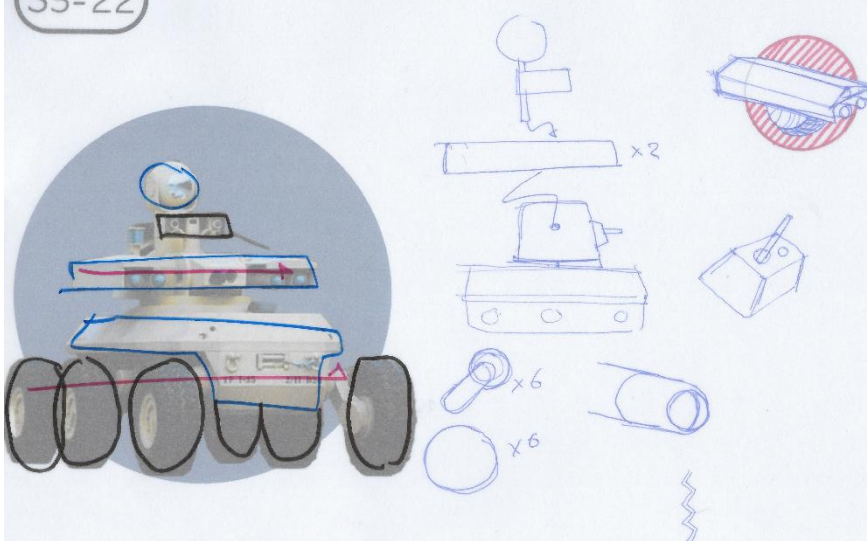
15. Dominant Design from Set 3



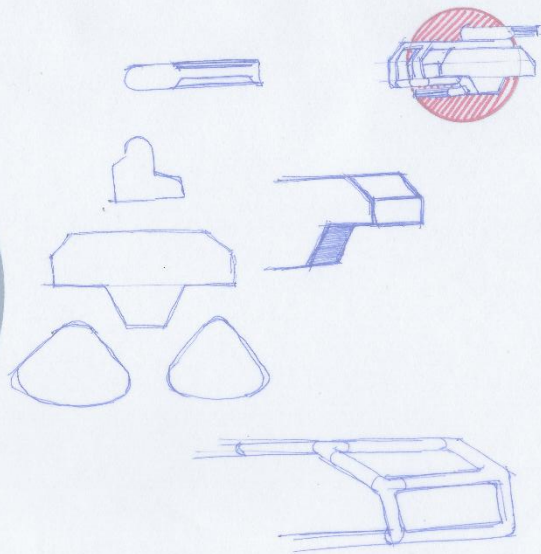
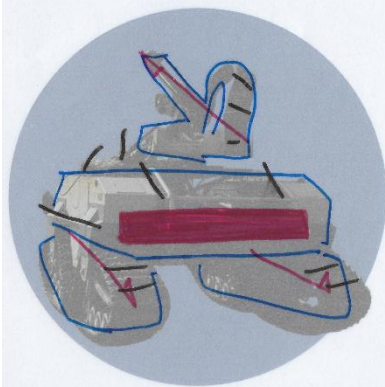
S3-18



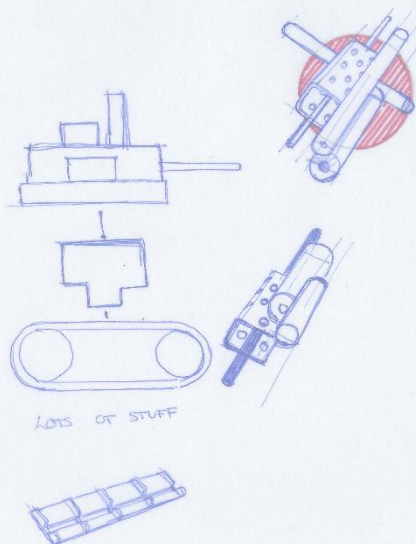
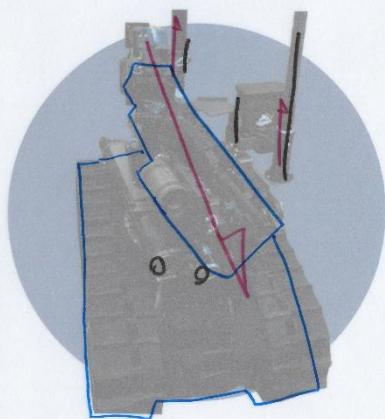
S3-22



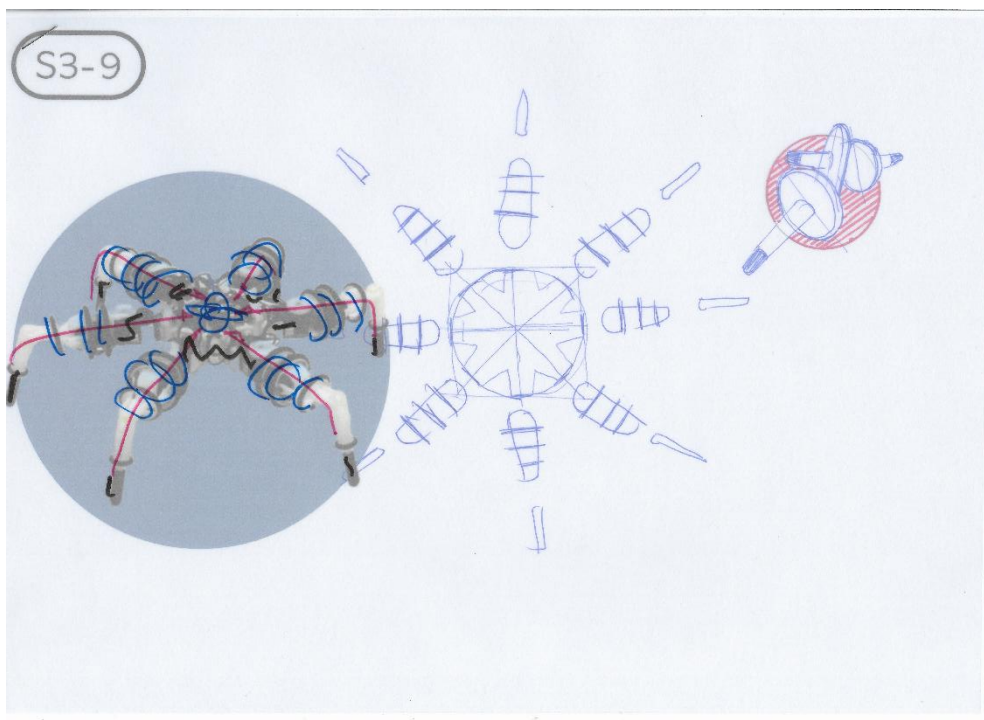
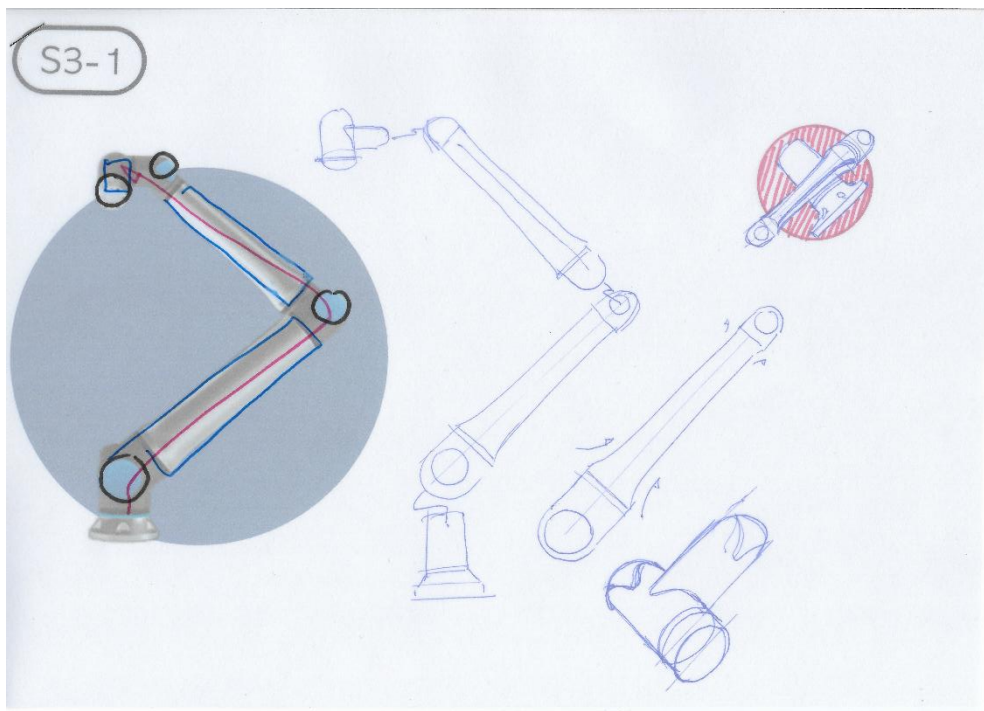
S3-23



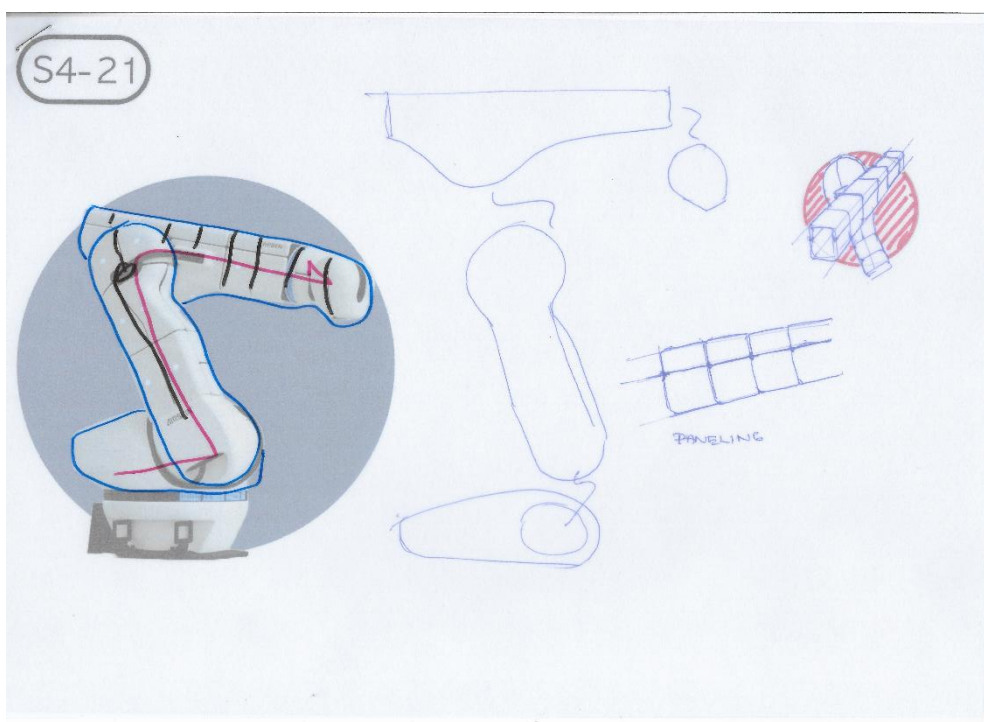
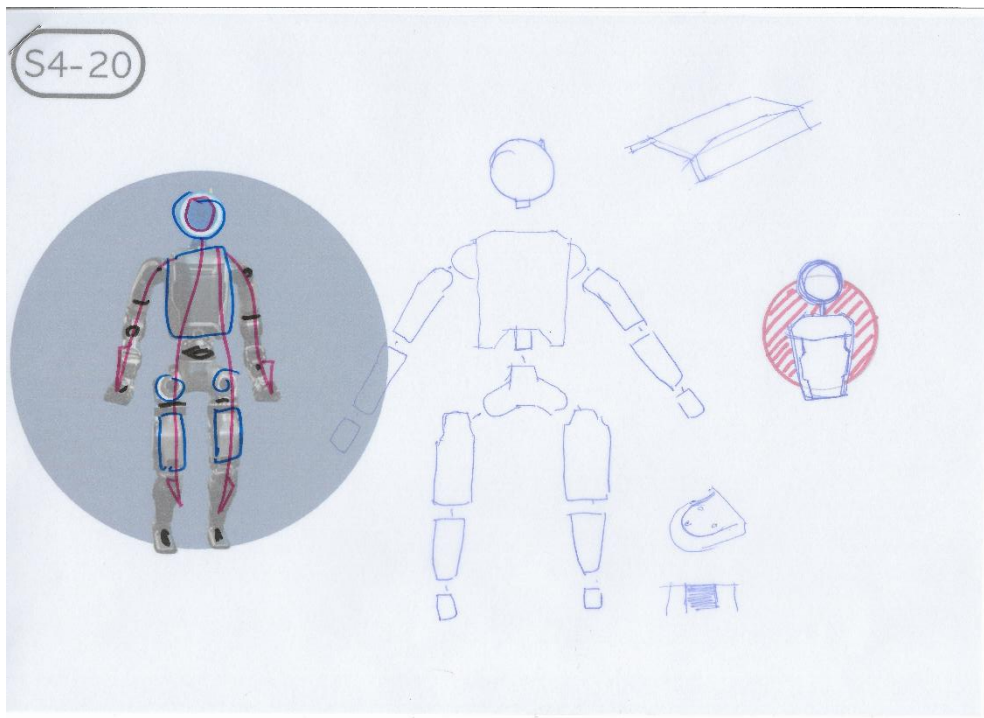
S3-24



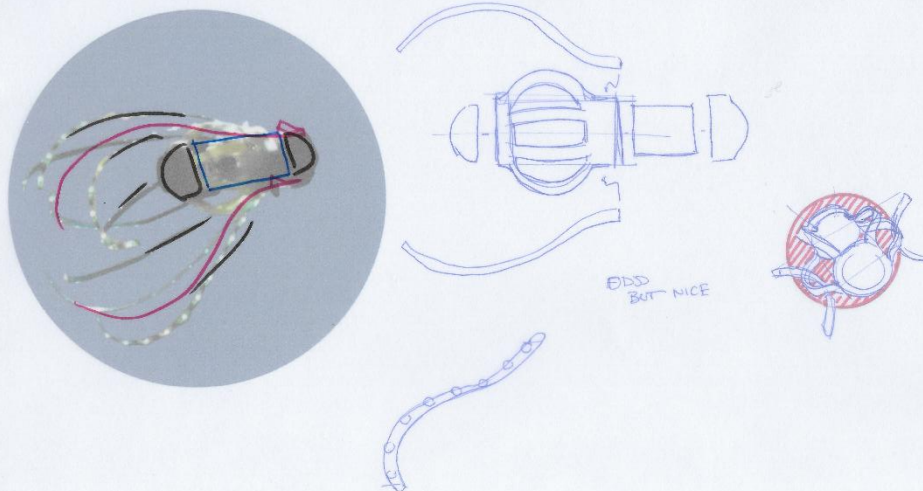
LOTS OF STUFF



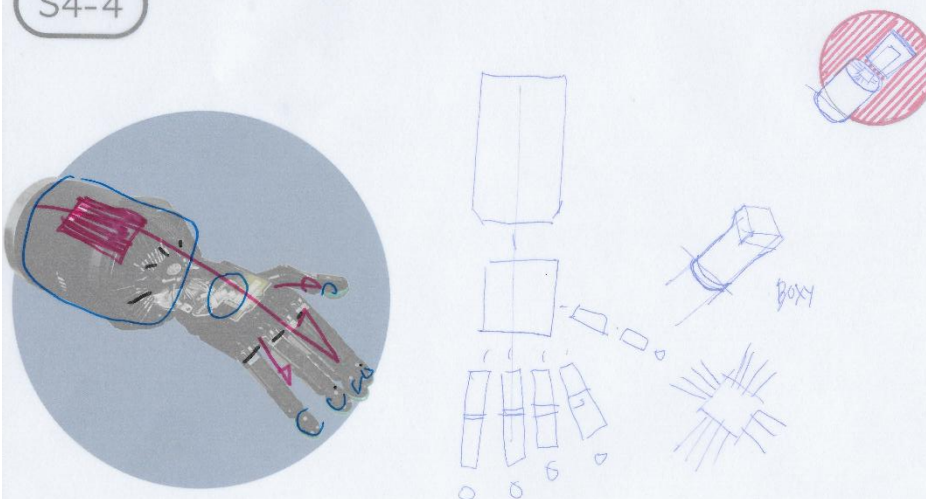
16. Dominant Design from Set 4



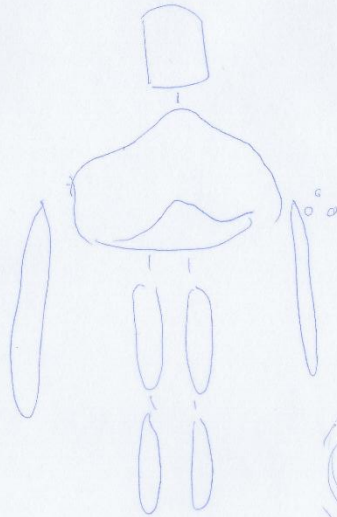
S4-24



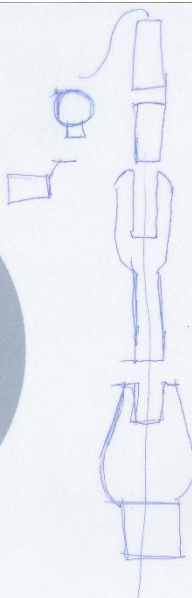
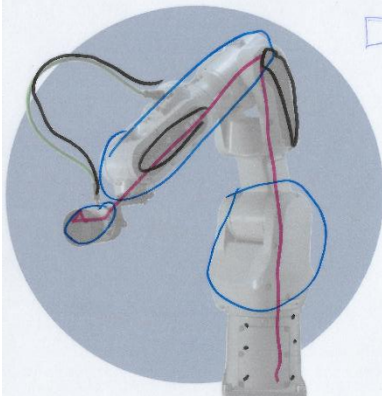
S4-4



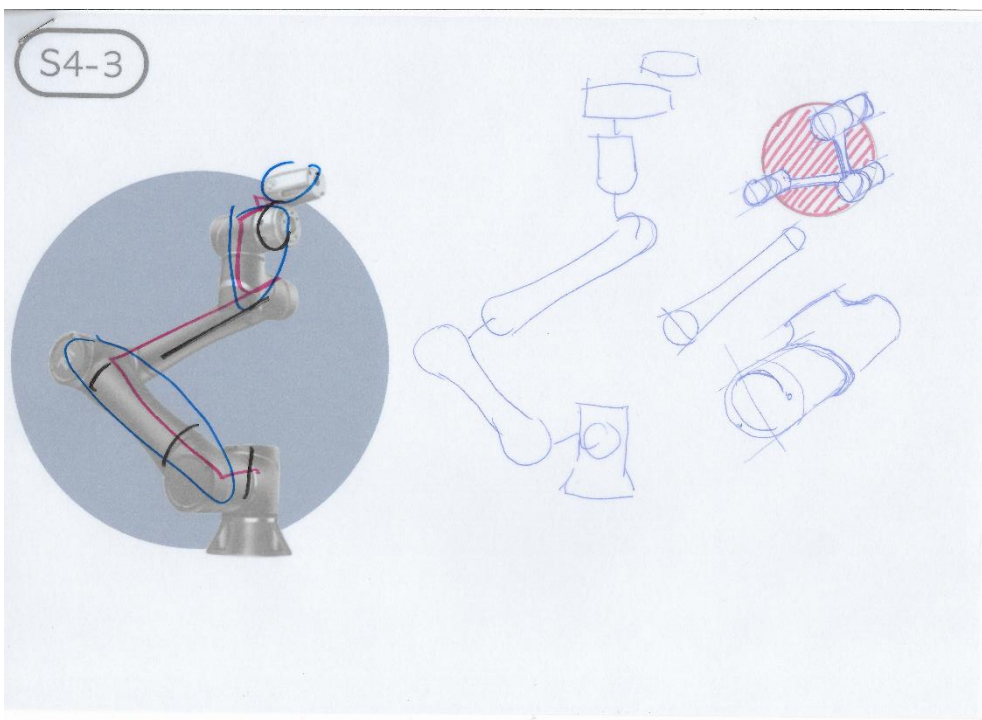
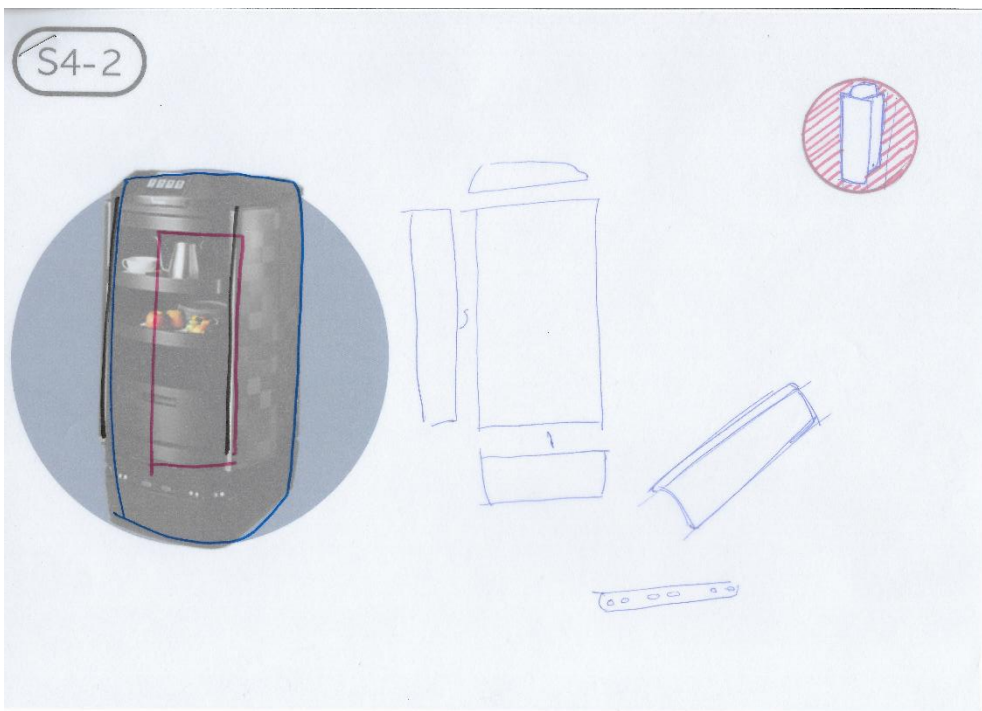
S4-18

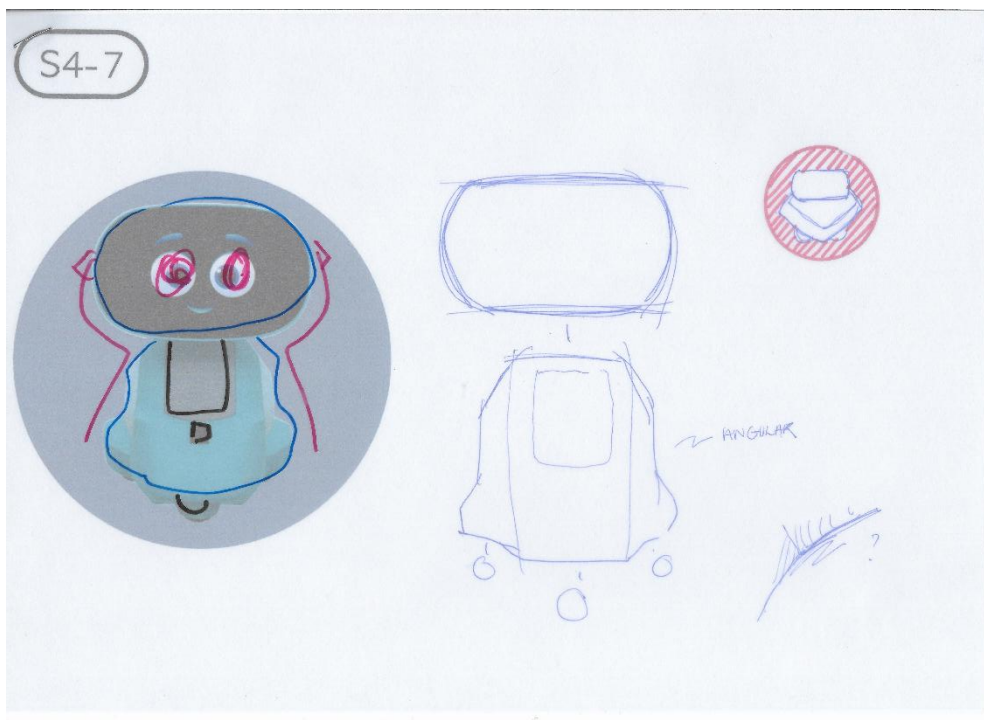
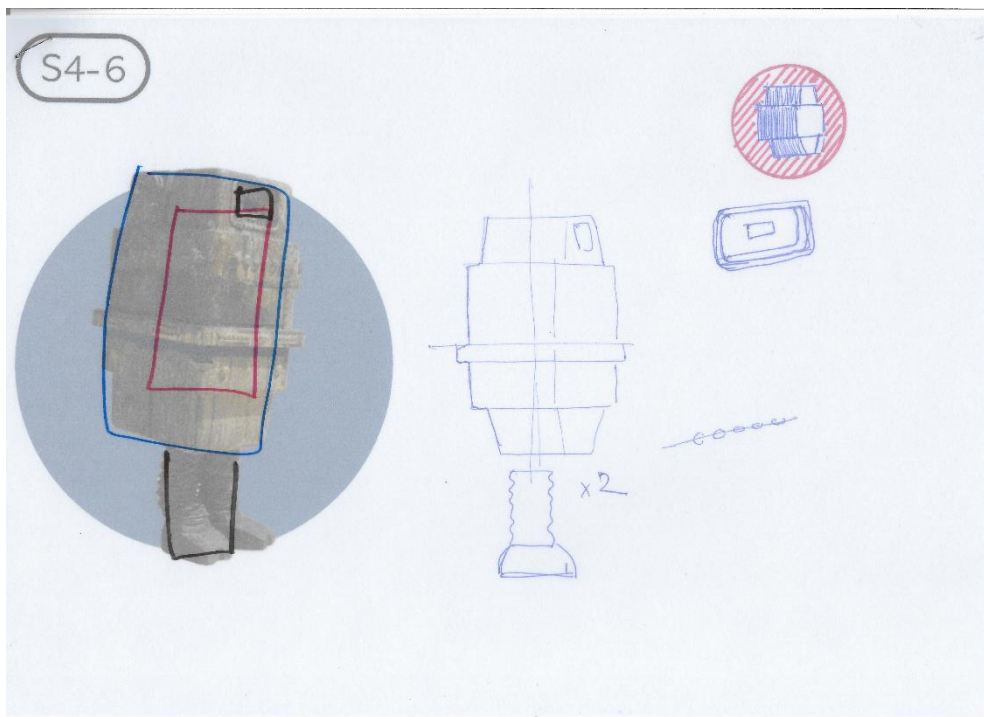


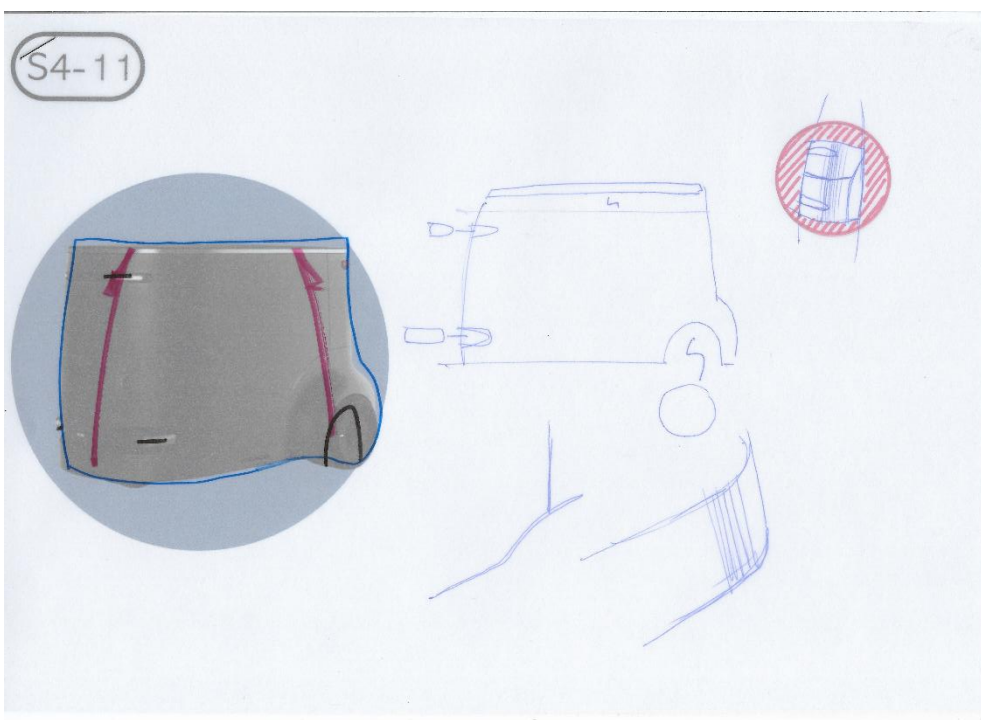
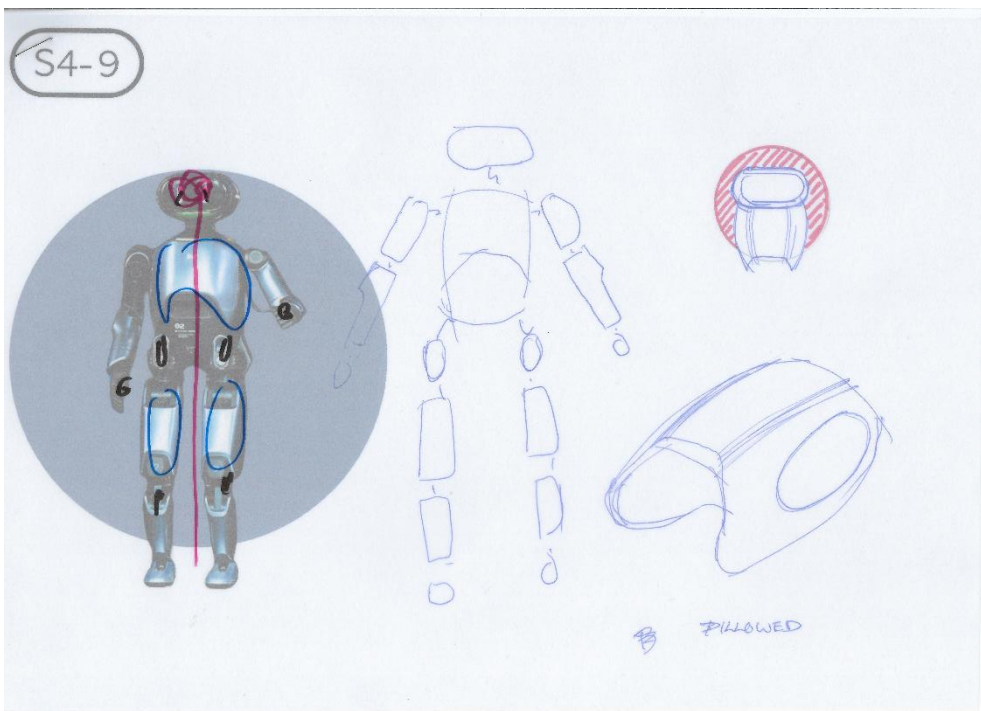
S4-1



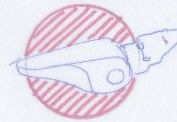
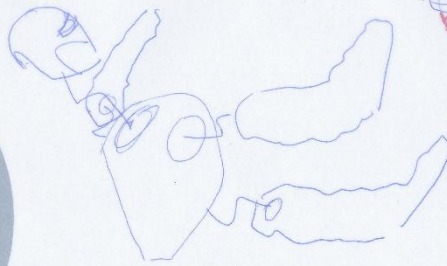
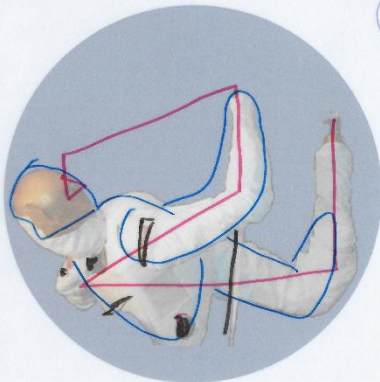
CYLINDERS
MEET RECTANGLE



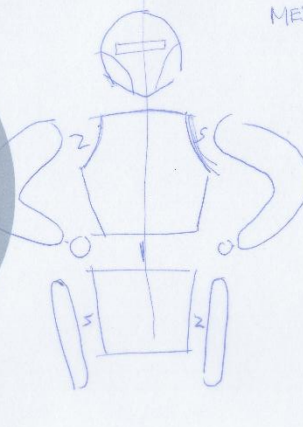
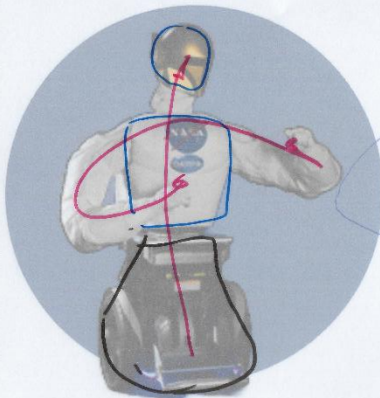




S4-13



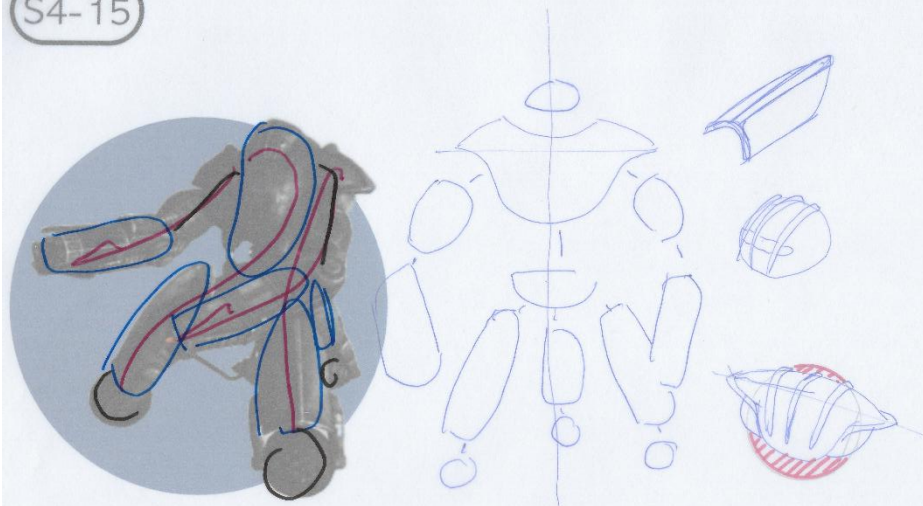
S4-14



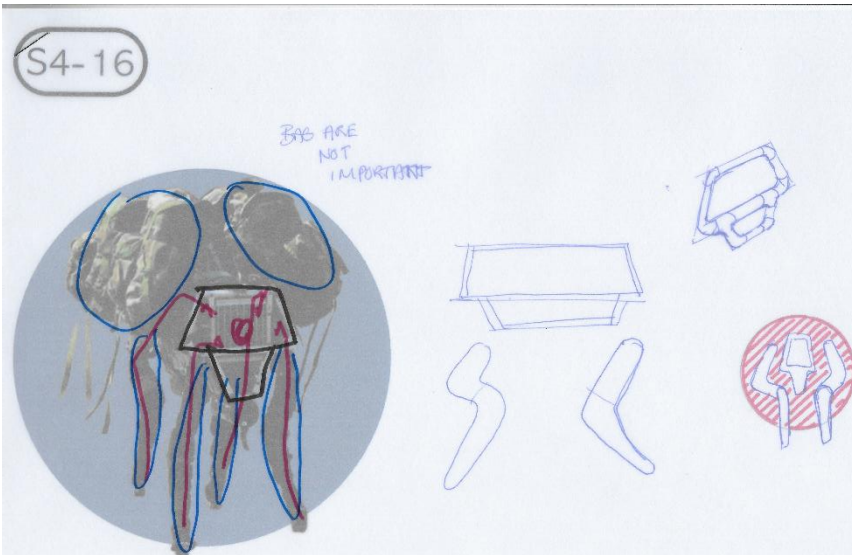
MESSY



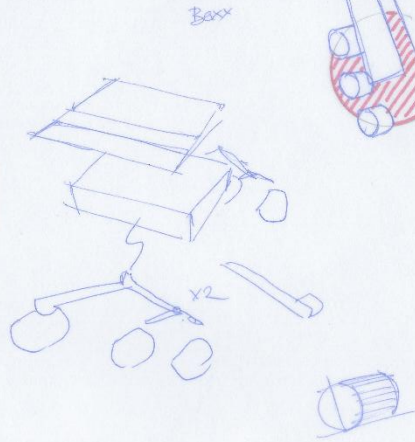
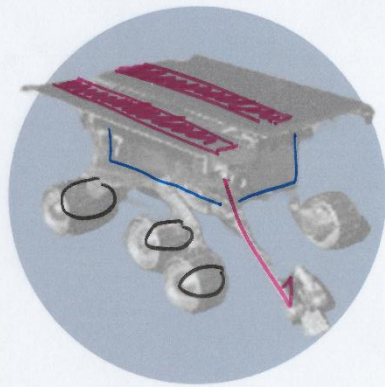
S4-15



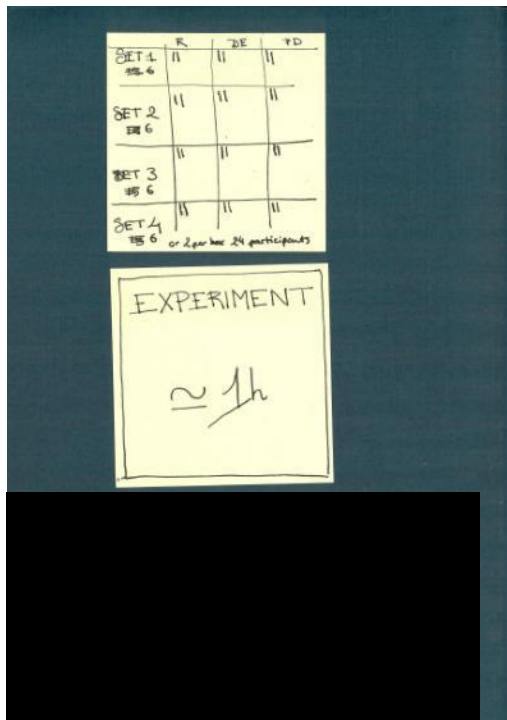
S4-16



S4-17



Appendix D – Reflexive Journal



Robotist

Participant 1
Date: 30/7/24

Set 1

The participant understood the morphological terms but when an anthropomorphic element was used in a robot design (e.g. Arm or Head) rather than a full anthropomorphic design the "arm" like robot was considered an object. Components of the human form were considered objects but a more complete humanoid design was anthropomorphic. Meaning an anthropomorphic design was seen as anthropomorphic. This was the same for zoomorphic designs. The participant did not draw or mark on the robots/analysis area. He was much more comfortable gesturing along with his verbal descriptions. Realism was seen at times as being linked to feasibility & functionality such as with more functional designs. Yet realism was also seen in robotic designs that mimicked humans or animals. The clarity of joints lead to evaluating the robot as more mechanical and this clarity of joints determined the perception of functionality and how the joints would move. Chaos seems to be associated with danger or abnormal aesthetics of humanoid or zoomorphic designs. After the joints exceeded three joints akin to a human arm it was seen as less anthropomorphic yet still called an arm. The clarity of joints affected the sense of realism and the way in which it was categorized. The type of joints at times made the robot seem more abstract. Natural and strange were associated together at times due to the novelty of design or number of joints with curved designs. This was the opposite if the morphology was more reminiscent of an animal for example but had a mechanical appearance. Strong functional

//////

Natural/curved elements were seen as strange. The morphology could be familiar and yet the aesthetic exclusion would render something familiar akin to a face as strange/chaotic (e.g. the absence of skin). The participant considered the act of stylization to be present when there were more curving forms or a lack of clarity on perceived functionality. Participant had seen Robot 1B of Set 1 in person and had a more pronounced emotional experience seeing the face as "terrifying" and into the uncanny valley. For now he saw the mechanical design as conveying clarity despite the obscure functionality. Yet at times purpose was seen as making it realistic. The "coverings" as he referred to the plastic shrouds would determine the strangeness of unity of a design as if it was anthropomorphic or zoomorphic with exposed mechanical element it was seen as strange. Yet if it went outside natural morphologies (e.g. more joints) it was seen as natural if it had curved elements or mechanical with angular elements but seen to be strange & chaotic.

Design Engineer

Participant 2
Date: 31/7/24

Set 2

Participant had a more pronounced emotional experience. It seems that when it's positive the experience is wider and details of why emerge. Whilst when it is negative the experience focuses on those negative details. When names were on the robots this affected the experience, typically negatively in this with this participant as she did not associate the names to be as cute as the robot design. The participant associated covered joints creating a sense of unity and exposed as a sense of chaos. Colours were associated with different experiences and preexisting objects such as red related to luxury, or black and red with 2017 professional cameras, and a negative experience with hospital colours, white & blue. Poorly executed aesthetics reduced the perceived value, and less reliable and weaker. This also made the participant think that the designers were inexperienced. In line with the literature blue seemed to have not association emotionally speaking. Styling was associated with abstraction, and this varied in terms of the positivity and negativity this seem to depend on how coherent the meaning is being conveyed by the design aesthetics. Designs with a more abstract that were perceived to have two opposing morphologies such as functionalism and anthropomorphism seemed unfinished or when a design had a more dominant morphology that was well executed aesthetics but was dominant and in the

Rs
Date

in the experience and the inferior morphology with poor aesthetics was eventually ignored and unwanted. Participant had ~~a~~ very pronounced emotional reactions to "cute" robots with highly rounded forms with iconographic faces. Seeing them as toys, or babies and being small in stature. "Cool" robots with silver or warm colours with ~~and~~ more energetic and angular lines was seen as masculine and separate from herself. She wanted to own cute robots and saw them as closer to her. Subdued colours and softly transitioning form with an easy/calm sense of flow were considered as more domesticated. This could be because calm is associated with the home. Anthropomorphic designs ~~that~~ caused much more pronounced emotional experiences ~~to~~. Silver and sweeping form seem to be seen as fast. For ~~the~~ the exposed mechanisms were not associated with realism but the design was seen as abstract. This could be due to the merry composition and that different areas were associated with different objects.

Rs
Date

7.

Maybe this is why he was trying to determine the feasibility of its ~~function~~ design to fulfil the perceived function. Does his more subdued ~~exp~~ aesthetic experience is because of him looking at surface level rather than having an intuitive or subjective experience.

Robotist

Participant 3
Date 1/8/24
Set 3

Participant was not interested in marking, writing or drawing on the page. The idea of determining if it was designed purely around a function seemed perplexing to him at times. Functionorphic to him was whether it appeared to be able to fulfil the purpose he perceived for it. Not whether the designers had to consider other elements. Although I suppose this isn't incorrect from ~~that~~ a more technically minded perspective. Participant preferred evaluating the terms rather than deeply explaining and exploring his aesthetic experience. When the manner in which the robot could move was not clear he saw it as less functional. More of the robots with out legs, or the robots that were fixed in place were seen as more functional. A functionorphic than those with legs. Card 13 was associated with common household objects but was seen as strange. Could this be because of the unclear function of extending neck design. The robot with a combination of morphologies ~~was~~ seemed to be seen as less functional. Participant made more references to previous cards rather than spending more time on the aesthetic experience. This participant ~~also~~ evaluated more aesthetic dimensions ~~in~~ in the middle mark than any other participant. With that he at times marked the ~~most~~ most striking morphology first and then evaluated the aesthetic dimensions. At times jumping around both areas. Robotist tend to want to evaluate KPIs.

Robotist

Participant 4
Date 1/8/24
Set 4

Participant wanted to know the scale of the robots as he felt as though it would change his emotional and aesthetic experience. Unfortunately many of the robots did not have any indicated scale in the photographs of them. The addition of mechanical elements to the design seemed to make him exclude it from zoomorphism and to him they felt alien like. Indicating that there should be a different morphology for strange alien designs. With the functionality being unclear this increased the sense of strangeness and was seen as being alien like. He strongly associated the anthropomorphic robots ~~that~~ that had large joints with apes and other types of primates. The clarity of ~~the~~ the functional requirement seemed quite important to him. Card 13 the robots morphology was too strange to zoomorphic due to the components being relatively simple. Card 20 for a humanoid robot and therefore anthropomorphic ~~was~~ considered also zoomorphic possibly due to the aesthetics of the design. Many of the co-bot style robots were seen to be growing like plants. ~~With~~ that it seemed that the colours didn't affect the analysis of the forms when the forms were seen as unpleasant. What ~~was~~ is compositionally dominant guides the experience but with robotists the functionality in relation to the perceived purpose guides the evaluation of the robots aesthetics more than anything.

Participant 5
2/8/24

Product Designer

Set 2

A linking to a ~~remembered~~ object ~~that~~ draws that functionality into to robot as well as ~~all the~~ the relevant associations and elements of the relationship. The perception of ~~design~~ ~~being~~ ~~being~~ being proprietary ~~to~~ made the design seem more functional and therefore functionomorphic. To this participant functionomorphic meant ~~functional~~ how function the design was not whether it was designed around purely designed around functional considerations. This participant had a very different emotional experience to Participant 2, the female DE, less of a focus on human/cute design elements. Not reference to social standing concepts such as 'luxury'. Screens were identified as interactive elements but seemed ~~unnecessary~~ unnecessary when other control surfaces were present. A poor integration of different morphologies resulted in its meaning and function being unclear. Amorphism was linked in a negative way, to clarity of function at times. Participant saw red and "black" as "cinematically movie evil". Tapering towards joints seemed unnatural. Realism was linked to preexisting connotations/links such as looking like a factory robot. For some reason he saw rotating limbs as unnatural. I suppose limbs don't rotate along their length but the twist at joints and shift occurs in a manner that achieve rotation in a different way than robotic limbs do. Asymmetric/noise joint design makes them feel new. For (6) the overly simple rounded design made it seem

less sophisticated and was seen as a child's toy, a learning robot, as well as the colours giving this connotation. Straight design elements were seen as more mechanical. The distance between joints ~~made~~ had an effect on how natural it was perceived to be. As in the further apart the more unnatural and the more seamless, so to speak, they ~~were~~ were perceived to be more natural. The repetition of forms made the design less amorphic, therefore the repetition gave structure. The size of joint also had an effect on how natural is seemed. Large exposed joints seemingly less natural. Functionomorphism & function was linked to purpose to this participant. This participant linked modernity to neomorphic. It seems that participants that are more closed minded/biased, towards their perception of themselves and of matters relevant to the objects in question and were not ~~the~~ seemingly good at intuiting the subjective and were ~~extrapolated~~ ~~see~~ see what they count to see about themselves and what they count to see in the world in the object. Should I note design who was extrapolated and who was introverted? More humanoid robots were seen as less functional when ~~they~~ ~~had~~ participant saw human interaction as a function. Social interaction not seen as a real function. This could be due to ~~the~~ robots being objects and objects being not living things and as such it is impossible for an object to have any social interaction. The more neomorphic the

Participant 6
2/8/24

Product Designer

Participant 6
2/8/24
Set 3

more stylized it seemed. But playful near with a new morphology seemed ~~amusing~~ amusing to the participant. For (10) It was seen as abstract yet mechanical, typically mechanical results in a 'realistic' evaluation. Moreover the new morphology of the robot was not seen as such due to there not being any outer casing. The specialization of the design seemed relatively pointless to the participant. Previous exposure to robot makes it more realistic. Very anthropomorphic designs seemed impractical for real need yet impressive. If certain designs echoed different objects and had no other perceived function but movement, then it was seen as to not be neomorphic. For (14) the repeating pattern meant it had no distinct overall form. Could this be due to the function of the design being unclear and ~~the~~ a simple pattern obscuring perceived function/ not giving clarity on how it works and what it does. ~~Refer~~ to other objects imparted their meaning too. For (15) body panels were seen as to distract from function. Maybe aesthetics is seen as superfluous? Aesthetics not seen as related to function. Perceived function matching appearance meant that it was seen as more functional. Movement seems more important when the design is less understandable?

For some reason the participant saw the colour blue as modular and the identified that the colour separation was what was also giving a sense of modularity. Another participant who saw the arm form as a organic part of a plant in this case the roots. Different colours and sense of scale affect ~~the~~ which type of environment the robot seems appropriate for. Smaller scale with white colours ~~and~~ and rounded modular for seems more appropriate within a lab and with shorter limbs ~~and~~ and more joints it seems capable of more complex movement. Plumbing pipe were seen as modular. Small end effectors were seen as more precise when seen as small compared to the rest of the robot. (2) had a toy like appearance and was seen as being remote controlled. Other designs with wheels were to seen to be RC like. The greater the joint distance and the thinner the link the less accurate the robot was perceived to be. This participant seemed to feel that more colour was inappropriate for a robot. The participant saw flowing forms as safer to work with and larger joints as lacking mobility. Flowing forms seems like to a soft sense of movement assuming the sense of movement is soft. The sense of complexity inform and perceived movement seems ~~related~~ ~~to~~ ~~precision~~ ~~and~~ ~~comp~~ safety. If the sense of flow ~~is~~ is complex, distinct, and not violently energetic. If this is matched with

the perceived environment such as a laboratory then the aesthetics will combine with the perception of movement and context creating a positive and possibly deep emotional experience. This participant had more negative experiences of unusual designs. (6) has a halo and was seen as angelic but interpreted as a 'bumper'. This interpretation of protective 'bumpers' made the robot seem less safe and with poor functionality. Exposed mechanisms were seen as unpleasant. The sense of scale was altered by the composition of the aesthetics. In the case of (6) it was the posture of the legs. Are there more appropriate aesthetics for different scales. The addition of perceived necessary design elements, such as headphones, came among the participant as robots can't hear. The participant pulled the functionality and meaning of object the recalled in relation to the robot aesthetics. But this can cause a mismatch when the functionality of the object that is recalled does not match that of the robot. So the memory is more powerful when dealing with new circumstances and objects. It seems that whatever seems the least clear from the aesthetics is what create an uneasiness in participants. Participant saw humanoid robot as 'creepy' and 'unnatural'. The combination of human (upper) and other parts of one other morphology seem to be very unpleasant. Mechanical was seen as less reactive on legs, reactive. Scale & complexity of detail indicates scale.

Not knowing robot from previous experience results in more visceral reaction and of aesthetic experience and reliance on the aesthetics. All they have is the aesthetics to interpret. A mismatch between morphology (e.g. zoomorphic) and aesthetic dimension (e.g. mechanical) results in the design being strange. Features that appear to be hiding were seen as unpleasant and almost malicious.

Participant 7

3/8/24

Product Designer

Set 1

Many participants as Product Designers saw the arm of the robot as phytonomorph. Typically ~~some~~ associated with a flower. End effectors in robots and other robots seemed to imply primary function. What the robot aesthetics imply through the participant remembers/recall other objects/phenomena/context/media extends the functionality and purpose of the design. Excessive simplicity and not communicating the way in which it functions and movement results in the design appearing strange. Movement continues to be important to almost all participants. They imagine the more movement based on the perception of joints/areas that could result in movement which is then affected by the meaning of the aesthetics with whatever is recalled from the participants' experience that imparts further meaning, function, and purpose. (3) the participant saw the quantity of the curvature as "an attack on the senses" with the motor covering which were colored as not leading any where. Clearly, there is a threshold where curvature mixed with high complexity and high chaos creates an unpleasant experience. Visual areas draw the eye especially in reference to what morphology ~~reminds~~ the design reminds people of, in terms of how it doesn't fit the morphology and the recalled thing. This participant was more aware of made it clearer that the robots were designed by designers with

a clear intent. (1) has a very dominant anthropomorphic design with very mechanical features but the participant evaluated it a natural ~~thing~~ whilst he said it had an "incomplete face" that was "skinned". Less this because the very dominant anthropomorphic design made it seem natural or that the mechanical elements were curved plastic covers? Many robots throughout the participants were referred to as toy like. Is this due to the perception of scale, in the absence of other factors such as context, being based on quantity and complexity of detail. I think in the case of (3) it is due to the soft rounded features. Function was perceived to be hidden by aesthetic features. Aesthetics not considered a function. Although aesthetics is not considered a function it seems to be linked with purpose and meaning as it imparts these ideas to the participant. Flat back on being regularly associated with carrying things. Using certain morphological characteristics but inverting them ~~or~~ changing them result in the design being evaluated as strange. (4) has a more abstract evaluation due to the complexity of all the arms with a clear compositional direction. Pre-existing knowledge and assumptions reduces aesthetic reliance during their experience. In some cases with roboticists does humanizing robots de-humanize humans in their eyes of the participant? Does Morphology dominate the experience when there is a lack of aesthetics?

Participant 8
Date: 6/8/24
Set 4

Design Engineer

The set was out of order unfortunately but this didn't make a difference. This participant didn't want to view it on the viewing mat. Design elements not clearly integrated into the purpose become unclear. When a robot had a 'head' ~~there~~ as akin to a human then the head was identified first. Pipes were seen when separated lines were large enough compared to the body but when thinner they were seen as wires. The function was ~~top~~ inspired by what the design reminded the participant of. This ~~imposed~~ ~~seem~~ to be recurring ~~and~~ through out the different participant types the meaning and purpose implied by the aesthetics and effected by the emotions reminds participants of different phenomenon or objects and draws in those movements and behaviors into functions and purpose. His analysis returns to a functional analysis after initial reaction. What is deemed acceptable seems to be determined by the perceived purpose, appropriate context, and perceived function. At times when certain functions were unclear design element appeared superfluous. ~~Maybe~~ the design ~~seems~~ seem poorly executed. Participant seemed to look at the eye catching elements, then if present element that were unclear for perceived to be incorrect, then looking then ornamentation. This participant seemed more interested in technical functional analysis. Thematic meaning draws mind to phenomenon/object with similar function.

Participant 9
Date: 8/8/24
Set 4

When functionality seemed unclear the participant assumed that ~~imposed~~ ~~for the~~ the design element was for purely aesthetic purposes, especially when it was seen as pretty. Perceived function affect sense of usability and thus what is seen as negative first and then what is positively seen. Prop objects help imply function and manner of movement (e.g. Food denotes hospitality and as such move towards you). If the movement was not clear it was seen as stationary to this participant. ② The fact that the door could close was not perceived by the participant. As well for ③ the decorative pattern was a total mismatch in terms of the perceived meaning of the robot and the meaning of the pattern. The digital pattern was seen as "collapsing" and destroying the food and thus bias against its perceived purpose of hospitality. The robot designs ~~where~~ were regularly seen as having not purpose due to not end effectors being present. But still could be seen as functional. ③ was seen as very intimidating due to giving the same feeling as Hal 9000 from 2001: A Space Odyssey. Generally featureless but having and not having a face. Participant stated "peering right into you". The whole body had a implication of having a face. Clothing on the robot was seen as forced on as robots don't need to be warm. Humanizing robots through ~~where~~ perceived mimicry of different things robots uses and do seem to be unwanted by

Participant 9
Date: 8/8/24
Set 4

Robotist

all participants. When there was no distinction ~~in robots that appeared~~ of the part of robots that appeared monolithic the participant circled the whole robot and then identified different elements. Legs were seen as unstable if they had no clear line.

Participant was focused on identifying functional design elements more than was he saw as the aesthetics. End effectors continue to be seen as implying the function of the robot. Movement of part and whether it is stationary or not imply context, and purpose. Concave design elements of ③ made the design seem more abstract. Maybe because concave form appear less structural. The robotist considered the human hand to be an object but changed his mind. Could this be because he was trained as a Product Design Engineer but now work more in robotics. Recall of ~~previous~~ other objects continues to influence perceived function, context, ~~and~~ purpose, and meaning. White still associated with medical/lab/clean room contexts. Eyes seen as anthropomorphic especially attached to a head. Mouths seem unwanted. Eyes perceived on designs without a head (where the eyes are a part of the body) then it was still ~~anthropomorphic~~ anthropomorphic but less so and they were seen as cannons. Does the level of detail of the eye element affect this? It seems so. Not knowing function leads to low functional evaluation despite functional meaning. ~~the~~ the participant perceiving the robot being designed around functional requirements. Technically one does not need the function ~~to~~ purpose to understand this. Human interaction not really seen as a function except when it may be the only function. Robotists seem to use aesthetics to perceive functions based on prior robotic experience.

No.
Date

Eye eliminated the design from being considered as phytomorphic. In more aesthetically considered designs there was more interest in the aesthetic and playful behaviour. Scale continues to be linked to size of detail and complexity. He circled points of interest and underlines with some notes. Remote controlled characteristic/function seen due to movement ability. ~~Maybe~~ Maybe due to antenna and type of vision system as well? This participant filled the page with more organization.

Design Engineer

Participant 10
Date 14/8/24

~~Set 1~~

Set 1

When participant perceived how it would function he seemed to consider it to be functionomorphic. As it must have been designed this way for a reason. Movement continues to be an important part of the aesthetic, functional analysis, and emotional experience. Joint size changed the perception of strength. The end effector continues to be relevant to determine the functionomorphism of the robot. Some robots ~~were~~ were seen at times to ~~look~~ look like a rabbit leg. Folding movement ~~is~~ of design was seen as to interfere with the sense of curvature. Is this due to the perceived movement not matching the ~~shape~~ aesthetics. Human body parts seen as object. Perception seems to "head"/end effector, Body/Chest area, which is usually the means of movement. Perceived movement continues to affect the emotional and aesthetic experience. Identified "known" elements and then unknown elements. Swivle face like element are perceived by different participant maybe except the roboticists. Excessive curvature and complexity ~~results~~ can result in the movement being unclear and the participant having an unpleasant experience and a lack of trust. Complexity ~~without~~ detail ~~and~~ and curvature without detail makes the design more amorphic. That is with a lot of complexity. A lack of pleasing aesthetics made the participant think it must have been designed around ~~a~~

No.
Date

function. Does this mean it is seen that humans are seen to make things less functional? Or that aesthetically ~~pleasing~~ pleasing design are seen as useless? Eyes seen as adding emotion. More playful design of eyes seen as toylike. Perception of design being made up of parts of different designs was seen as not being abstract. Is this because using designs that are well known icons of designs that are well known in the aesthetics of a robot or other objects results in the participant recalling and constructing associations ~~with~~ using the remembered objects and applying these associations to the robot or other object. Rounded plastic designs regularly associated with toys and the stacking toys. Distinct morphologies seen as "it must have been designed this for a reason". There is an expectation that the designs are reasonably designed. The perception of the direction seemed rather important to the abstractness of the design. Front to back was seen as more relevant than top to bottom. Top to bottom was perceived through the natural way ~~of~~ objects are perceived and images on the page. From top to bottom. Swivle design cue such as joint and limb design making the robot appear more natural and familiar. Such as subtle bulges in "forearms" or joints appearing

No.
Date

like shoulder. Haphazard and incoherent aesthetics with exposed metal and circuit made design seem like prototypes. End effectors conducting one task seen as usual in robotics. Detail, volume, and ~~complexity~~ complexity of detail continue to ~~define~~ ~~to~~ imply the sense of scale. Unclear function made the design seem more abstract. Very anthropometric morphologies seen as strange and not very functional as "you could design it for a function ~~too~~ different away". Dominant morphologies evaluated first. Cameras seen as faces/eyes. Colder too need to be inline with perceived function and purpose. This is the case with all the aesthetics ~~matching~~ the complementing the function and purpose.

Participant 11
Date 14/8/24

Design Engineer

Set 3

Participant identified 'links' and 'joints' regularly on the different robot designs, especially the co-bots. Tapering designs from base to end effector, where the base is larger and the wrist of the end effector is smaller, was seen as natural. Maybe due to the similarity to trees. Some joints were described as "self intersecting" and were unclear to the participant and created a strange sense of movement. If movement path not limited and self intersecting as described, then it results in an unpleasant experience. Functionorphism was low for designs that appeared obscure in form or movement. Identifying points that implied the construction of the design made it more comprehensible to the participant. Such as porting lines and bolt points. Curved elements seemed less functional to the participant. Maybe integrating the aesthetics and functionality as one would produce a more valuable design. Where aesthetics, function, and purpose combine. Using elements of amorphology but not all of it appeared odd to the participant, especially when it came to anthropomorphic robots. Unclear functionality made a design seem more abstract. With a "cube" face, rounded forms appeared playful. The projected meaning affects the aesthetic

experience of the form. Curvature with complex ~~abstract~~ compositional lines that intersect was seen as abstract but with ~~whole~~ compositionally whole curved shapes were seen as more pleasant and cute if it had a iconographic baby face. Exposed components were seen as less pleasant and the aramid design ~~also~~ also. Designs were rated as abstract when the function or purpose wasn't understood. Design emotion scale would have been useful maybe. Although the emotion are being recorded in a sense. Exposed mechanical designs with no ~~wire~~ wire were seen as clearer to understand to the participant. Plastic enclosures were seen as decorative and made the design less functional. Dotted pattern on beige plastic was seen as skin. (13) with a mixed morphology was ~~referred~~ referred to as a "chimera". Participant wanted to know if a cultural artefact was considered an artefact. Such as characters or mythological beings. Designs with blob shapes and protrusions are regularly associated with viruses. There will need to be sub-categories to the morphologies. Same with the aesthetic dimensions, taxonomy. Paradoxia seen in simple designs with car-like head lights. Association with other designs continue to help construct meaning and affect perception of design.

Participant 12
Date 15/8/24

Design Engineer

Set 2

Participant regularly started with functional analysis and identifying DoFs. There is a degree of association with other robots and animals ~~as~~ towards co-bots such as Boston Dynamics ~~robot~~ 'spot' legs or dog legs. End effectors continue to be relevant to perception of what function it achieves and how functional it is. Functionorphism seen as functional. Participant had a better grasp of aesthetics than other design engineers. She even mentioned an aesthetic style that is contemporary called "Fridgier Aero" which no one has done really except snowing fallout or stormtroopers. A very open and emotional experience. Association with pre-existing objects continues. Eyes seen as unpleasant. Aesthetics not seen as functional. Blue and white seen as medical. Matt and "cheap" plastic seen worsen the design. Adding aesthetic that goes away from the purpose creates a negative association. This balance between function, aesthetics, purpose, and meaning ~~needs~~ seems relevant to positive view and experience of the aesthetics. Participant evaluated the theory and discussed ~~her~~ her analysis and then wrote her thoughts she ~~discussed~~ discussed. Movement continues to be relevant to aesthetic experience. Knowledge of robot affects the aesthetic experience. Sense of scale determined by size and complexity of detail. Participant rebelled more and could imagine

the design in different way outside of the function she perceived. Eyes with the whites of their eyes was seen as being uncanny. Scale assumed due to recall of pre-existing object. Robots that are perceived to have an amalgamation of pre-existing parts seen as less unpleasant than shapeless forms with tools attached.

Participant 13
22/8/24

Robotist
Design Engineer

Set 2

Not identified on most designs but end effectors without clear tool made the purpose unclear. Morphologies were evaluated first. Most cases aesthetics elements were seen added after the functional side of the robot was designed and he associated curvature with aesthetics but not angularity. Meaning was built more from functional and theoretical interpretation rather than open imaginative creation in a sense. Are these two behaviours? With the sense on view the object as something else and viewing the self through the object. One design, (2), ~~was~~ was perceived by the participant as though it shouldn't move due to him associating it with a tripod/ optical lab equipment as they don't move either. Blue and white seen as medical. Being able to imagine how it moves made seem more familiar and have more utility. Iconographic humanoid faces with just eyes seen as more appealing than realistic faces. The lack of clarity in how a robot could move made it seem strange. The clarity of function and movement also made it seem more familiar as he could image what it could do and how it could move. The sense of how fast it could move was also important to how comfortable he was with the design. Sense of scale determined by size and complexity of details as well as the

presence of known design elements. (3) the humanoid robot was seen as more function despite him saying it was an inefficient design previously. Was this due to the mechanical design making it appear more functional? Purpose of design ~~was~~ relevant to participant to determine function. Designs with wires and rough aesthetics was seen as being engineered and prototypes as well as designed purely around function. Blob designs with protrusions was seen as a virtue. Design that copied animals or humans were seen closely were seen as being in the uncanny valley. He mentioned that (20) was designed to look like it had been designed to be functional which was interesting. Means of movement identified first when this included foot or locomotion, and then the part that determines function/purpose like an end effector. Robotists consider aesthetics superfluous to the function yet use it to determine how the robot functions. Design engineers have a balanced experience between the aesthetic experience. Product designers have a more open experience to the aesthetic and could expand on it creatively. But this differed on the creativity an openness of the participant and how much they see themselves in the design or see beyond it (self-centredness).

Participant 14
23/8/24

Product Designer

Set 4

Anthropomorphism seen as the evaluation of the design compare to the whole human body 'not the wire'. Implication of functionality based on perceived design elements such as camera results in being seen as recording something. Many functions was seen as though it could have secret functions hidden. Exposed components gave a sense of complexity. One went through analysis of function and purpose of the design and then had very creative interpretations and exploration of all the designs. Exploring and expanding away beyond what she consider the original function or what the robot reminder her of. Construction of meaning from multiple different sources. Perception of simple movement made it seem less accurate (3) but for (21) the thicker design was seen as more precise. Creative exploration of possibilities of object. (1) was seen as anthropomorphic due to it being able to be used by humans not being anthropomorphic in form. Sense of scale determined by size and complexity of detail and the sense of proportion of the composition of the design. Some designs were seen as having the function, although I think she meant purpose, of entertainment yet entertainment not seen as a function. Functionality and movement ~~was~~ imagined based on perceived possible context ~~for~~ when she imagined multiple contexts.

Robotist

Participant 15
27/8/24

Set 1

~~Participant~~ Participant drew on robot to identify linkages and joints. Straight lines were links and corners were joints. Designs that were seen as both curvature and mechanical were seen as being in conflict in a sense. He preferred designs being clearly one or the other. Designs being very abstract ~~reduced~~ reduced their functionalism. The same was seen if the design had more of a focus on aesthetics. Designs were seen as free floating if the joints were in line. Sense of scale determined in the same manner previously but he didn't bring it up that much. Function, foot, and kinematics seemed important to ~~the~~ the participant. Large joints were seen as unnatural. Seemed to perceive ~~being~~ elements in the order of novel part/ end effector, face/sensors, stand/locomotion. The highly curved designs made the participant feel although the robot would move in a very fluid manner, such as (5). (5) looked natural, flowing, and chaotic. Aesthetically pleasing designs were seen as less functional. Objects that were recalled or parts of objects continue to draw in the associated meaning ~~and~~ function, and context. Wires were seen to make the designs more mechanical. Realistic anthropomorphic designs were seen as being very unpleasant. But just a screen with a adaptable arm was seen as flexible, approachable, and friendly. Specifically, if the

design just had eyes without the iris or the white. Although I imagine this could depend on the design. Eyes also reduced the phyto rating. ⑧ was seen as paracitic. When function was unclear he tried to see if it was meant to ~~do~~ something. Mostly roboticists and ~~some~~ design engineers have ~~high~~ made high evaluations on function due to it existing. It must be functional regardless of whether they think it is useful. ⑫ has a soft appearance but he has seen it move and it makes it feel more mechanical due to the style of movement. Movement seems to affect the ~~whole~~ whole aesthetic experience especially when it is contrasting with the other major element. Such as form. The printed nature of ⑭ made it seem more precise but the quantity and complexity of the arms means that it is strange and chaotic. Especially due to it being a surgical robot. Fixed faces would look 'creeping' to him. He mentioned for ⑮ that its 'light' made it seem like it wasn't like an existing object. Designs like ⑯ that appear wide but dissimilar seem to reduce its ~~best~~ functionality and quality of function. Colour on a mechanical design like ⑰ made it seem friendlier. For ⑱ he mentioned that the umbilical was functional but not the robot. Despite it being attached by a cable to the robot. He split this design. The umbilical wasn't integrated.

Robotist

Participant 16

28/8/24

Set 2

Designs that were evaluated as realistic at times were seen as having a practical purpose. Exposed mechanical designs with wires and exposed components were seen as more grounded and realistic. Robot arms tend to be seen at times as mimicking plant growth especially when it has green accents. Female participants generally seem more reactive to cute 'baby-like' designs and want to own them. When movement and method of locomotion is unclear then it came across as more abstract. Scale still determined by complexity and design of detail, such as ④ where the number of bolt holes at the base made her think it is large. ⑤ was perceived to be a camera robot and other participants were reminded of a camera. But she never said this, but drew in the meaning and purpose of the camera into the robot. White and blue seen as medical and dental still. Exposed pipes, mechanisms, and wires still ~~seem~~ ~~are~~ resulting the robot being seen as a being a prototype. Black and red sinister, ~~the design~~ ~~make~~ The lens linked to standard practical needs of ~~the~~ of robots a design is and more focused on human needs the lens functional the design is seen. Separation between prototypes and designs for sale based on the styling of the plastic shells and their 'sassy legs' in some way. The movement

and locomotion are seen as separate concepts. In very anthropomorphic designs such as ⑬ the absence of a head was seen as unpleasant. This participant saw neomorphic as novel rather than modern styling. Red seen as luxurious at times but also for visibility. Design choice and functional choice seen as separate. Volume of port (⑮ head is black) seen as heavier. Sometimes the perception of purpose affect the evaluation of the aesthetic dimensions towards that purpose. As in ⑲ is very angular but it was seen as curved due to the perceived need to mimic nature for camouflage. Is it the case that which ever part of the aesthetic experience is ~~more~~ strongest and guided by which ever part of the design aesthetics or robot aesthetics that links to that and the meaning?

Product Designer

Participant 17

2/9/24

Set 1

One of the few times texture ~~was~~ has been mentioned. White and grey in a two tone style seen as ~~space~~ being for space. Exposed screws, parting lines, ~~and~~ points, and holes gives it a mechanical. Posture of robot mention in ② making it seem like a giraffe. For ③ large joints seen as crab like ~~along~~ with piece end-effectors. Participant had more of a mixing and separation of the aesthetic dimensions and morphologies such as the aesthetics being chaotic ~~and~~ but the morphology being familiar. Many participants evaluated them separately. 'Too many joints' seen as functional, maybe due to the larger variety of movement. Participant saw more aesthetics having two side of the same dimension but didn't seem happy by putting in the middle. Same structure as ~~initial~~ initial ideas, emotions and meaning into the object from its aesthetics, perceived function, and purpose. Strong evaluations of zoo ^{roboty and} and phyto seem exclude artemorphic evaluations. Participant stated that he thought curvature and zoomorphism and phytomorphism were linked. Eyes make things seem anthropomorphic. Deliberate faces seemed to have an unclear purpose. Complexity of lines with unclear movement ~~the~~ and function made design seem chaotic. Some participants interpret rotation and movement due to parting lines, cylinders, and cups. The perception of DoF

No.
Date

seems separate from the sense of movement.
① seen as costume almost. Is this because robots shouldn't have fabrics on them. The aesthetics details could be mechanical but the structure and pose of the design seemed more ~~anthropomorphic~~ anthropomorphic therefore to the participant it seemed more natural. The theory might seem to be changed to accommodate these differences. Saw different parts of the designs being seen to have different aesthetic dimensions and morphologies. For ② participant mentioned brutalism as a related style.

Design Engineer

Participant 18
15/9/24

Set 3

Tapering form towards an end effector. Participant identified DoF regularly but never seemed to have any views about how the robot could move. A large amount of joints removed the design ~~being~~ being zoomorphic but with hyper redundant systems or more curved ~~design~~ aesthetics. It was seen as a tentacle like shape. For ③ the visuals implied a different function and was seen as strange despite the joints being clear to her. Also visually the design seem segmented into two parts. This made it curved, and strange, and and amorphic. Longer robot arm design seem to regularly be seen as giraffe necks. I think this has been exclusively mentioned by female participants. Just help make ~~design~~ seem more human but not in an unpleasant way usually. But with just the upper section of the body it's seen as unpleasant probably due to the head being present. Maybe is seems more like ~~a~~ someone who has suffered or is suffering. Female participants respond with 'cute' to baby like designs. Interpretable parts made the design seem familiar. Looking akin to ~~an animal~~ an animal made it seem more realistic. ④ was seen as very functional and no attention was paid to aesthetics. Does this mean that the perceived intentional placement of visual and other design elements is seen as ~~not~~ involving more aesthetic design.

Participant 19
12/9/24

Set 3

Product Designer

Joints ~~tapering~~ with that compliment tapering and form was seen as appropriate. Designs with too much DoF and joints was seen as less functional. The aesthetics of ② that had more hidden mechanisms was seen as being less clear and chaotic despite the smooth appearance. Clear joint forms made it seem as if they serve a purpose such as in ③. For this participant the designs reminded them of multiple artefacts at times. Longer forms leading to a small point was seen as being more precise. ~~The purpose of the co-robots and their end effectors~~ should be clarified as to whether it is meant as reminding someone of an object or multiple. Although when a design ~~reminded~~ reminded the participant of multiple objects the anthropomorphic evaluation was low. The purpose of the co-robots and their end effectors was generally seen as unclear. The lack of mouth seemed appealing. ~~Driving~~ Driving meaning seems to direct the experience. Sometimes curvature was seen as excessive and detracting from the functionality of the robot.

Product Designer

Participant 20
16/9/24

Set 2

Futuristic was associated ~~with~~ with white and ~~smooth~~ continuous forms. Mechanical and computer designs was seen as more functional maybe due to those ideas being associated with function. Akin to previous participants the purpose of some designs seems unclear through the ~~form~~ aesthetics ~~and~~ along with the general generosity of the end effector being unclear. Eyes associated with anthropomorphism. In ③ the participant associated black being mechanical despite the form of the design due to ~~the~~ the design ~~resembling~~ being reminiscent of a camera which is inherently mechanical. How much the colours are associated with certain parts of the aesthetic dimensions? It seems that the colours link to objects that have them and then the second objects meaning is drawn into the first. ~~Aesthetic dimensions~~ The evaluation of the aesthetic dimensions seems to be made on what is dominant rather than the details. This seems to be the same with the morphologies. Clear human features results in higher anthropomorphic evaluation. Emphasis on the clear, unclear or modified human features seems to be unpleasant for participants. Robots that lack clear locomotion such as having hidden wheels, tended to be associated with household

appliances or objects. Apart from showing the wheels how do you communicate how ~~a~~ a robot moves. For ③ was one of the few times or maybe the only time that someone associated an Chinese character that was animal first and human second "Frog Man". Typically the participants saw it as a distortion of a human rather than a new being. This could be due to the lack of head. Maybe a similar experience is had with "spot". Also this participant saw more mechanical designs as strange than others. The reason as to why might be due to the composition of the design ~~and~~ and meaning. Why these associations are made will be more valuable that what associations are made. Lack of clarity seems linked to abstract & chaotic. Trends continue to increase the functional evaluation. Anything really practical in purpose increased the functional evaluation, positively.

to the dimensions and morphologies. In ④ "eye" was associated with the end effector despite it not being camera. This could be due to the composition giving the design a living quality as ~~the~~ the ~~is~~ ~~quite~~ ~~the~~ composition is quite dominant in the image. Function and purpose seem to overtake some of the experience when ~~was~~ imagined movement is unclear. ⑤ was rather unclear and meaning had to be built from multiple almost dissected component to understand the aesthetic experience and imagine the ~~point~~ purpose, context, and movement. Asymmetry was seen as being more biological.

Mechanical continues to be associated with familiar. This is possibly due to it being ~~more~~ easier to understand and imagine compared to highly stylised occluded designs. Clarity of possibilities with beautiful ideas through aesthetics is an interesting approach. Curvature is linked to abstraction but also ~~before~~ it seems to be linked to the design not allowing or not being conducive to ~~imagination~~ people being able to imagine what could happen. This is the same in terms of ~~the~~ context not being imaginable to viewers. Curvature is not ~~linked~~ ~~with~~ readily seen to be related to function. Exposed and unfinished part leads the participants to ~~being~~ associating it with being very functional. Female participants continue to have stronger reactions to curve and soft rounded forms. Despite ③ & ④ being very aesthetically powerful they were both seen as functional due to the exposed circuits. There is clearly room for interpretation on the value of on objects ~~but~~ ~~the~~ yet participants want to separate functionality as not being an aesthetic. There is something exploitable and explainable here it just needs to be defined. Movement and purpose are ~~the~~ ~~imagined~~ imagined. ③ was seen as not being alive. The aliveness of the design is something to bring forward maybe. These associated concepts could be linked

Participant spent the start of most ~~analysis~~ of his analysis of the images but ~~of~~ determining ~~the~~ ~~how~~ ~~good~~ the design choices were from an engineering design perspective and then how that would impact the functionality. Bent legs seems more animalistic to most participants. ② has a monitor for a head. For the participant this monitor, and possibly not the face on it, was seen to increase functionality. Is this because of the visibility of a screen? Despite the human face on the screen the design was seen as "100% function" as he said. ~~the~~ The perception of lower DoF was seen as simplifying controls. Maybe there is something there? The more "human" form of ③ was seen as natural and that it would be around people. No other participants didn't seem too fond of anthropomorphic designs. Why is he fond then? Meaning from other objects seem to be drawn out last for this participant ~~due~~ due to his interest in analysing the feasibility of the design. Largest compositional and most ~~known~~ ~~known~~ known element is pickie first then the most known. This I assume is the participants trying to understand the robot and the trying to relate the ~~unfamiliar~~ ~~unfamiliar~~ to the humans and imagine what they could be used for. ③ was seen as being more muscular.

suppose the initial emotional reaction is still there. ~~the~~ the realism evaluation of was ~~due~~ due to him seeing it as a final product. Rather the mechanical feasibility and usability. Two ~~opposing~~ opposing aesthetics ~~seem~~ or morphologies seem create unpleasant experience due to the discordance between them. The opposing aesthetics of the south of France with the sensuality and the gothic architecture is ~~an~~ an example where opposing ideas can become something else. It just seems that the aesthetics are not finished or fused properly. For ~~the~~ the participant determined it was near its developmental stage rather than it being enough for what it did. In the later images the participant expressed his aesthetic experience first and then the functional analysis. ~~was~~ was seen as self aware due to the control it could have and possibly the sheer number of sensor looking devices across the robot.

Design Engineer

Participant 23
Date 1/10/24
Set 4

and ~~both~~ geometric details ~~are~~ are seen as mechanical. This seems to be due to the elements associated with mechanical as seen as such due to them making it easier to distinguish the different parts, functions, and possible movement. Natural bodies are linked to millions of year of evolution and are covered with skin and muscle. The flexion of the muscle creates force. Maybe this is why robots can ~~not~~ cause more ~~anxiety~~ anxiety? Because the force cannot be perceived before it is released. For the lack of singular or clear function resulting ~~from~~ in the participant's story that "doesn't know what it is" which means that the lack of clear function or the ~~lack~~ lack of clear function on the ~~robot~~ robot but that the design's functionality is opaque to the user results in the design ~~of~~ seeming confused or lacking purpose. ~~It~~ was also associated with "airfryer" maybe it is the case that people associate certain robot designs more strongly with other objects when they seem to have unclear purposes, ~~and~~ function and functionality. Mechanical associated with realistic and exposed components links the designs to realistic and mechanical. Curvature is ~~not~~ times associated with a modern design aesthetic as in ~~the~~ this is helped by the white colouring. The lack of end effectors of ~~the~~ made it seem to lack purpose. The face screen of ~~the~~ was seen as

making the design more anthropomorphic as the ~~the~~ participant imagined the face could change. Its shape ~~led~~ led to the participant perceiving the design to be small and as such as a small creature. A zoomorphic body with an ~~an~~ anthropomorphic face. This design lacks details on the form which might be why it was perceived as smaller. That and the perspective of the image being more top down. Curvature and abstraction are usually associated with strange but maybe this is more linked to end effectors and clarity of purpose and functionality. One could design a curved design with open mechanisms. This could mean that all these findings are light rules that can be overcome with skill and creativity. The speaker like designs were seen as not being able to move. Clearer wheels and joints would help with that. The white humanoid designs ~~are~~ as well as the others are seen typically as test dummies. The mix morphological of ~~the~~ were seen as creepy. Probably due to poor execution ~~between~~ and integration ~~between~~ of the two conflicting morphologies into one design. Flexing and rounded styling was seen as not relating to the functionality and made designs more neomorphic.

Product Designer

Participant 24
Date 9/10/24
Set 4

Participant recognised that ~~aesthetics~~ the ~~and~~ aesthetics could be the result of manufacturing choices. Robots with clear ~~forms~~ forms and joints but when it has a simple, uniform ~~the~~ body then its functionality and purpose become unclear. Possibly due to these designs hiding compartments and functions. For ~~the~~ the participant perceived the soft curved forms ~~could~~ ~~be~~ be matched ~~with~~ with the imagined movement of the robot. In the case of ~~the~~ it could move in a soothing manner. For ~~the~~ the association of mechanical elements with the anthropomorphic design was seen as fearful or ~~causing~~ causing fear. But the exposed mechanisms made the design of ~~the~~ seem more accurate and with better performance. White, pure white, seems to add abstraction. Cuteness associated with comfort. A lot of participants associate designs with simple forms to dehumidifiers, speakers, or air-purifiers. Curvature linked to aesthetics and as such ~~was~~ resulted in some designs being seen as less functional. ~~It~~ was seen as the designers getting it wrong: "they got it wrong" as it appeared humanoid but didn't seem like it could move. This participant was the same as the rest a lot of the design purpose was unclear to them. But sometimes they

could gather the context through form and colour. The more clearly mechanical and metal the less emotional the design seemed to him. ~~the~~ the participant seems to think that due to ~~the~~ looking as if it was made of silver it was fragile. Was this because it seems polished and precision surfaces are delicate or did he think that it was made of silver. Participant had more imagination around possible situation with the robots. Emotional context imagined by ~~the~~ him add inspired by the important idiosyncrasy. Other creative participants did this too.

Appendix E – Sorting Experiment Data

Participant ID	Group	Set	Image	An	Zo	Ph	Ar	Fu	Am	Ne	R/A - A/I	N/C - M/A	F/U - S/C
P-1	Robotacist	1	1	5	8	2	3	9	6	6	3	7	2
P-1	Robotacist	1	2	9	2	2	8	10	3	4	2	10	2
P-1	Robotacist	1	3	9	2	2	10	8	3	3	2	9	3
P-1	Robotacist	1	4	2	5	2	6	7	7	7	9	10	7
P-1	Robotacist	1	5	4	2	6	3	6	6	7	7	6	8
P-1	Robotacist	1	6	7	2	2	4	10	8	8	1	11	8
P-1	Robotacist	1	7	2	2	2	9	4	4	6	5	7	2
P-1	Robotacist	1	8	2	10	2	9	3	9	8	9	2	10
P-1	Robotacist	1	9	11	1	1	10	10	2	3	2	10	10
P-1	Robotacist	1	10	9	2	2	9	3	5	7	9	3	5
P-1	Robotacist	1	11	1	9	1	8	9	6	7	9	8	9
P-1	Robotacist	1	12	1	10	1	9	8	3	5	2	7	3
P-1	Robotacist	1	13	1	7	1	6	9	4	7	3	10	9
P-1	Robotacist	1	14	5	1	4	2	11	7	9	2	11	10
P-1	Robotacist	1	15	2	2	2	3	7	5	7	9	5	2
P-1	Robotacist	1	16	2	2	2	8	5	5	5	9	4	4
P-1	Robotacist	1	17	2	9	1	9	10	6	4	9	9	8
P-1	Robotacist	1	18	10	1	1	10	6	3	3	3	3	6
P-1	Robotacist	1	19	1	8	1	9	9	5	6	2	11	8
P-1	Robotacist	1	20	1	4	1	3	10	3	7	2	11	9
P-1	Robotacist	1	21	1	1	1	6	9	6	5	2	10	6
P-1	Robotacist	1	22	1	2	1	3	11	6	7	2	11	6
P-1	Robotacist	1	23	1	1	1	3	6	8	8	10	10	6
P-1	Robotacist	1	24	7	1	1	6	6	7	8	8	9	6
P-1	Robotacist	1	25	7	2	2	4	3	6	8	10	8	10
P-2	Design Engineer	2	1	2	2	7	1	2	4	3	8	2	2
P-2	Design Engineer	2	2	4	2	2	7	9	9	2	2	9	5
P-2	Design Engineer	2	3	9	4	4	5	4	3	7	8	2	2
P-2	Design Engineer	2	4	8	4	4	7	6	3	7	7	3	3
P-2	Design Engineer	2	5	3	1	1	10	5	3	8	7	4	4
P-2	Design Engineer	2	6	1	1	1	2	4	9	1	3	5	9
P-2	Design Engineer	2	7	9	2	2	2	3	4	6	9	3	4
P-2	Design Engineer	2	8	11	3	2	2	3	2	5	9	2	2

P-2	Design Engineer	2	9	5	10	2	2	4	2	8	9	4	3
P-2	Design Engineer	2	10	1	1	1	1	11	11	1	1	11	11
P-2	Design Engineer	2	11	3	1	1	7	7	3	3	7	3	4
P-2	Design Engineer	2	12	11	1	1	2	3	3	4	8	3	3
P-2	Design Engineer	2	13	1	1	1	9	5	3	5	4	8	7
P-2	Design Engineer	2	14	1	9	11	1	5	1	10	10	4	2
P-2	Design Engineer	2	15	1	1	1	9	5	4	7	7	7	5
P-2	Design Engineer	2	16	1	10	1	1	4	2	9	9	8	7
P-2	Design Engineer	2	17	1	11	1	1	4	4	8	9	3	3
P-2	Design Engineer	2	18	1	1	1	9	6	7	4	7	3	2
P-2	Design Engineer	2	19	1	1	1	4	4	7	3	7	4	3
P-2	Design Engineer	2	20	3	1	1	4	5	3	7	9	3	4
P-2	Design Engineer	2	21	7	5	1	1	2	3	7	10	5	7
P-2	Design Engineer	2	22	1	1	1	10	4	1	11	11	8	3
P-2	Design Engineer	2	23	3	1	1	2	9	9	1	3	10	9
P-2	Design Engineer	2	24	1	1	1	10	3	3	7	9	7	3
P-2	Design Engineer	2	25	1	1	1	8	6	8	2	4	7	5
P-3	Robotacist	3	1	6	6	1	9	6	9	1	2	10	1
P-3	Robotacist	3	2	1	5	1	1	9	8	8	8	3	4
P-3	Robotacist	3	3	1	1	1	1	8	6	8	7	4	5
P-3	Robotacist	3	4	2	1	1	1	8	6	3	6	6	3
P-3	Robotacist	3	5	1	1	2	1	3	4	3	7	6	6
P-3	Robotacist	3	6	6	6	1	7	1	2	8	8	7	8
P-3	Robotacist	3	7	8	1	1	9	7	3	6	8	4	4
P-3	Robotacist	3	8	1	9	1	1	1	2	6	6	9	8
P-3	Robotacist	3	9	1	10	1	1	1	3	6	6	8	9
P-3	Robotacist	3	10	1	11	1	1	1	2	11	10	10	9
P-3	Robotacist	3	11	5	1	1	1	3	3	8	6	10	3
P-3	Robotacist	3	12	1	9	1	8	5	1	4	6	10	6
P-3	Robotacist	3	13	1	1	5	8	8	6	3	10	6	10
P-3	Robotacist	3	14	1	1	1	1	8	3	2	5	3	5
P-3	Robotacist	3	15	1	8	1	9	9	2	1	1	6	3
P-3	Robotacist	3	16	1	1	1	9	9	6	1	6	4	4

P-3	Robotician	3	17	11	1	1	2	9	1	6	6	6	6
P-3	Robotician	3	18	6	6	1	1	1	1	11	11	6	11
P-3	Robotician	3	19	1	10	1	2	1	2	8	6	6	9
P-3	Robotician	3	20	6	1	1	2	9	1	3	11	6	2
P-3	Robotician	3	21	1	5	1	10	6	3	1	11	6	3
P-3	Robotician	3	22	1	1	1	6	9	3	2	1	9	1
P-3	Robotician	3	23	1	1	1	4	9	3	2	1	6	2
P-3	Robotician	3	24	1	1	1	5	9	3	1	1	10	2
P-3	Robotician	3	25	4	1	4	2	5	1	4	10	3	10
P-4	Robotician	4	1	2	2	1	2	9	5	2	4	9	5
P-4	Robotician	4	2	2	2	2	9	6	6	3	5	5	4
P-4	Robotician	4	3	2	2	6	2	7	6	7	4	4	8
P-4	Robotician	4	4	11	11	2	11	11	1	1	1	10	3
P-4	Robotician	4	5	1	1	6	1	11	1	1	7	4	8
P-4	Robotician	4	6	9	6	1	11	1	11	1	7	4	11
P-4	Robotician	4	7	7	7	1	6	6	1	1	10	3	2
P-4	Robotician	4	8	2	2	2	9	6	1	11	9	3	4
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P-4	Robotician	4	10	7	7	1	9	5	4	6	7	4	5
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P-4	Robotician	4	12	1	1	8	11	1	11	6	8	3	9
P-4	Robotician	4	13	7	1	11	1	1	11	1	6	9	11
P-4	Robotician	4	14	11	10	1	1	9	1	7	3	9	4
P-4	Robotician	4	15	8	7	1	8	4	6	1	3	11	11
P-4	Robotician	4	16	1	11	1	11	11	1	6	3	10	6
P-4	Robotician	4	17	1	1	1	1	11	3	11	2	8	5
P-4	Robotician	4	18	9	8	1	1	4	11	8	6	3	9
P-4	Robotician	4	19	1	7	1	9	11	1	6	3	10	5
P-4	Robotician	4	20	11	9	1	1	7	1	9	10	3	4
P-4	Robotician	4	21	7	1	6	11	11	3	11	10	3	7
P-4	Robotician	4	22	6	6	1	1	7	2	8	9	4	9
P-4	Robotician	4	23	1	11	1	8	11	1	9	4	4	8
P-4	Robotician	4	24	1	11	9	6	6	5	7	4	4	7
P-4	Robotician	4	25	7	7	1	1	5	1	10	7	7	5
P-5	Product Designer	2	1	5	5	1	5	8	3	8	3	4	2
P-5	Product Designer	2	2	3	1	1	6	9	2	6	3	11	3
P-5	Product Designer	2	3	2	2	5	8	9	2	9	4	5	2
P-5	Product Designer	2	4	4	4	4	3	8	4	9	4	8	7
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P-5	Product Designer	2	6	3	4	3	8	8	4	7	4	10	3
P-5	Product Designer	2	7	9	3	1	7	6	3	9	3	8	3

P-5	Product Designer	2	8	9	2	2	4	3	4	7	7	2	4
P-5	Product Designer	2	9	1	8	1	2	6	2	9	8	5	7
P-5	Product Designer	2	10	1	1	1	3	9	9	7	10	10	10
P-5	Product Designer	2	11	2	3	2	4	9	3	8	3	9	5
P-5	Product Designer	2	12	9	1	1	4	7	2	9	4	8	4
P-5	Product Designer	2	13	1	1	5	5	5	6	5	10	10	9
P-5	Product Designer	2	14	1	7	5	1	2	4	5	9	4	9
P-5	Product Designer	2	15	1	8	1	7	7	5	5	6	10	8
P-5	Product Designer	2	16	1	10	1	3	7	7	7	5	9	5
P-5	Product Designer	2	17	1	11	1	8	6	2	8	5	3	2
P-5	Product Designer	2	18	1	1	1	5	9	2	8	5	7	4
P-5	Product Designer	2	19	4	1	1	3	8	4	9	3	4	4
P-5	Product Designer	2	20	3	1	1	1	3	7	4	10	10	10
P-5	Product Designer	2	21	5	1	1	1	7	5	6	10	11	11
P-5	Product Designer	2	22	1	1	1	5	9	7	3	4	9	10
P-5	Product Designer	2	23	1	1	1	8	10	3	7	2	11	3
P-5	Product Designer	2	24	1	2	1	3	9	4	7	1	10	2
P-5	Product Designer	2	25	1	3	1	2	8	3	8	3	10	2
P-6	Product Designer	3	1	5	1	2	6	9	1	1	2	9	1
P-6	Product Designer	3	2	3	2	8	9	5	3	4	5	2	4
P-6	Product Designer	3	3	8	6	7	9	6	2	3	8	2	8
P-6	Product Designer	3	4	8	7	3	3	8	2	2	3	3	3
P-6	Product Designer	3	5	3	2	1	6	7	1	1	3	2	3
P-6	Product Designer	3	6	10	9	1	3	2	1	4	2	3	8
P-6	Product Designer	3	7	9	1	1	7	2	3	4	7	4	9

P-6	Product Designer	3	8	1	10	1	1	3	2	4	5	1	3
P-6	Product Designer	3	9	1	11	4	1	1	2	4	8	2	8
P-6	Product Designer	3	10	1	11	1	1	2	4	4	3	1	8
P-6	Product Designer	3	11	8	5	2	1	4	1	1	2	4	4
P-6	Product Designer	3	12	6	11	1	1	1	3	4	2	2	2
P-6	Product Designer	3	13	1	1	7	9	7	5	5	9	7	9
P-6	Product Designer	3	14	7	7	3	2	3	1	1	8	2	8
P-6	Product Designer	3	15	2	2	1	7	4	2	1	7	5	3
P-6	Product Designer	3	16	1	1	5	8	1	5	1	5	3	3
P-6	Product Designer	3	17	11	2	2	1	5	1	1	1	2	1
P-6	Product Designer	3	18	10	4	1	7	6	1	2	3	6	10
P-6	Product Designer	3	19	3	10	4	5	7	1	3	8	7	8
P-6	Product Designer	3	20	11	3	1	1	4	1	2	3	5	3
P-6	Product Designer	3	21	3	4	2	1	8	1	7	11	5	10
P-6	Product Designer	3	22	1	4	1	7	7	1	1	4	3	11
P-6	Product Designer	3	23	1	3	1	7	7	1	2	2	11	3
P-6	Product Designer	3	24	1	3	1	3	9	1	1	2	11	2
P-6	Product Designer	3	25	5	10	3	1	1	3	7	10	2	9
P-7	Product Designer	1	1	4	2	1	8	6	3	3	3	11	3
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P-7	Product Designer	1	5	1	9	8	2	1	1	11	11	11	11
P-7	Product Designer	1	6	6	9	2	1	6	3	5	2	10	8
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P-7	Product Designer	1	10	9	4	1	9	3	6	6	9	8	4
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P-7	Product Designer	1	12	1	11	1	1	6	2	4	11	3	1
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P-7	Product Designer	1	14	3	1	2	5	4	4	5	9	10	9
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P-7	Product Designer	1	18	9	1	1	11	9	3	1	11	3	1
P-7	Product Designer	1	19	6	10	2	2	2	5	9	7	6	8
P-7	Product Designer	1	20	1	1	8	9	8	4	6	2	10	8
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P-7	Product Designer	1	24	11	3	1	6	8	3	1	11	11	1
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P-8	Design Engineer	4	1	4	2	2	5	4	2	4	4	11	3
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P-8	Design Engineer	4	4	9	3	2	5	8	8	5	3	6	6
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P-8	Design Engineer	4	10	5	6	2	9	5	3	7	9	2	4
P-8	Design Engineer	4	11	2	2	2	9	11	2	7	3	3	1
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P-8	Design Engineer	4	13	9	2	2	2	7	2	2	7	4	9
P-8	Design Engineer	4	14	9	3	3	11	4	1	2	10	11	10
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P-9	Robotacist	4	16	1	10	1	5	10	3	4	2	10	2
P-9	Robotacist	4	17	1	1	1	9	9	6	6	2	10	8
P-9	Robotacist	4	18	10	1	1	6	4	4	6	11	3	8
P-9	Robotacist	4	19	1	1	1	11	10	3	9	3	7	7
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P-9	Robotacist	4	21	1	1	1	10	6	4	1	9	3	2
P-9	Robotacist	4	22	4	9	1	3	7	5	6	2	9	7
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P-9	Robotacist	4	24	1	11	10	5	6	7	5	3	3	5
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P-10	Design Engineer	1	1	1	3	1	2	10	1	3	5	3	3
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P-10	Design Engineer	1	3	10	3	1	1	7	1	4	2	3	2
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P-10	Design Engineer	1	7	9	1	1	9	3	1	5	2	4	1
P-10	Design Engineer	1	8	2	3	2	4	8	4	6	8	3	4
P-10	Design Engineer	1	9	11	1	1	11	8	1	1	2	9	5
P-10	Design Engineer	1	10	8	1	1	4	10	1	6	8	2	4
P-10	Design Engineer	1	11	1	11	2	2	8	2	6	9	7	4
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P-10	Design Engineer	1	13	6	6	1	3	11	9	9	10	10	10
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P-10	Design Engineer	1	15	3	1	1	4	8	2	6	8	5	5
P-10	Design Engineer	1	16	1	1	1	6	10	1	1	9	9	1
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P-10	Design Engineer	1	18	11	1	1	3	3	1	2	3	9	2
P-10	Design Engineer	1	19	1	9	1	1	10	3	9	10	9	10
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P-10	Design Engineer	1	25	2	4	4	3	2	1	7	5	6	3
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P-11	Design Engineer	3	3	1	4	2	1	6	3	5	7	7	5
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P-11	Design Engineer	3	7	10	3	1	7	1	1	3	11	3	1
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P-11	Design Engineer	3	14	1	9	4	1	1	1	4	2	2	5
P-11	Design Engineer	3	15	1	1	1	10	2	4	4	9	2	7
P-11	Design Engineer	3	16	1	3	7	9	7	3	2	10	2	10
P-11	Design Engineer	3	17	11	1	1	4	8	1	1	1	1	1
P-11	Design Engineer	3	18	6	6	6	8	9	1	7	1	3	9
P-11	Design Engineer	3	19	1	9	4	7	10	1	1	2	10	5
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P-12	Design Engineer	2	15	1	10	1	4	9	1	7	3	2	3
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P-13	Robotacist	2	24	1	5	1	5	9	1	1	2	10	5
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P-14	Product Designer	4	15	7	1	1	7	3	2	9	10	10	3
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P-16	Robotacist	2	3	7	1	6	11	4	5	5	8	4	2
P-16	Robotacist	2	4	1	1	1	1	11	1	1	3	10	2
P-16	Robotacist	2	5	2	1	1	1	9	1	2	2	5	2
P-16	Robotacist	2	6	1	1	1	1	10	1	1	3	5	2
P-16	Robotacist	2	7	8	2	1	1	6	1	7	1	8	1
P-16	Robotacist	2	8	10	1	1	1	4	4	8	8	2	1
P-16	Robotacist	2	9	1	11	1	8	1	1	9	8	7	1
P-16	Robotacist	2	10	1	1	1	1	11	6	5	1	11	9
P-16	Robotacist	2	11	1	1	1	1	8	1	6	2	5	2
P-16	Robotacist	2	12	11	1	1	1	6	1	11	8	9	1
P-16	Robotacist	2	13	1	1	1	1	6	7	7	9	10	10
P-16	Robotacist	2	14	1	11	9	10	5	1	11	7	3	11
P-16	Robotacist	2	15	1	11	1	7	7	1	4	3	10	2
P-16	Robotacist	2	16	1	11	1	1	7	1	7	2	10	8
P-16	Robotacist	2	17	1	11	1	1	5	1	9	2	1	1
P-16	Robotacist	2	18	1	1	1	11	4	7	3	4	2	1
P-16	Robotacist	2	19	8	1	1	10	6	3	5	9	1	1
P-16	Robotacist	2	20	5	1	1	5	3	1	1	2	11	3
P-16	Robotacist	2	21	7	1	1	1	7	1	6	3	11	1
P-16	Robotacist	2	22	2	1	1	5	8	1	2	3	11	7
P-16	Robotacist	2	23	1	4	1	1	11	1	4	2	11	1
P-16	Robotacist	2	24	1	1	1	11	8	1	1	2	4	1
P-16	Robotacist	2	25	1	6	1	1	9	1	1	2	11	3
P-17	Product Designer	1	1	5	2	2	9	9	1	3	4	3	1
P-17	Product Designer	1	2	5	8	2	10	9	1	1	3	5	2
P-17	Product Designer	1	3	7	10	1	2	9	3	5	5	7	4
P-17	Product Designer	1	4	2	2	4	6	7	7	3	6	3	4
P-17	Product Designer	1	5	3	8	7	9	10	2	5	8	2	5
P-17	Product Designer	1	6	2	1	1	8	4	7	1	2	10	8

P-17	Product Designer	1	7	7	10	1	10	10	2	8	9	2	2
P-17	Product Designer	1	8	1	10	1	7	8	5	5	4	2	7
P-17	Product Designer	1	9	9	1	1	3	4	5	3	3	10	8
P-17	Product Designer	1	10	9	5	1	3	9	4	7	4	4	4
P-17	Product Designer	1	11	1	9	1	1	8	4	6	4	3	5
P-17	Product Designer	1	12	8	9	1	1	9	1	6	7	3	1
P-17	Product Designer	1	13	8	1	1	11	9	3	8	4	4	8
P-17	Product Designer	1	14	1	6	6	6	7	7	3	1	8	8
P-17	Product Designer	1	15	4	1	1	9	6	5	6	8	7	9
P-17	Product Designer	1	16	1	1	1	8	4	6	6	8	6	4
P-17	Product Designer	1	17	1	9	1	1	10	4	4	2	6	3
P-17	Product Designer	1	18	10	1	1	1	7	3	6	3	4	7
P-17	Product Designer	1	19	1	10	1	1	7	4	8	3	2	10
P-17	Product Designer	1	20	1	1	5	8	3	9	3	1	11	10
P-17	Product Designer	1	21	4	8	1	5	10	2	5	1	8	1
P-17	Product Designer	1	22	3	1	1	10	11	5	1	1	11	1
P-17	Product Designer	1	23	6	1	1	10	3	5	9	8	9	9
P-17	Product Designer	1	24	11	1	1	1	11	3	6	8	9	2
P-17	Product Designer	1	25	7	7	7	1	1	5	8	7	4	7
P-18	Design Engineer	3	1	7	4	2	7	8	2	4	2	10	5
P-18	Design Engineer	3	2	3	2	5	5	5	3	7	5	7	7
P-18	Design Engineer	3	3	3	3	2	4	4	4	5	8	7	9
P-18	Design Engineer	3	4	4	4	2	4	8	3	3	3	3	9
P-18	Design Engineer	3	5	2	4	5	2	7	3	6	5	7	8
P-18	Design Engineer	3	6	7	5	2	3	9	3	5	4	9	5

P-18	Design Engineer	3	7	7	5	2	6	5	3	5	7	5	3
P-18	Design Engineer	3	8	3	6	2	2	10	3	8	8	10	9
P-18	Design Engineer	3	9	3	9	6	2	10	2	7	4	9	3
P-18	Design Engineer	3	10	3	9	2	2	9	3	7	5	9	4
P-18	Design Engineer	3	11	8	6	2	2	6	2	6	4	5	3
P-18	Design Engineer	3	12	5	9	2	3	9	2	5	5	8	3
P-18	Design Engineer	3	13	4	3	3	8	7	6	6	9	4	2
P-18	Design Engineer	3	14	2	4	4	2	7	3	5	7	5	8
P-18	Design Engineer	3	15	3	3	1	8	7	6	5	8	4	3
P-18	Design Engineer	3	16	1	1	1	9	7	6	5	9	3	2
P-18	Design Engineer	3	17	10	5	2	4	6	2	7	2	4	2
P-18	Design Engineer	3	18	7	5	1	8	5	3	8	7	7	7
P-18	Design Engineer	3	19	2	8	4	2	9	4	7	7	8	8
P-18	Design Engineer	3	20	6	4	2	2	8	3	4	8	7	7
P-18	Design Engineer	3	21	2	7	6	7	9	3	8	6	5	3
P-18	Design Engineer	3	22	4	2	2	9	10	2	5	4	8	4
P-18	Design Engineer	3	23	2	2	2	10	10	3	1	5	11	3
P-18	Design Engineer	3	24	1	1	1	10	10	4	3	4	11	4
P-18	Design Engineer	3	25	2	9	7	1	7	3	10	7	5	8
P-19	Product Designer	3	1	9	6	3	8	8	2	2	2	8	2
P-19	Product Designer	3	2	3	3	2	3	2	6	5	8	5	8
P-19	Product Designer	3	3	2	2	2	7	10	2	3	2	2	3
P-19	Product Designer	3	4	4	2	2	4	9	2	2	2	3	2
P-19	Product Designer	3	5	2	2	2	6	5	2	5	4	3	5
P-19	Product Designer	3	6	4	8	1	1	2	2	8	8	9	8

P-19	Product Designer	3	7	9	7	1	11	2	1	2	2	3	2
P-19	Product Designer	3	8	1	5	1	2	1	6	5	11	10	10
P-19	Product Designer	3	9	1	8	2	2	5	3	5	7	10	7
P-19	Product Designer	3	10	1	7	1	3	4	4	5	3	11	9
P-19	Product Designer	3	11	5	6	1	1	6	1	6	8	8	4
P-19	Product Designer	3	12	1	7	1	3	5	4	2	3	10	3
P-19	Product Designer	3	13	1	1	1	5	2	6	2	4	2	7
P-19	Product Designer	3	14	1	1	1	5	5	2	4	2	3	3
P-19	Product Designer	3	15	1	1	1	7	5	2	2	2	2	2
P-19	Product Designer	3	16	1	1	1	8	6	2	4	2	3	3
P-19	Product Designer	3	17	10	1	1	1	8	1	1	2	10	1
P-19	Product Designer	3	18	7	2	1	8	2	6	4	10	9	11
P-19	Product Designer	3	19	1	8	1	7	3	6	7	8	10	8
P-19	Product Designer	3	20	8	4	1	3	8	1	2	7	4	4
P-19	Product Designer	3	21	1	9	1	5	2	2	8	9	8	8
P-19	Product Designer	3	22	5	1	1	9	9	2	2	4	10	4
P-19	Product Designer	3	23	1	1	1	9	7	2	2	2	10	2
P-19	Product Designer	3	24	1	1	1	7	3	4	6	8	11	8
P-19	Product Designer	3	25	1	8	1	1	3	4	6	10	10	8
P-20	Product Designer	2	1	2	2	1	4	3	7	6	8	3	8
P-20	Product Designer	2	2	1	1	1	5	9	3	4	8	10	3
P-20	Product Designer	2	3	3	1	5	5	3	3	7	9	3	3
P-20	Product Designer	2	4	6	2	3	1	7	3	9	8	2	2
P-20	Product Designer	2	5	1	3	1	5	5	6	7	10	8	10
P-20	Product Designer	2	6	2	2	1	2	4	4	4	9	4	2

P-20	Product Designer	2	7	8	5	1	1	3	3	6	3	10	6
P-20	Product Designer	2	8	8	4	1	2	1	1	6	8	3	2
P-20	Product Designer	2	9	2	8	1	3	1	8	9	8	5	10
P-20	Product Designer	2	10	2	2	4	1	4	9	9	8	10	11
P-20	Product Designer	2	11	2	4	1	1	7	4	4	8	8	3
P-20	Product Designer	2	12	9	9	3	2	7	1	9	2	3	2
P-20	Product Designer	2	13	1	1	4	8	8	9	7	11	11	11
P-20	Product Designer	2	14	1	11	4	7	1	5	8	3	1	11
P-20	Product Designer	2	15	4	8	5	2	2	3	7	6	10	8
P-20	Product Designer	2	16	1	9	3	3	6	2	4	4	3	5
P-20	Product Designer	2	17	1	11	1	2	4	1	2	1	1	1
P-20	Product Designer	2	18	1	1	1	10	6	2	1	11	11	1
P-20	Product Designer	2	19	4	2	1	1	2	5	4	9	4	3
P-20	Product Designer	2	20	4	5	3	7	9	5	7	6	6	11
P-20	Product Designer	2	21	8	3	3	2	9	2	9	4	9	8
P-20	Product Designer	2	22	2	2	2	7	2	2	5	10	9	3
P-20	Product Designer	2	23	1	1	1	1	8	5	2	10	10	2
P-20	Product Designer	2	24	1	8	1	8	7	3	8	4	10	7
P-20	Product Designer	2	25	1	5	2	2	9	5	5	6	9	10
P-21	Robotacist	3	1	3	4	5	8	9	2	2	2	9	2
P-21	Robotacist	3	2	2	2	2	3	7	7	5	4	7	4
P-21	Robotacist	3	3	2	2	2	2	7	7	7	5	5	4
P-21	Robotacist	3	4	2	2	2	5	8	8	2	2	8	4
P-21	Robotacist	3	5	2	2	2	3	7	7	7	5	5	5
P-21	Robotacist	3	6	5	3	1	1	8	8	7	2	10	5
P-21	Robotacist	3	7	8	2	2	7	3	7	7	7	4	3
P-21	Robotacist	3	8	2	8	2	3	8	8	5	2	10	7
P-21	Robotacist	3	9	2	8	2	4	8	8	4	2	9	7
P-21	Robotacist	3	10	2	5	2	2	7	8	7	4	10	4
P-21	Robotacist	3	11	7	8	2	2	5	8	8	4	7	4
P-21	Robotacist	3	12	4	7	2	2	9	8	4	2	10	2

P-21	Robotacist	3	13	1	1	1	1	4	8	8	8	7	8
P-21	Robotacist	3	14	2	2	2	2	5	4	7	5	5	3
P-21	Robotacist	3	15	8	7	2	2	4	3	5	3	7	3
P-21	Robotacist	3	16	2	2	2	3	5	4	7	4	7	5
P-21	Robotacist	3	17	9	1	1	8	5	2	7	3	4	2
P-21	Robotacist	3	18	8	8	2	8	2	8	8	7	4	8
P-21	Robotacist	3	19	2	8	2	2	8	3	7	7	5	9
P-21	Robotacist	3	20	7	2	5	2	7	4	7	7	9	8
P-21	Robotacist	3	21	2	7	7	7	7	7	7	8	10	10
P-21	Robotacist	3	22	2	2	2	8	7	2	7	2	10	2
P-21	Robotacist	3	23	2	2	2	9	9	2	8	2	10	2
P-21	Robotacist	3	24	2	2	2	8	9	2	9	3	10	2
P-21	Robotacist	3	25	2	9	9	2	8	5	9	8	3	9
P-22	Design Engineer	1	1	2	4	1	2	10	1	1	2	8	2
P-22	Design Engineer	1	2	1	3	3	2	11	1	1	1	9	2
P-22	Design Engineer	1	3	5	5	2	3	8	1	4	2	5	3
P-22	Design Engineer	1	4	2	1	4	6	10	8	4	4	10	8
P-22	Design Engineer	1	5	3	3	2	5	5	1	9	2	6	3
P-22	Design Engineer	1	6	5	8	1	4	11	5	8	8	9	3
P-22	Design Engineer	1	7	8	8	1	10	6	4	10	2	4	5
P-22	Design Engineer	1	8	7	7	6	8	7	2	4	3	4	2
P-22	Design Engineer	1	9	8	4	1	11	8	1	11	8	8	10
P-22	Design Engineer	1	10	6	6	1	5	11	3	1	5	11	6
P-22	Design Engineer	1	11	2	10	1	8	9	2	8	3	5	2
P-22	Design Engineer	1	12	5	11	1	11	7	1	7	3	2	1
P-22	Design Engineer	1	13	7	5	1	6	9	8	5	9	10	9
P-22	Design Engineer	1	14	8	3	7	4	11	1	1	2	11	4
P-22	Design Engineer	1	15	8	1	3	5	7	7	8	8	3	8
P-22	Design Engineer	1	16	5	8	1	8	9	6	8	1	9	4
P-22	Design Engineer	1	17	3	5	1	8	11	4	3	1	11	2
P-22	Design Engineer	1	18	10	8	1	9	8	2	5	2	3	1

P-22	Design Engineer	1	19	7	8	1	6	11	5	2	9	6	10
P-22	Design Engineer	1	20	2	2	1	6	10	8	3	3	11	7
P-22	Design Engineer	1	21	4	7	1	6	11	2	1	5	11	5
P-22	Design Engineer	1	22	7	1	1	6	11	1	1	3	11	8
P-22	Design Engineer	1	23	2	4	1	4	9	9	3	8	9	9
P-22	Design Engineer	1	24	8	10	1	6	7	2	8	9	8	9
P-22	Design Engineer	1	25	8	8	4	4	5	8	7	10	3	10
P-23	Design Engineer	4	1	1	1	1	1	10	1	2	2	10	4
P-23	Design Engineer	4	2	1	1	1	5	6	2	2	3	8	5
P-23	Design Engineer	4	3	1	1	2	1	10	1	8	3	4	2
P-23	Design Engineer	4	4	8	1	1	3	9	1	9	4	11	1
P-23	Design Engineer	4	5	1	1	1	1	10	1	11	3	2	1
P-23	Design Engineer	4	6	10	1	1	3	1	1	3	8	10	9
P-23	Design Engineer	4	7	8	8	1	3	5	2	9	10	2	4
P-23	Design Engineer	4	8	2	5	1	3	8	2	10	6	5	10
P-23	Design Engineer	4	9	11	1	1	2	8	1	7	6	6	1
P-23	Design Engineer	4	10	3	10	2	3	6	1	10	11	2	9
P-23	Design Engineer	4	11	1	3	1	5	8	1	9	5	4	9
P-23	Design Engineer	4	12	1	1	5	4	6	1	8	11	2	10
P-23	Design Engineer	4	13	9	1	1	8	9	6	7	9	8	11
P-23	Design Engineer	4	14	10	1	1	3	9	1	2	3	8	8
P-23	Design Engineer	4	15	9	1	1	1	10	1	3	2	10	4
P-23	Design Engineer	4	16	1	11	1	3	11	1	10	1	11	3
P-23	Design Engineer	4	17	1	8	1	2	11	1	7	1	11	6
P-23	Design Engineer	4	18	8	1	8	4	6	1	11	10	2	6

P-23	Design Engineer	4	19	1	3	6	4	9	1	9	5	6	11
P-23	Design Engineer	4	20	9	1	1	1	6	1	6	8	7	4
P-23	Design Engineer	4	21	1	1	1	1	8	1	9	7	7	2
P-23	Design Engineer	4	22	3	8	1	2	10	1	8	5	9	3
P-23	Design Engineer	4	23	1	10	1	1	9	1	11	9	10	10
P-23	Design Engineer	4	24	1	11	5	8	9	1	3	1	1	11
P-23	Design Engineer	4	25	1	9	1	3	9	1	11	5	7	2
P-24	Product Designer	4	1	1	1	1	7	11	2	1	1	11	2
P-24	Product Designer	4	2	1	1	1	11	2	11	1	10	6	6
P-24	Product Designer	4	3	1	1	1	7	11	1	1	4	4	1
P-24	Product Designer	4	4	5	1	1	11	4	1	1	3	11	1
P-24	Product Designer	4	5	1	1	1	11	11	1	1	11	4	1
P-24	Product Designer	4	6	1	1	1	1	1	11	1	11	11	11
P-24	Product Designer	4	7	1	1	1	7	1	1	1	11	11	2
P-24	Product Designer	4	8	1	1	1	9	6	1	5	10	9	1
P-24	Product Designer	4	9	6	1	1	3	1	1	1	11	6	1
P-24	Product Designer	4	10	2	1	1	11	1	9	1	11	5	3
P-24	Product Designer	4	11	1	1	1	11	8	1	9	10	8	1
P-24	Product Designer	4	12	1	1	1	11	1	11	1	11	9	1
P-24	Product Designer	4	13	4	1	1	1	1	1	10	11	6	11
P-24	Product Designer	4	14	6	1	1	6	1	1	6	11	5	11
P-24	Product Designer	4	15	5	1	1	9	11	1	6	11	11	1
P-24	Product Designer	4	16	1	6	1	11	11	1	1	1	11	1
P-24	Product Designer	4	17	1	1	1	1	1	1	1	1	11	1
P-24	Product Designer	4	18	6	1	1	1	5	1	9	11	6	1

P-24	Product Designer	4	19	1	1	1	11	1	11	1	11	2	11
P-24	Product Designer	4	20	5	1	1	1	1	1	1	8	11	1
P-24	Product Designer	4	21	1	1	1	11	8	6	1	10	11	1
P-24	Product Designer	4	22	1	9	1	1	11	1	5	1	11	1
P-24	Product Designer	4	23	1	6	1	11	6	6	1	11	1	1
P-24	Product Designer	4	24	1	11	11	1	1	10	1	8	6	9
P-24	Product Designer	4	25	1	1	1	1	11	1	5	1	10	8

Appendix F – Expert Transcriptions

17. Robotacist – Short Design Process

R-27/2/26

Questionnaire:

1. Do you understand the toolkit?
Yeah it makes sense..

2. Would you use it?
It is a bit complicated at first.
Makes sense as a procedure to follow.

3. In what context would you use it?
Class or course work. Industry
some of the steps would combine
industry context & user needs combined
to teach

4. What would you change?
More colour to differentiate different
parts. Looks cramped

5. Would this be useful in your work?
& use
Yes. Year one PhD before Lit.
Would have simplified research
methodology

6. Would you use it in your work?

Extra

Figure 106 - Notes from Robotacist Interview

Transcript

1. Do you understand the toolkit?

Yeah, it makes sense.

2. Would you use it?

It is a bit complicated at first. Makes sense as a procedure to follow.

3. In what context would you use it?

Class or course work. Industry, some of the steps would be combined: Industrial context & User needs, combined.

4. What would you change?

More colour to differentiate different parts. Looks cramped.

5. Would you use it and it be useful in your work?

Yes. Year one PhD before Lit. Would have simplified Research methodology.

18. Design Engineer - Medium Design Process



Transcript

1. Do you understand the toolkit?

Place for development seems disconnected. But I get it. Main phase/step number 9&12 seem disconnected.

2. Would you use it?

It's giving good ideas. Bubbles are very useful. Morphology icons are really useful. Icons communicate well.

3. In what context would you use it?

Process for robot design. Use more than once. Also use for machine design; Bubbles are inspiring.

4. What would you change?

Arrows. 4 to 5. Line Gradient. Draw eye to next phase/step. 9 and 12. Bigger numbers.

5. Would you use it and it be useful in your work?

Very useful. Makes you think outside the box. Adapted to interaction focus.

EXTRA: Good direction. Curricular/ flow design is good. Flow around design. Will constantly look at previous ideas (this is good). Bubbles very useful. Morphology and styling icons good. Could be changed and adapted for interaction technology tool. Brings emotions into mechanics.

19. Product Designer - Long Design Process

PD - 27/2/26

Questionnaire:

1. Do you understand the toolkit?
Yes. But I need to use it first

2. Would you use it?
Use it to teach contextual research to master students to understand the design process in terms of product design, service design from practical, technical, research perspectives.

3. In what context would you use it?
To teach people, consultants, especially organisations to understand the implications of a social environment or supplier or moving to work robotic, group working with different sectors, contrast with different specialist

4. What would you change?
Define Not just use different people towards mind map include design sheet more historical rather than future growth or sure. Different user research

5. Would this be useful in your work?
Yes I would use it in teaching and consulting good to put it all together. Good grid of process. Master students. Valid in Design and robotic. Expanded out to other areas on contextual research

6. How would you use it in your work?
Extra: It is good that it is not linear. as process process reduce iteration on the current layout allows and encourages flexible work

Figure 108 - Notes from Product Designer Interview

Transcript

1. Do you understand the toolkit?

Yes. But I need to use it first.

2. Would you use it?

Use it to teach contextual research to master students to understand the design process in terms of product design, service design from practical, technical, research perspectives.

3. In what context would you use it?

To teach people consultancy, company, organisations to try and understand the implications in a social environment. To a supplier moving towards robotic design. Group work with different sectors. Contrast with different specialists.

4. What would you change?

(Define phase) Not push people towards mind map and use different tools. Include something other than persona sheet, as it is more historical rather than future based. Different user research.

5. Would you use it and it be useful in your work?

Yes I would use it in teaching and consulting. Good that it is all together. Good grip of the process. Master students. Valid in Design and robotics. Expanded out to other areas of contextual research. Can be taken out of robotics.

EXTRA: It is good that it is not leaner as linear processes reduce iteration and the current layout allows and encourages flexible work.

Appendix G – Robot Design Work

Short Robot Aesthetics Design Process

Primer: This version of the process is best suited for those with greater experience in other fields or which to define the direction of the project in short time. You need to go from the Define phase, to Design, to Final and follow the order of steps. There are robot aesthetic definitions to the right of the page and technical terms at the bottom of the page.

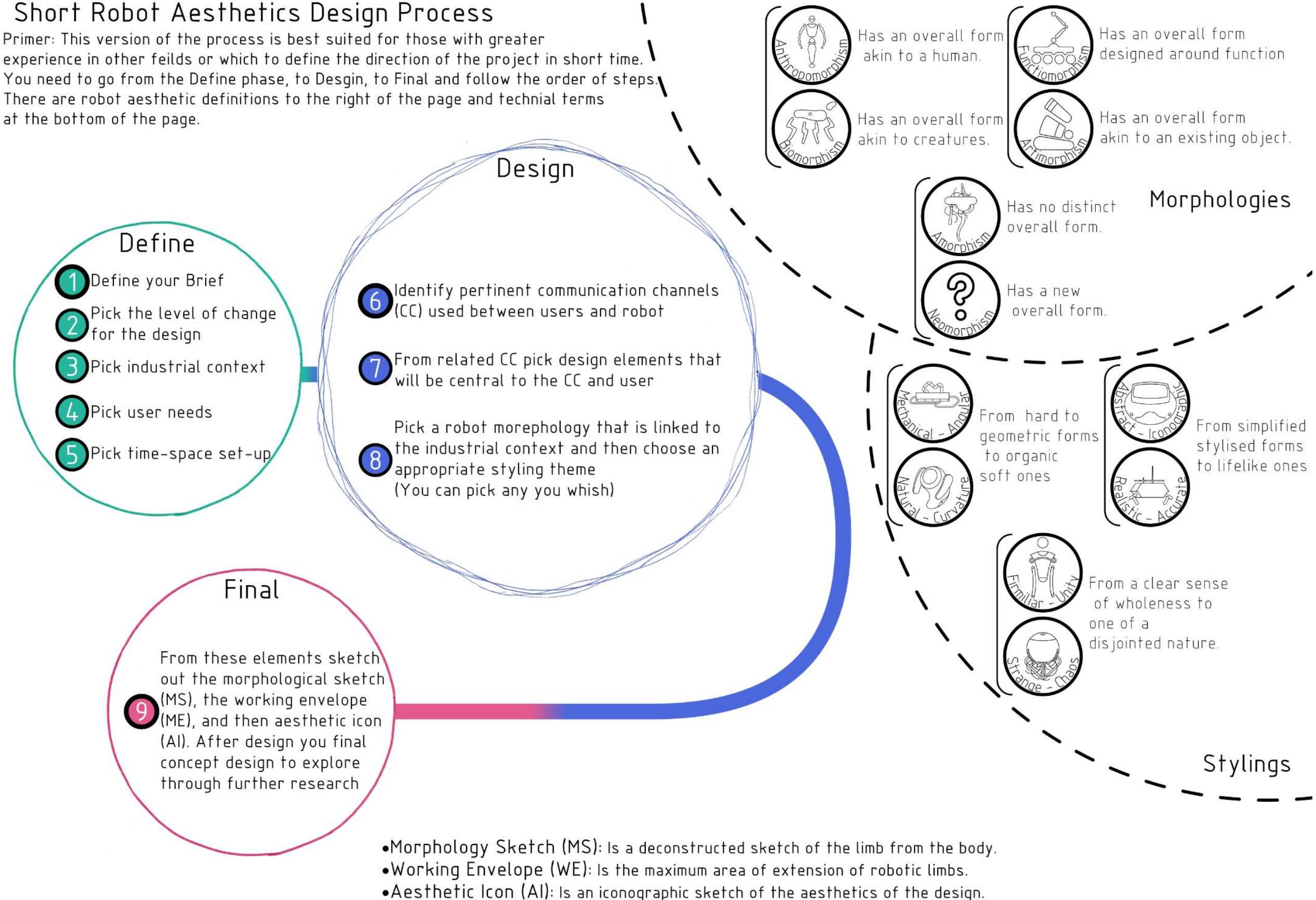


Figure 109 - Final Short Process Design - Explanation Sheet

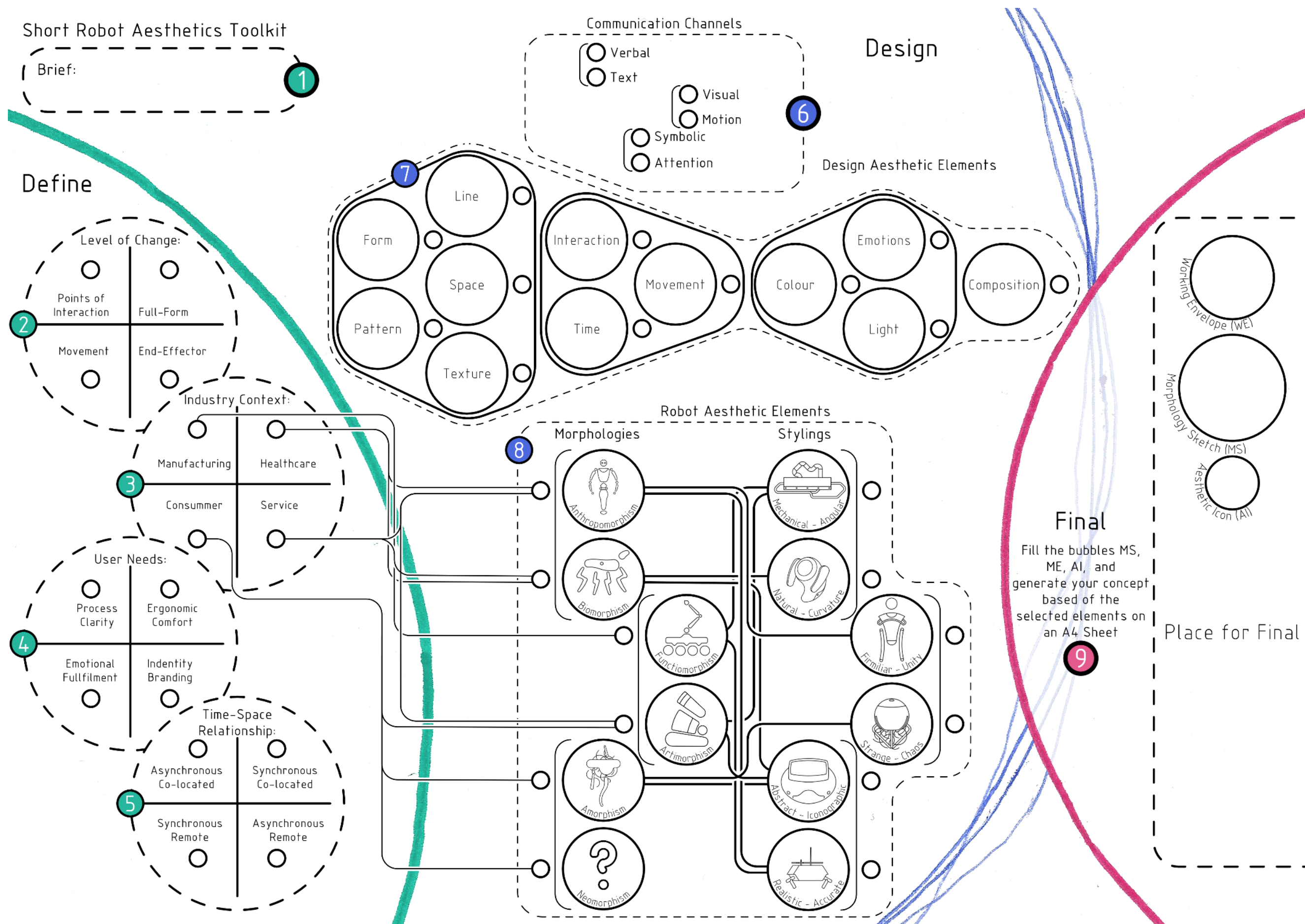


Figure 110 - Final Short Process Design

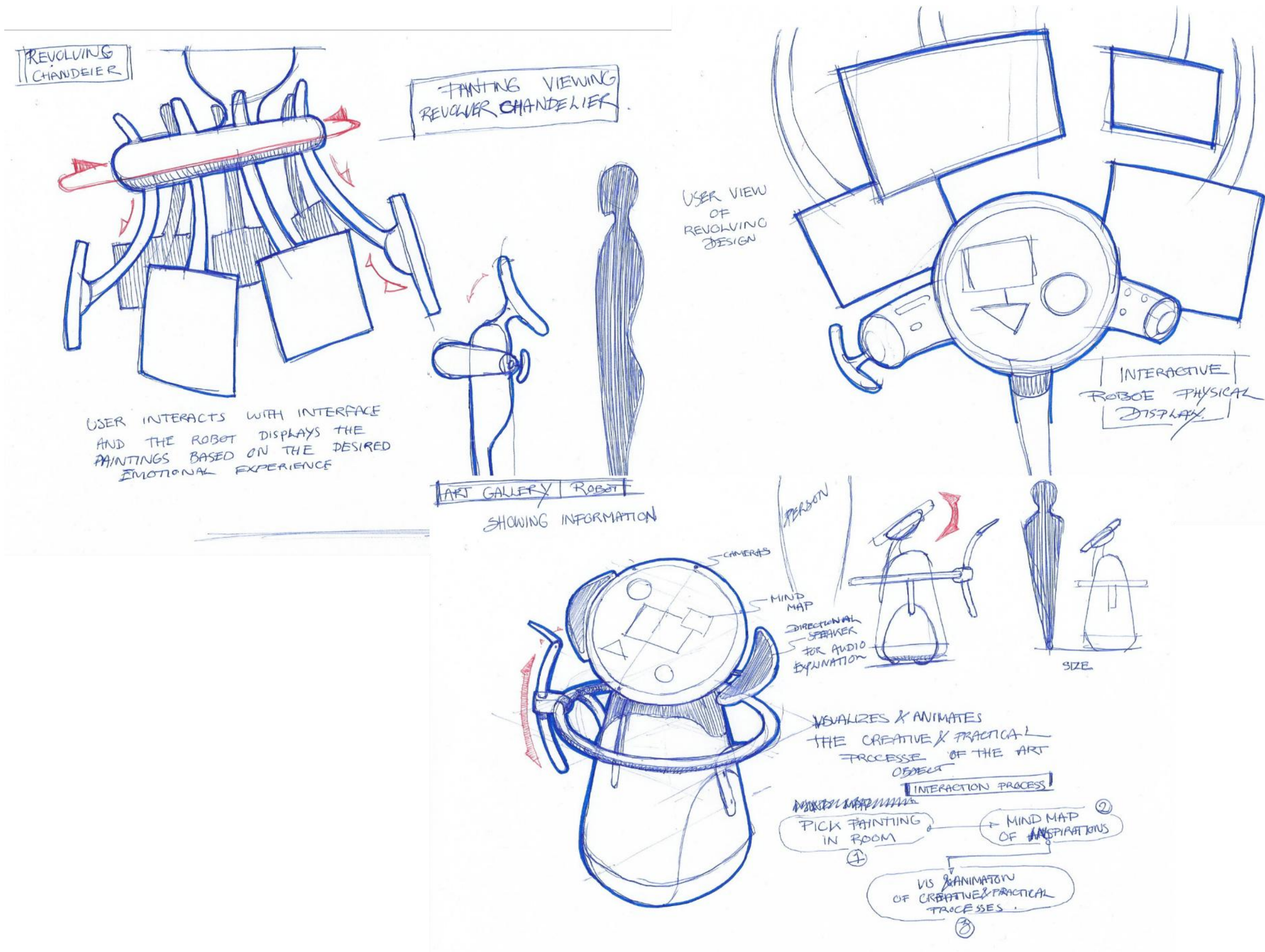
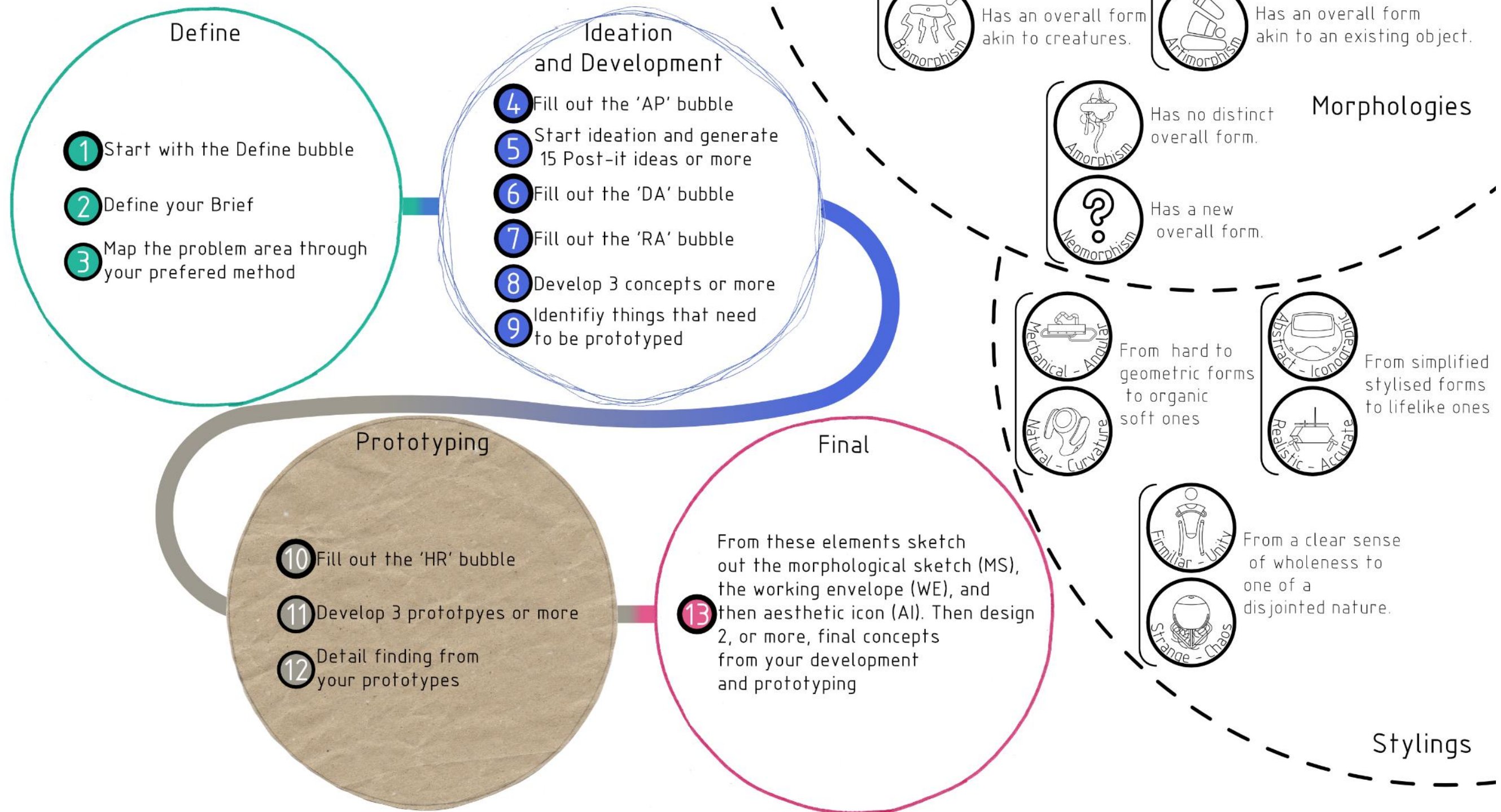


Figure 111 - Short Design Process Concepts

Medium Robot Aesthetics Design Process

Primer: This version of the process is best suited for those with experience in design and another field. You need to go from the Define phase to Ideation and Development, to Prototyping, to Final and follow the order of steps. There are robot aesthetic definitions to the right of the page and technical terms at the bottom of the page.



- Morphology Sketch (MS): Is a deconstructed sketch of the limb from the body.
- Working Envelope (WE): Is the maximum area of extension of robotic limbs.
- Aesthetic Icon (AI): Is an iconographic sketch of the aesthetics of the design.

Figure 112 - Final Medium Process Design - Explanation Sheet

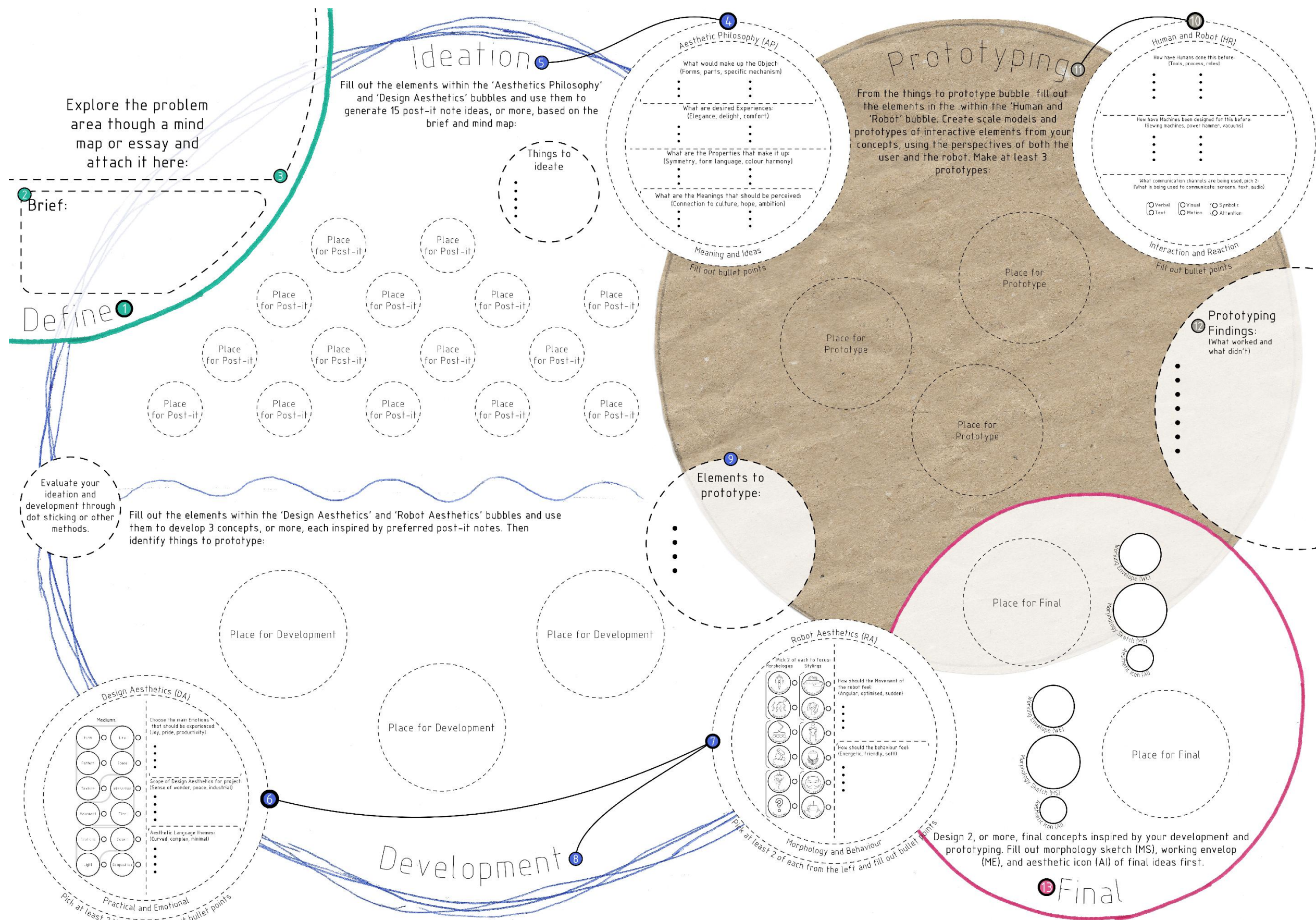
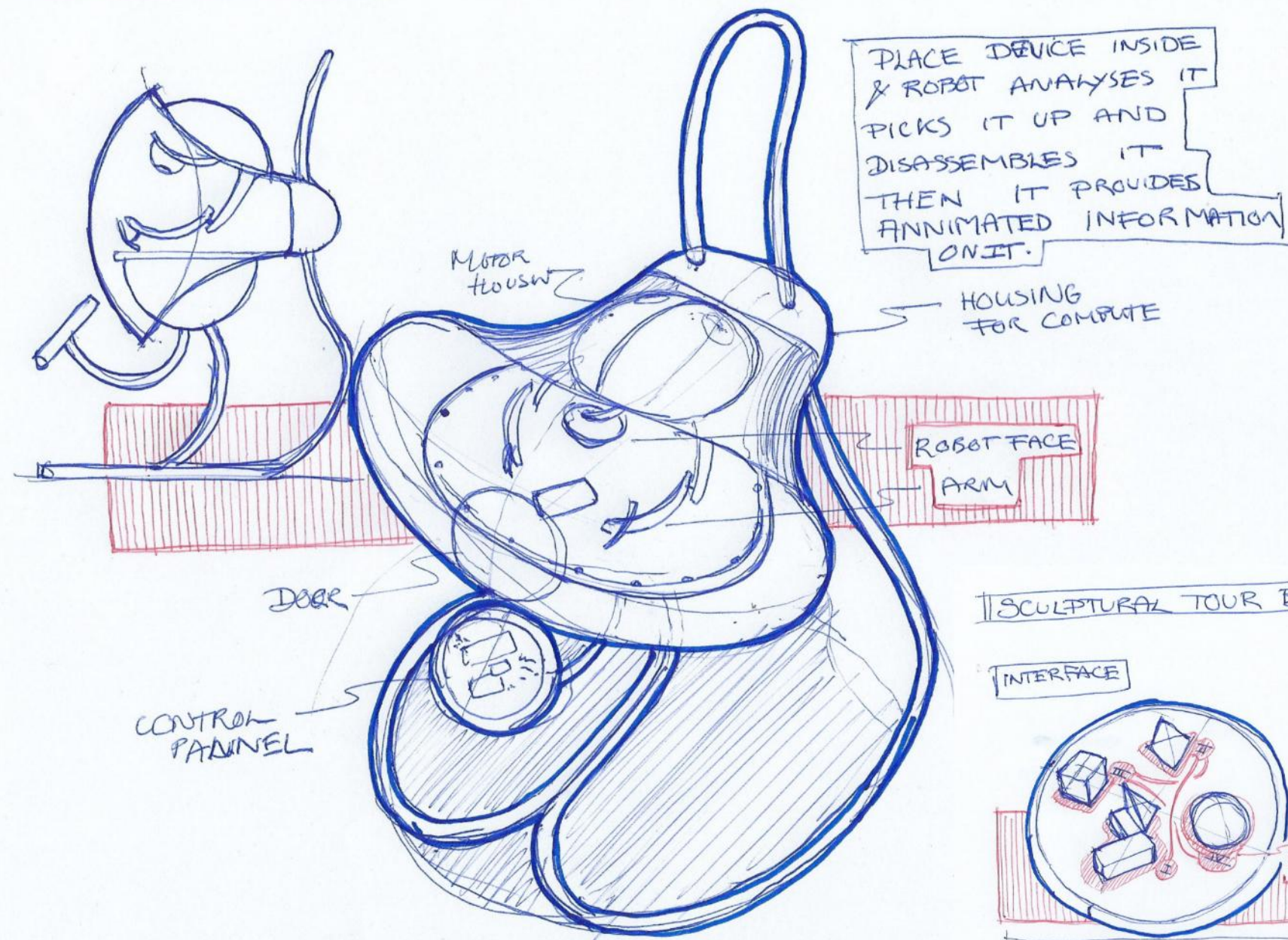


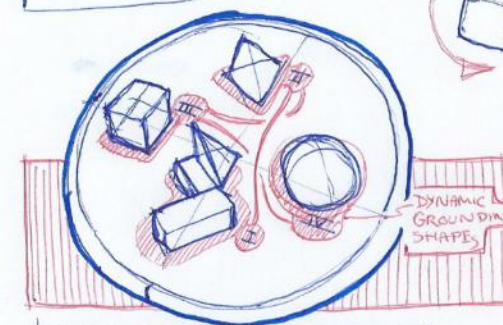
Figure 113 - Final Medium Process Design

DECONSTRUCTOR 6000



SCULPTURAL TOUR BOT

INTERFACE



MECHANICALLY CONSTRUCT
PREFERRED MUSEUM TOUR
(COULD WORK IN ANY MUSEUMS)

(BLOCK ARE AT CHARGING DOCK)

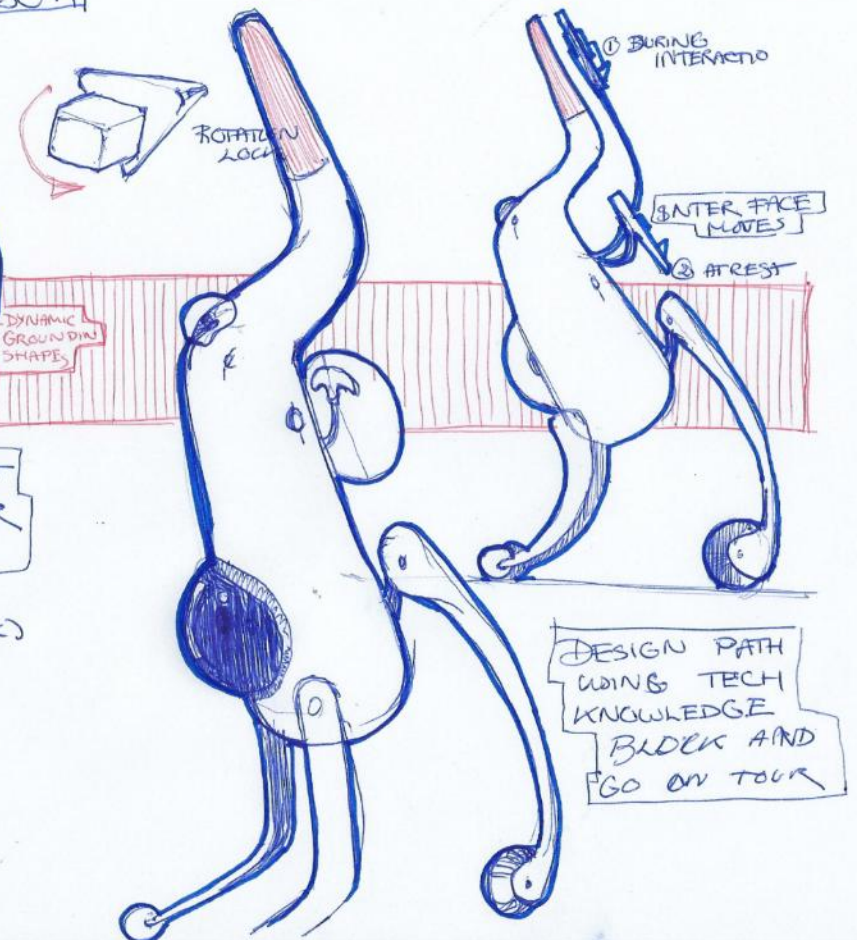
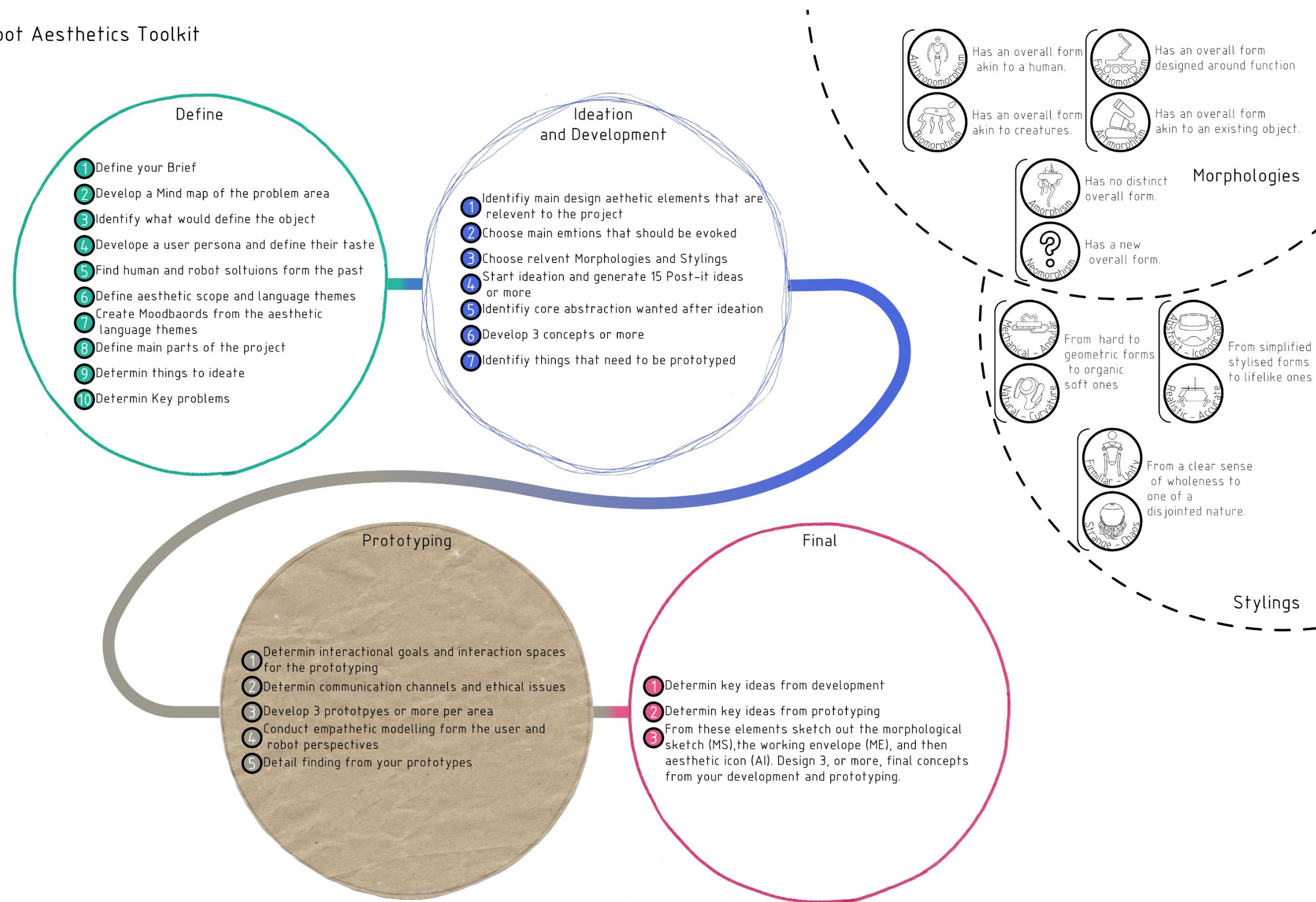


Figure 114 - Medium Design Process Concepts



- Morphology Sketch (MS): Is a deconstructed sketch of the limb from the body.
- Working Envelope (WE): Is the maximum area of extension of robotic limbs.
- Aesthetic Icon (AI): Is an iconographic sketch of the aesthetics of the design.

Figure 115 - Final Long Process Design - Explanation Sheet

Robot Design Toolkit

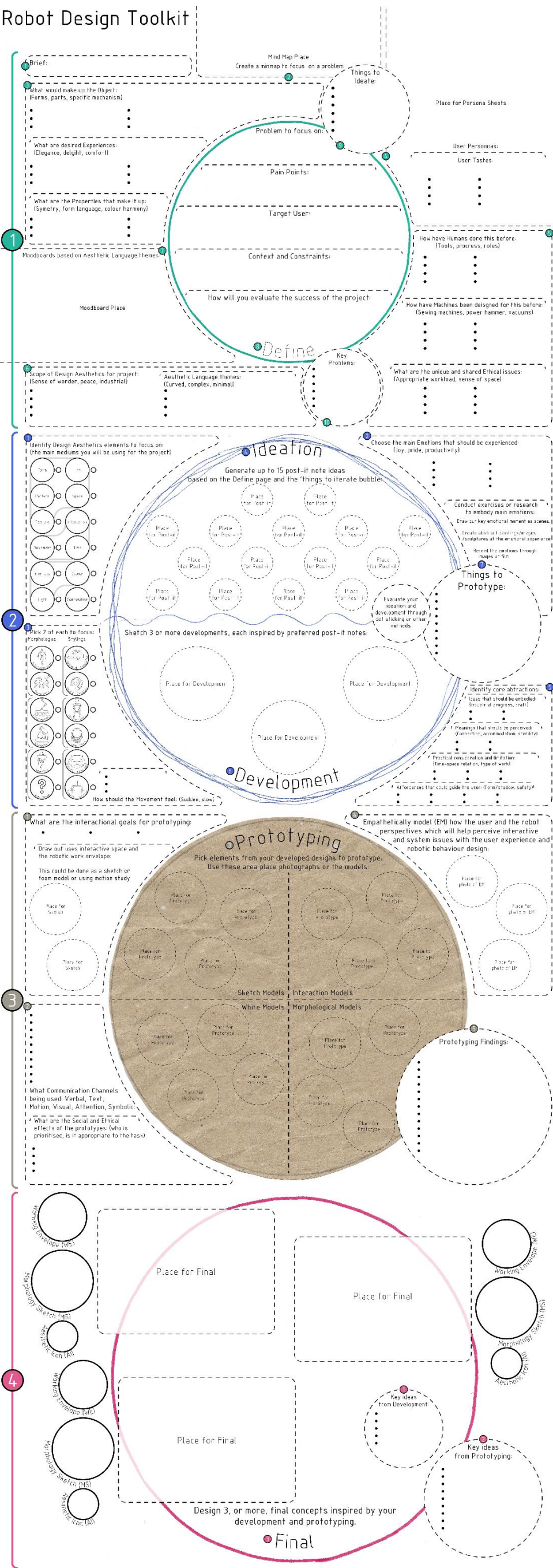
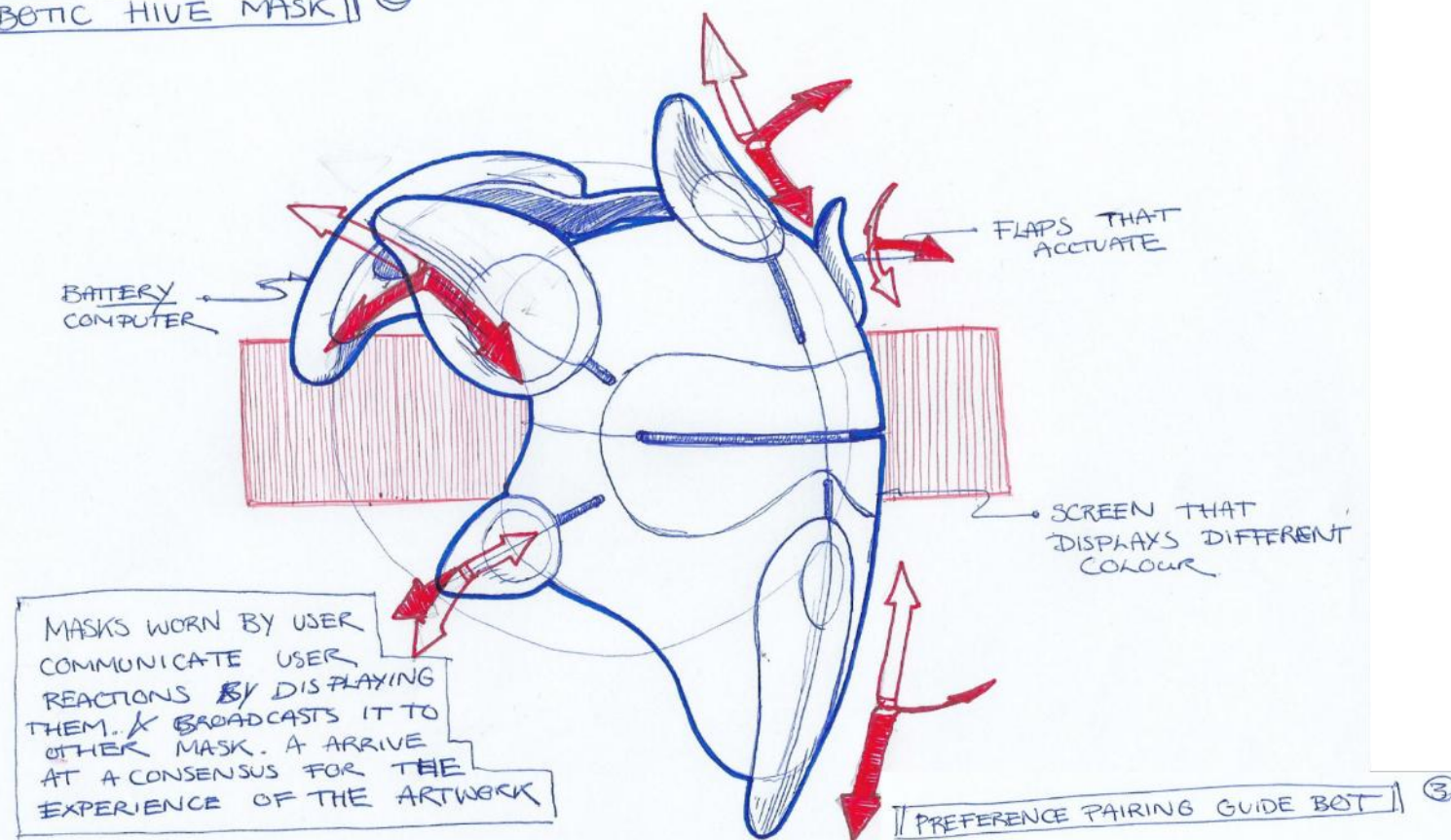


Figure 116 - Final Long Process Design

ROBOTIC HIVE MASK ②



ROBOTIC PERCEPTION LENSES ①

USER CONDUCTS PERSONALITY TEST TO DETERMINE PREFERENCES THE BLINDER THEN CAN HIDE OR REVEAL PREFERRED ART OR REPULSIVE ART. WHICH COULD ISOLATE THE USER WITH AN EXPERIENCE THAT THEY FIND SUBLIME OR CONFRONTING

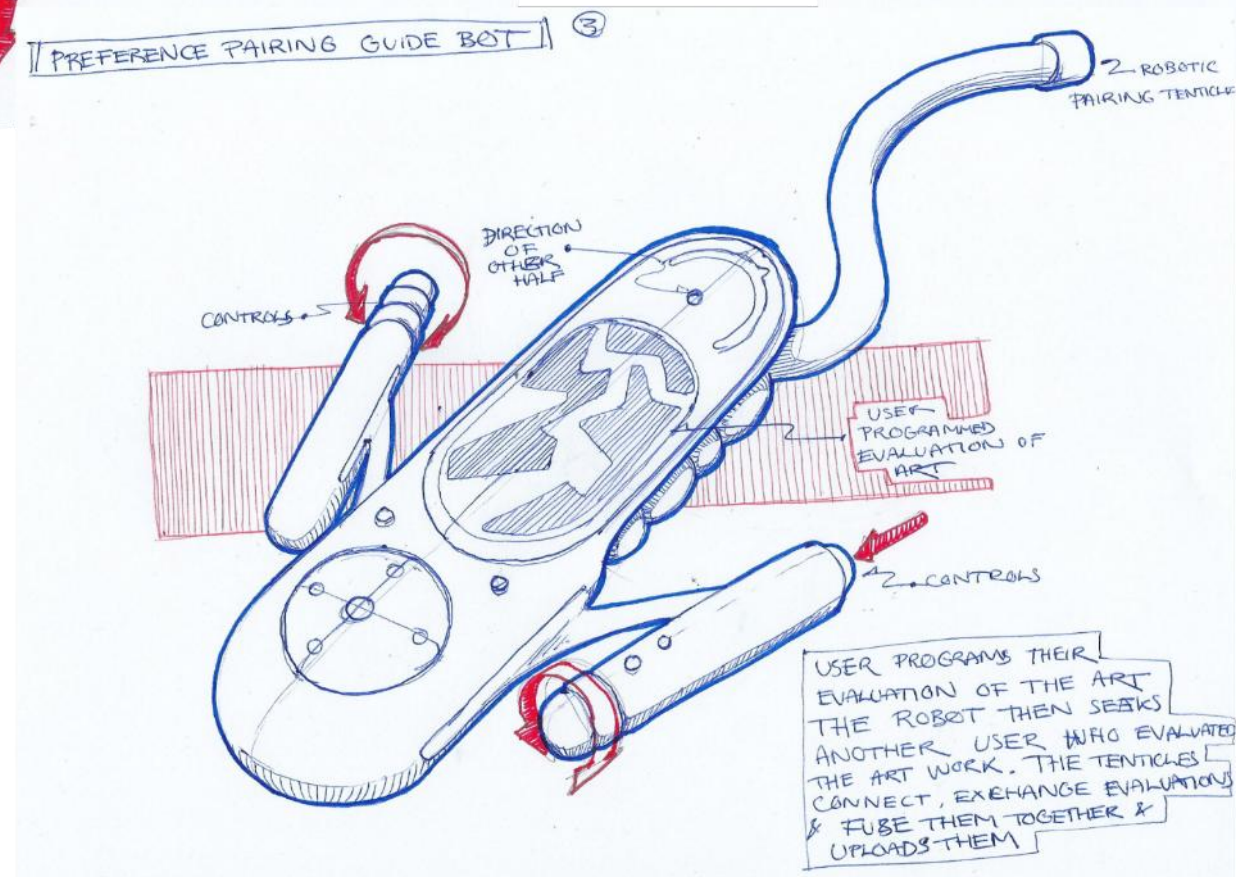
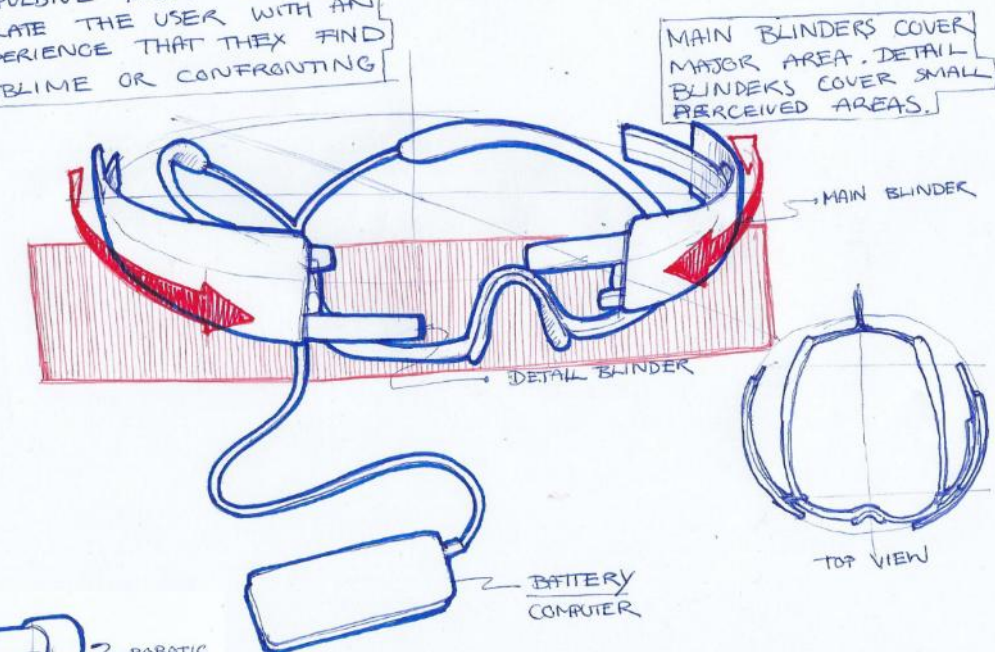


Figure 117 - Long Design Process Concepts