IMPERIAL

Exploring Cognitive Effort Investment in Mental Imagery during Digital Product Customisation:

Case Studies in the Fashion Industry

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Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Dyson School of Design Engineering

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London, April 2024

BOWEN ZHAN

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ABSTRACT

Mass customisation combines the flexibility of custom-made products with the efficiency of mass production, addressing individualisation and sustainability across various industries. This trend, driven by digital advancements and adaptable manufacturing, faces challenges in the widespread adoption of product configurators. These tools, while enabling users to be a part of the product development process, often have limitations such as predefined options that may not fully satisfy customisation needs and complexity in aligning user requirements with the final product.

As such, this research seeks to answer the question: **How might we improve the digital customisation experience to support a more user-centred experience, ultimately resulting in products that users find satisfying and cherish, thereby promoting their long-term use?**

This thesis presents an investigation into the user experience during the digital product customisation process, focusing on case studies in the Fashion Industry. The research adopted the Design Research Methodology (DRM) framework, employing a mixed methods approach across three interlinked studies.

The research offers new insights into the role of mental imagery in digital product configuration and its impact on customisation efficacy. It proposes a new construct for understanding the relationship between cognitive effort, mental imagery, and the effectiveness of digital product customisation processes. This approach emphasises the need for configurator designs that support multiple types of mental imagery.

By enhancing user satisfaction and bridging the gap between digital decisions and real-world outcomes, this research supports users in becoming co-designers and enables more effective mass customisation

in digital manufacturing systems. This research sets a promising direction for improving digital product customisation by addressing user experience challenges and developing products that align closely with user needs and preferences. The goal is to create customised items that are more valued, used longer, and ultimately contribute to sustainable production and consumption practices.

ABBREVIATIONS

2D	:	Two-Dimensional
3D	:	Three-Dimensional
AI	:	Artificial Intelligence
AR	:	Augmented Reality
B2B	:	Business-to-Business
B2C	:	Business-to-Consumer
CAD	:	Computer-aided Design
CAM	:	Computer-aided Manufacturing
CNC	:	Computer Numerical Control
CvSS	:	Customisation vis Starting Solutions
DRM	:	Design Research Methodology
SDR	:	Design Science Research
EEG	:	Electroencephalograms
ERP	:	Enterprise Resource Planning
HCI	:	Human-Computer Interactions
IoT	:	Internet of Things
PLM	:	Product Lifecycle Management
SD	:	Standard Deviation
SMEs	:	Small and Medium-sized Enterprises
SUIS	:	Spontaneous Use of Imagery Scale
UI	:	User Interface
UX	:	User Experience
VR	:	Virtual Reality
VPN	:	Virtual Private Network
VVIQ	:	Vividness of Visual Imagery Questionnaire

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Throughout history, the dynamics of production and consumption have continually changed over time, reflecting technological advancements, economic shifts and social values (Kent, Kuksa and Fisher, 2023c). The development of production methods progressed from the origins of made-to-order craftsmanship to the emergence of mass production in modern times (Piller and Wang, 2018). As production methods have changed, and thanks to the development of digital technology, new methods and models continue to evolve, offering exciting prospects for the future (Aheleroff *et al.*, 2019).

In the earliest stages, at the dawn of human civilisation, the production of goods was driven by skilled craftsmanship. This remained the case for thousands of years. Artisans, with their detailed and careful work, dominated the production landscape. They employed made-to-order techniques, tailoring their creations to meet individual and specific needs and preferences (Piller, 2010). This era was characterised by a high degree of customisation, personalisation, and quality in production. However, this approach was inherently labour-intensive and time-consuming, making the goods produced not only unique but as modern civilisations evolved, often less accessible to the broader population due to the higher costs and longer production times (Bleier, de Keyser and Verleye, 2017).

The Industrial Revolution, spanning the 18th and 19th centuries, marked a transformative period in production methods. It introduced a radical shift from the artisanal, made-to-order approach to one that favoured mass production (Nayak and Padhye, 2017). Technological innovations such as steam engines and mechanised looms were at the forefront of this revolution. These advancements enabled the large-scale manufacturing of standardised items, forever transforming the landscape of production (Loghin *et al*., 2017). This era saw a dramatic increase in the efficiency of production processes, a reduction in costs, and a subsequent shift in customer habits. The ability to produce goods on a mass scale not only made them more affordable but also more readily available, significantly impacting how people accessed and consumed products (Henninger, Alevizou and Oates, 2016).

Entering the 20th century, mass production became the established norm, primarily driven by the principles of economies of scale, improved efficiency, and the rising customer demand for affordable goods (Pookulangara and Shephard, 2013). This era was exemplified by industrial pioneers like Henry Ford, who revolutionised the automotive industry. Ford's introduction of assembly lines and the concept of interchangeable parts played a critical role in reducing production costs. These innovations allowed a broader range of customers to access products that were once considered luxuries. The assembly line system not only sped up the manufacturing process but also broadened access to products, significantly influencing customer behaviour and expectations (Nayak and Padhye, 2017).

However, mass production presents several disadvantages. In the pursuit of cost efficiency and high output, the quality of mass-produced products may suffer, stemming from the use of materials, shortcuts in production processes or inadequate quality control measures (Patnaik and Patnaik, 2017). Meanwhile, the mass production model can be slow to adapt to changes in customer preferences or market trends, the inflexibility can make it difficult for retailers to respond to emerging demands and stay competitive in the rapidly evolving market (Wang *et al.*, 2017). More importantly, the sustainability issues behind mass production are under the spotlight. Mass production often involves repetitive, monotonous tasks for workers, leading to job dissatisfaction, low morale and increased turnover rates (Dissanayake and Weerasinghe, 2022). Furthermore, some facilities may neglect worker safety regulations, fair wages policies and adequate working conditions in the pursuit of cost reduction. Mass production could also result in overproduction and an abundance of inventory and waste (Henninger, Alevizou and Oates, 2016). This excess can put a strain on storage resources, force price cuts, and result in higher levels of waste when unsold items become outdated or are discarded (Dissanayake, 2020; Kent, 2021). Finally, for customers, mass production can lead to customers perceiving mass-produced items as less valuable due to their standardisation and widespread availability. As a result, customers may feel less inclined to treasure and maintain their possessions for extended periods (Mugge, Schoormans and Schiffersteinb, 2009). Mass production often promotes a disposable culture where items are easily replaced instead of treasured and preserved and this perception contributes to increased waste.

The landscape of production has seen significant advancements and emerging trends in recent years, driven by technological innovation, shifting consumer preferences, and global strategies like Industry 4.0 (Aheleroff *et al.*, 2019). Sustainable and eco-friendly manufacturing practices, alongside ethical and fair-trade production, have become increasingly important for companies aiming to meet the expectations of environmentally and socially conscious customers (Henninger, Alevizou and Oates, 2016). Mass customisation has emerged as a key trend, allowing companies to combine the benefits of mass production with personalisation to cater to the growing customer demand for unique experiences while maintaining cost efficiency (Gerards *et al.*, 2011). The integration of digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), and automation, is

transforming production processes, enabling improved efficiency, flexibility, and real-time data analysis (Loghin *et al.*, 2017). Additive manufacturing, or Three-dimensional (3D) printing, has revolutionised product design by enabling complex customisation with reduced waste and shorter lead times (Campbell and Bernabei, 2017). The shift toward localised on-demand production has streamlined global supply chains and minimised transportation-related emissions (Pookulangara and Shephard, 2013; McNeill and Snowdon, 2019). Collaborative robots have been introduced to enhance human capabilities and productivity while raising awareness about social and ethical issues (Torn and Vaneker, 2019). There has also been an uptick in demand for ethically produced goods that also meet environmental requirements(Boër *et al.*, 2018; Gembarski *et al.*, 2018). These developments signal a shift towards more sustainable, efficient, and personalised manufacturing environments.

This research focuses on investigating mass customisation as one of the solutions to address the challenges of traditional mass production, while adapting to evolving market dynamics and customer preferences. Mass customisation is also a timely response to today's shifting market landscape, where sustainability and ethical production have become increasingly valued among customers (Fisher, Kuksa and Kent, 2023). By embracing developments in digital technologies, mass customisation offers a more environmentally conscious approach by reducing production waste. Moreover, it creates an atmosphere that values possessions rather than encouraging the disposable culture that plagues mass production (Piller and Wang, 2018). By focusing on mass customisation, this research seeks to understand and investigate how this production model could benefit from digital developments to offer a sustainable and end-user-driven approach, meeting the needs of the evolving modern market.

1.1 Research Context

Designing products that satisfy customer demands has become the primary goal for most companies. Simply increasing product range is no longer enough in today's competitive market. Modern customers expect individualisation, the ability to tailor items and services according to their individual needs and preferences (Kang and Kim, 2012). At the same time, rising demands on production and consumption

have given rise to growing sustainability concerns (Moorhouse and Moorhouse, 2017). As mass production becomes more and more problematic due to environmental repercussions, industries are searching for viable solutions - with product customisation emerging as one potential solution (Dissanayake, 2020).

Product customisation has grown increasingly popular in both industry and academia, driven by its potential economic, social, and environmental advantages. But how can it be implemented successfully? In order to guarantee a satisfying end-user experience, companies must address individual needs and preferences so that customisation becomes more accessible and acceptable - thus maximising the advantages that can be derived from product customisation (Kuksa, Fisher and Kent, 2023).

In order to make customisation a more accessible and appealing option in today's digital age, where customisation also benefits from digital development, industries should begin by creating a seamless and user-friendly experience (Streichsbier, Blazek and Partl, 2014; Zheng *et al.*, 2017; Blazek *et al.*, 2018). This includes providing intuitive digital interfaces, offering a diverse range of customisation options, and ensuring timely delivery of customised products (Oertzen, Odekerken-Schröder and Mager, 2020). By creating products that the end-user would find satisfying and treasure, encouraging their long-term use, the industry can ultimately drive the adoption of sustainable production practices.

1.1.1 Defining Customisation

Defining customisation within the context of product design and customer interaction involves distinguishing it from closely related concepts such as personalisation, configuration, and co-creation, each of which represents a distinct approach to tailoring products or services to meet individual customer needs (Wang *et al.*, 2017; Kuksa, Skinner, Kent, *et al.*, 2023). Customisation refers to the process where the customer is given the opportunity to modify the features of a product within a set range of options provided by the manufacturer. It is a manufacturer-driven process where predefined options are available for the customer to choose from (Kuksa, Skinner, Kent, *et al.*, 2023). Personalisation, in contrast, is often initiated by the system or provider, using data and algorithms to

tailor the product or service to the individual's preferences or past behaviour without the customer's direct input (Kuksa, Skinner, Kent, *et al.*, 2023). Configuration, a term sometimes used interchangeably with customisation, specifically denotes the technical process of selecting and combining different components or features of a product to meet the user's specifications (Felfernig, Bagley and Tiihonen, 2014). Lastly, co-creation is a collaborative approach where customers are actively involved in the creation process of the product or service, contributing ideas and feedback that shape the final outcome beyond mere selection from predefined options (Özdemir *et al.*, 2020).

This research utilises customisation as the primary terminology to describe the process of product configuration because it most accurately captures the scope and nature of customer involvement as conceptualised in the study. Customisation emphasises the active role of customers in selecting and modifying product features within a framework established by the manufacturer, aligning with the research's focus on exploring how technological systems facilitate customer choice and individualisation of products. By adopting customisation as the main term, the study acknowledges the balance between customer and manufacturer in the product development process, highlighting the strategic importance of offering a tailored experience that remains efficient and scalable for manufacturers. This distinction is critical for understanding the implications of customisation on customer satisfaction and the overall success of the customisation strategy.

1.1.2 Defining Users

For the purposes of this research, it is important to establish clear terminology regarding the individuals involved in the digital product customisation process. In this thesis, the term "users" is primarily employed to refer to individuals who interact with digital product configurators to customise products according to their preferences. These are the individuals who engage directly with the configurator interface, regardless of whether they ultimately make a purchase.

The choice of "users" over alternatives like "customers" or "end-users" is deliberate. While "customers" emphasises the transactional aspect of the relationship and is more appropriate in general purchasing

scenarios, "users" highlights the interactive nature of the digital customisation process. It underscores the active role these individuals play in co-creating the product through their engagement with the configurator interface, which may or may not result in a purchase.

It's worth noting that in certain contexts, particularly when referencing established concepts or direct quotes from literature, terms such as "customers", "consumer" or "end-users" may appear. The term "customer" is used when discussing general purchasing scenarios or established concepts in marketing and consumer behaviour. However, unless specifically referring to such contexts or quotes, "users" will be used consistently throughout this thesis to refer to the individuals engaged in the digital product customisation process.

This consistent terminology aims to enhance clarity and precision in discussing the various aspects of user interaction, decision-making, and satisfaction within the context of digital product customisation. By focusing on "users", this research emphasises the human-centred approach to understanding digital product customisation, considering not just the potential economic transaction, but the entire experience of interacting with digital interfaces to create personalised products.

1.1.3 Product Customisation

Retailers offering product customisation services are on the rise, yet this concept is nothing new. Before the industrial revolution, all products were custom-made. Nowadays, most everyday items are mass-produced for affordability and efficiency. Customisation often represents exclusivity but is perceived as labour-intensive, slow, and costly (Marathe and Shyam Sundar, 2011; Henninger, Alevizou and Oates, 2016). To strike a balance between individualisation and efficiency, mass customisation has emerged as a popular idea in both academia and industry sectors.

Mass customisation seeks to combine the personalisation of bespoke products with the efficiency and low-unit costs of mass production (Chen, Wang and Tseng, 2009). This innovative model has been enabled by recent advancements in digital technologies, particularly configuration technologies. These

tools enable product customisation through personal devices, making end-users active participants in the product development process (Gerards *et al.*, 2011; Zhang *et al.*, 2016). By integrating cutting-edge digital solutions, mass customisation offers customers a viable path towards meeting their evolving needs without compromising affordability or efficiency.

1.1.4 Product Configurator

The configurators utilised in Business-to-Consumer (B2C) models can be categorised as mass customisation or co-design toolkits, where products are autonomously assembled from a well-defined set of components (Sandrin *et al.*, 2017). The primary role of the configurator is to establish a connection between the retailer and the end-user, facilitating the process of determining how best to implement customisation. The configurator serves as an interactive interface for users to personalise products according to their preferences. By providing a user-friendly platform, configurators empower users to make informed choices about various design elements, materials, and functionalities (Abbasi *et al.*, 2013; Trentin, Perin and Forza, 2014; Zhang *et al.*, 2016; Sandrin *et al.*, 2017; Parlangeli, Zucchiatti and Guidi, 2019). Ultimately, the configurator's purpose is to simplify the customisation process for both retailers and end-users by making it more accessible and efficient for everyone involved.

The configurator plays a crucial role as a mediator between the user and the manufacturer in the digital customisation process *(Figure 1-1)*. It acts as an interactive interface where users can submit their specific needs and preferences for the product (Schillaci, 2018). The configurator then processes these inputs to create a tailored set of specifications that reflect the user's decisions (Felfernig, Bagley and Tiihonen, 2014). Once the user's choices are configured, this information is forwarded to the manufacturer, effectively translating the requirements into technical specifications that the manufacturing process can utilise (Felfernig, Bagley and Tiihonen, 2014). Additionally, the configurator serves as a communication channel for ongoing updates and details, ensuring that both the user's expectations are met, and the manufacturer's capabilities are aligned with those expectations (Zhang *et al.*, 2016). This two-way communication facilitated by the configurator ensures that the final product

is as close to the user's initial decisions as possible, while also allowing the manufacturer to confirm or clarify production details before committing to the production process (Abbasi *et al.*, 2013).



Figure 1-1: Configurator as a Mediator Between the User and the Manufacturer

A product configurator is an interactive interface that guides customers through the customisation of a product by providing primary elements: product attributes and configurable options *(Figure 1-2)*. Product attributes are the characteristics of the product, such as its standard features, and any other predefined specifications that serve as the starting point for customisation. These attributes give the customer essential information about the product's baseline (Sabioni *et al.*, 2021). On the other hand, configurable options are the various elements that the customer can choice from, which might include choices in colour, size, components, patterns, or add-ons. The modern configurator provides real-time visual feedback, often in the form of a simulation or image that updates as options are selected, giving users a clear and immediate representation of their product (Schillaci, 2018). The simulation ensuring that users can tailor the product to their exact needs and preferences, thereby enhancing the user experience by providing a clear picture of the product's final appearance and functionality (Porterfield and Lamar, 2017). The configurator enhances customer engagement by allowing for personalised experiences and can directly connect to the e-commerce system to facilitate an easy and efficient checkout process (Gemser and Perks, 2015).

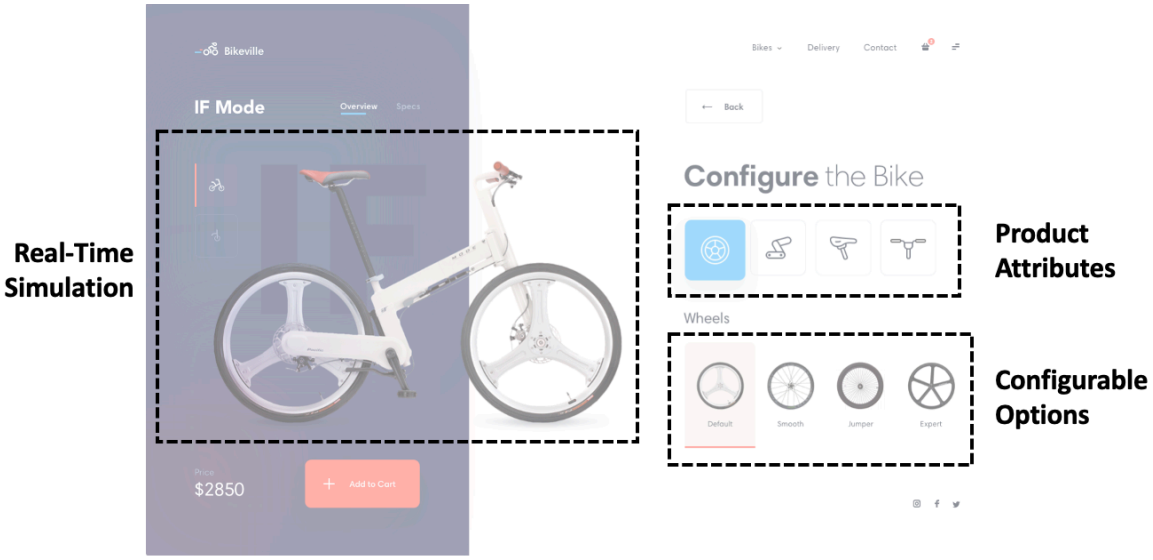


Figure 1-2. Configurator Key Elements (Bike Configurator design by Dan Klenkov) https://dribbble.com/shots/7120561-Bike-Configuration

Product configurators have been successfully applied across multiple industries, allowing customers to personalise a wide range of products, such as footwear (e.g., Converse's shoe design configurator) (*Figure 1-3),* furniture (e.g., IKEA's PAX wardrobe configurator) *(Figure 1-4)*, and automobiles (e.g., BMW's vehicle configurator) *(Figure 1-5).*

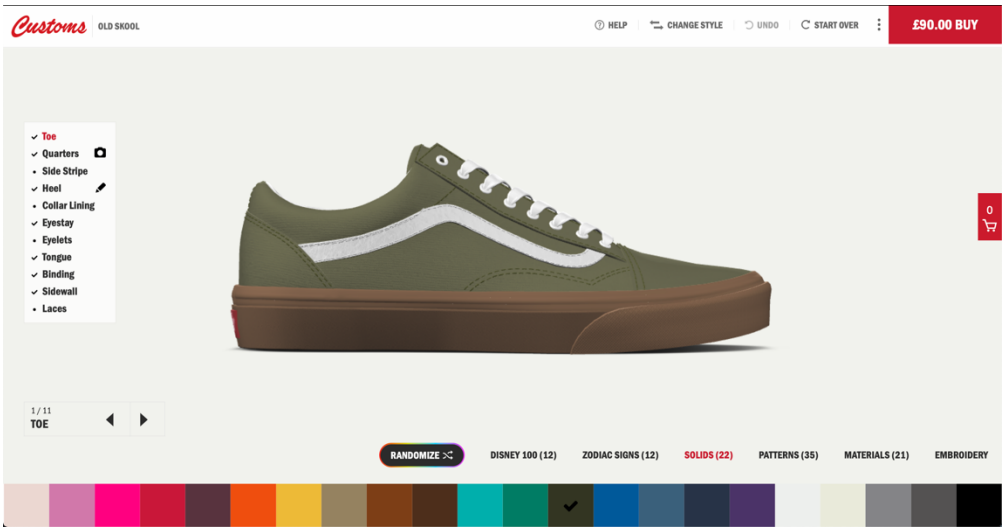


Figure 1-3. Converse Footwear Configurator (https://www.converse.com/uk/en/landing-design-your-own)



Figure 1-4. PAX Configurator by IKEA. (https://www.ikea.com/be/en/planners/pax-planner/)

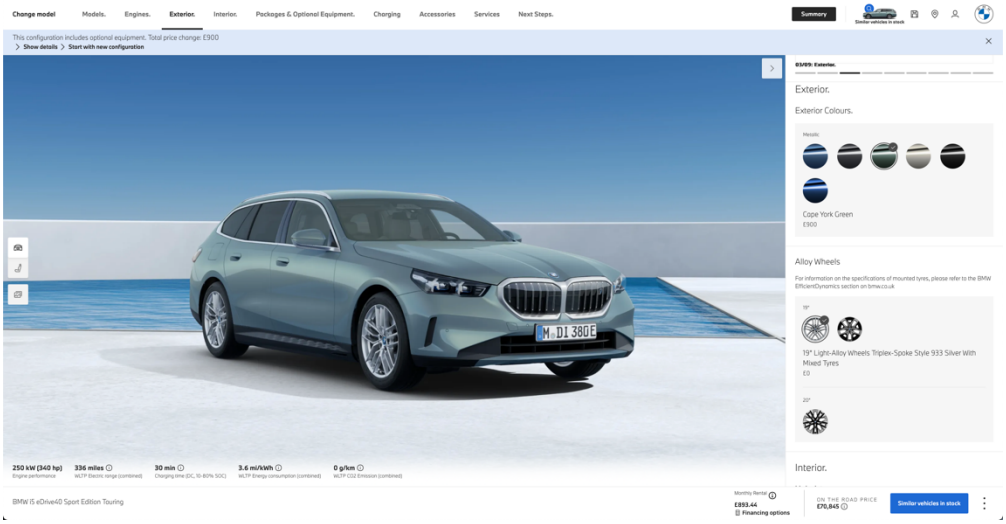


Figure 1-5. BMW Car Configurator (https://www.bmw.co.uk/en/configurator.html)

1.1.5 Process of Using a Configurator

The process of using a product configurator typically involves a series of steps that guide the user through the customisation and purchase of a product. Here's a description of the process (Buchenberg, 2018):

1. **Initiation:** The user accesses the configurator, either through a website or a dedicated application. The configurator may be presented as a standalone tool or integrated into an e-commerce platform.

2. **Product Selection:** If the retailer offers multiple configurable products, the user selects the specific product they wish to customise. This step may involve choosing from a catalogue or navigating through categories.

3. **Attribute and Option Selection:** The configurator presents the user with a set of attributes and options available for customisation. Attributes are the product features and elements that can be customised, the user will explore these attributes and selects their preferred options for each one. These attributes can be further categorised into (Piller and Wang, 2018):

- *Product Fit:* Attributes related to the dimensional properties of the product, such as size, length, or width.
- *Product Form:* Attributes related to the aesthetic properties of the product, such as colour, pattern, or shape.
- *Product Function:* Attributes related to the functional properties of the product, such as performance, features, or capabilities.

4. **Visualisation:** As the user makes selections, the configurator could provide real-time digital simulation of the product. This may include Two-dimensional (2D) images, 3D models, or interactive animations that update in real time based on the user's choices. The visualisation helps the user understand how their selections affect the appearance and functionality of the product.

5. **Constraint Management:** The configurator ensures that the user's selections are compatible and feasible. It may apply rules and constraints to prevent invalid combinations or guide the

user towards viable options. This step helps to minimise errors and ensure that the final product can be manufactured and delivered.

6. **Price Calculation:** As the user configures the product, the configurator calculates and displays the price in real-time. It may also provide cost breakdowns and other relevant financial information.

7. **Summary and Review:** Once the user has completed their selections, the configurator presents a summary of the customised product. This summary may include a detailed description, a visual representation, and the final price. The user can review their choices and make any necessary adjustments.

8. **Order Confirmation and Checkout:** If the user is satisfied with their customised product, they can proceed to the checkout process. After completing the checkout process, which may involve providing shipping and payment information. The customised product information is then transferred to the company's production systems, where the product is manufactured or assembled according to the user's specifications.

1.1.6 E-Commerce and the Fashion Industry Context

The rapid growth of e-Commerce has revolutionised the retail landscape, particularly in the fashion industry. According to recent statistics, global e-Commerce fashion revenue is expected to reach 781.5 billion U.S dollar in 2024, and 1.6 trillion U.S. dollar by 2030 (Statista, 2024). This digital transformation has not only changed how customers shop for fashion items but has also opened new avenues for product customisation.

The fashion industry, characterised by its dynamic nature and constant evolution of trends, presents unique challenges and opportunities for digital product customisation (Bellemare, 2018). Unlike some industries, such as electronics, where functionality might be the primary concern, fashion products are

deeply personal, reflecting individual style, identity, and self-expression. Fashion, at its core, represents the idea of self-expression, making it an ideal domain for exploring product customisation (Buecher *et al.*, 2018). And this personal nature of fashion items makes the industry particularly in need of effective customisation solutions. To summarise, the fashion industry presents a rich and compelling context for customisation studies due to several factors:

Successful adoption: The fashion industry has been at the forefront of adopting customisation, both in terms of customer awareness and overall purchase experience (Deloitte Digital, 2019). This widespread adoption provides a wealth of data and user experiences to draw upon *(Figure 1-6*).

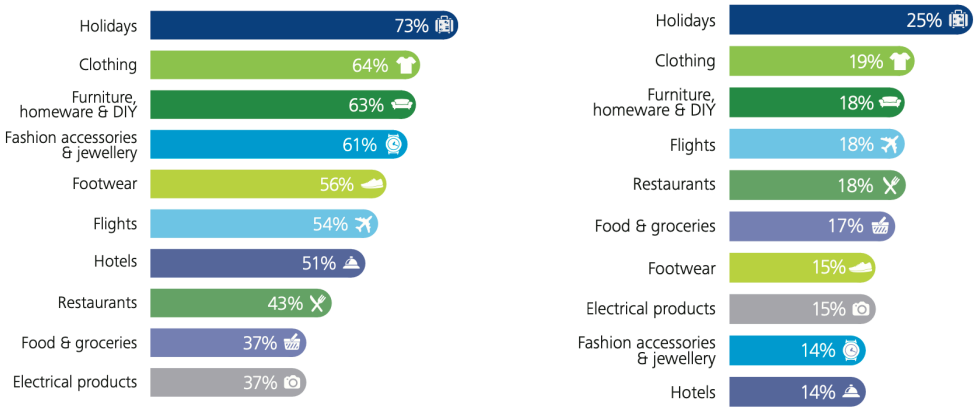


Figure 1-6. Customer's awareness (left) and purchased experience (right) of product or service customisation by category (Deloitte Digital, 2019)

Relatability: Clothing, shoes, and accessories are common consumer goods that the general public can easily relate to. This familiarity allows for more in-depth and insightful participant responses during research studies.

Depth of user insights: By using cases from the fashion industry, this research was able to provide more detailed and experienced feedback from participants, who often had prior experiences with fashion customisation to draw upon.

Variety of customisation options: Fashion products offer a wide range of customisable elements - from colour and material to fit and style - providing a complex and multifaceted landscape for studying user decision-making processes.

Moreover, the fashion industry's move towards more sustainable practices aligns well with the principles of product customisation. By producing items on-demand and tailored to individual specifications, customisation can potentially reduce overproduction and waste, addressing some of the environmental concerns associated with fast fashion (Dissanayake, 2020).

This research, therefore, is motivated by the need to understand and improve the digital product customisation process in the context of fashion e-Commerce. By focusing on user experiences, cognitive processes, and decision-making journeys in digital fashion customisation, this study aims to contribute to the development of more effective, user-centric customisation solutions. These insights have the potential to not only enhance user satisfaction and engagement but also to drive innovation in the fashion e-Commerce sector, potentially leading to more sustainable and efficient business models.

1.2 Challenges and Opportunities of Digital Product Customisation

Although configurators have emerged as a driving force for efficient customisation, designing a seamless and engaging digital experience can pose numerous challenges (Buchenberg, 2018). The first challenge lies in creating an interface that is easy to navigate while simultaneously providing enough freedom for users to achieve their desired level of customisation (Bakås *et al.*, 2018). This tension is evident in configurators that offer limited design options, restricting users to predefined combinations and preventing them from fully realising their customisation ambitions (Abbasi et al., 2013; Parlangeli, Zucchiatti, and Guidi, 2019; Wang, Mo, and Tseng, 2019). Meanwhile, the task becomes further complicated when considering that most users are not product experts, making it difficult for them to navigate complex design tools (Swait and Adamowicz, 2001; Blecker, Bernd KALUZA, and Gerold KREUTLER, 2004; Dellaert and Stremersch, 2005).

Secondly, the nature of remote digital environments introduces significant challenges in the form of uncertainty and potential dissatisfaction post-purchase (Park and Hill, 2018). Users are unable to

physically interact with the product prior to purchase, placing a greater emphasis on the need for accurate and comprehensive product information. This scenario heightens the risk of post-purchase dissonance, as customised items typically cannot be returned or exchanged, underscoring the importance of making well-informed decisions (Nelis et al., 2014; Steinmann, Kilian, and Brylla, 2014; Maier and Dost, 2018; Heller et al., 2019; Renner et al., 2019).

Lastly, the transition towards users assuming the role of designers in the customisation process introduces a unique set of tensions. On one hand, this enhancement influences a sense of ownership and emotional bonding with the product, leading to increased satisfaction (Grimal and Guerlain, 2014; Martinez-canas, 2014; Acharya et al., 2018; Ramaswamy and Ozcan, 2018). On the other hand, unlike most e-commerce situations, where users make a single purchase decision, the highly modular configuration process demands that users make several decisions along the way. The decision journey of the product configuration process, which involves navigating through a multitude of attributes and options, can be exceptionally effortful and lead to choice overload, a phenomenon where an excessive number of choices results in increased cognitive effort, confusion, and potential dissatisfaction with the final decision (Cardozo, 1965; Lala and Chakraborty, 2015; Park, Hill and Bonds-Raacke, 2015; Nettelhorst et al., 2017). This scenario presents a contradiction: minimising effort is a traditional principle for creating a user-friendly experience; however, the process necessitates effort investment to justify the decisions made. Therefore, striking a balance between these aspects is crucial to ensure the higher efficacy of the configuration process. By achieving this balance, users will be able to modify the product to fulfil their needs and preferences without being overwhelmed by the complexity of the process.

1.3 The Role of Cognitive Effort

In the context of purchasing scenarios, efforts are expended in various forms, such as the physical effort of driving to a store and searching for a product, or the financial effort required to obtain a product (Cardozo, 1965). Additionally, when faced with multiple choices, the effort involved in evaluating

alternatives is recognised as cognitive effort (Garbarino & Edell, 1997). In e-commerce, this cognitive effort expended becomes more complex due to a broader range of influencing factors that affect purchasing decisions and system usability (Streichsbier, Blazek and Partl, 2014). This complexity is particularly evident in digital product customisation, where the modular nature of product structures requires consistent decision-making, making it challenging to draw comprehensive conclusions using current methods for assessing cognitive effort.

Previous studies on configuration technology have mainly focused on system usability and the overall user experience (Sandrin et al., 2017). These studies have investigated various aspects of configurator design, such as the impact of user interface elements, the effectiveness of visualisation techniques, and the role of recommendation systems in guiding users through the configuration process (Forza & Salvador, 2002; Trentin et al., 2011; Randall et al., 2007). The primary goal of these studies has been to optimise the configurator's usability and minimise the cognitive effort required from users during the configuration process (Hildebrand et al., 2014; Franke & Piller, 2003). However, there is a notable lack of research that adopts a user-centred perspective, focusing on understanding of the relationship between the actual use of configurators and the cognitive processes involved in visualising, planning, and interacting with future products (Parlangeli, Zucchiatti and Guidi, 2019; Godse et al., 2018; Schnurr et al., 2018). This gap in the literature highlights the need for a more comprehensive understanding of the user experience, beyond the mere optimisation of the configurator's usability, to develop configuration systems that effectively support and engage users throughout their cognitive process of decision journey.

Today's customers are demanding a greater variety of options in customisation, which has led to an increase in the complexity of product structure (Gerards *et al.*, 2011; Bakås *et al.*, 2018). This poses challenges for retailers, who must balance the need to maintain autonomy and freedom for users to configure products that closely match their needs and preferences, while preventing the negative effect caused by choice overload (Scholl-Grissemann, Stokburger-Sauer and Teichmann, 2022). Therefore, this study suggests that cognitive effort should not be viewed as a whole but should instead be dissected into components that influence user decision-making. This approach aims to gain a deeper

understanding of how cognitive effort impacts user behaviour and decision-making in the context of product customisation.

1.4 The Role of Mental Imagery

In the context of digital product configuration, the absence of physical interaction with a product introduces unique challenges and opportunities in the user experience (Özdemir *et al.*, 2020). Without the ability to physically touch, feel, or directly observe a product, users rely heavily on visual information derived from their past experiences with similar items or their pre-existing knowledge about the product (Kim *et al.*, 2020). This reliance on visual representation necessitates a deeper exploration of visual mental imagery within this context (Heller *et al.*, 2019).

Mental imagery, often described as "thinking in pictures" or "seeing with the mind's eye," plays an important role in how customers evaluate products in digital environments (Kosslyn, Thompson and Ganis, 2014). This cognitive process enables individuals to create mental representations of objects or scenarios that are not presently observed, allowing for a vivid 'visualisation' of potential purchases before making a decision (Yoo and Kim, 2014). The significance of mental imagery in digital product configuration stems from its ability to bridge the gap between the intangible digital representation and the tangible physical product. It enriches the customer's interaction with the product by enabling a form of sensory engagement that compensates for the lack of physical contact.

Previous research has highlighted the importance of mental imagery in the digital product evaluation process and suggests that mental imagery not only influences customer perceptions of a product's attributes but also enhances the emotional and experiential aspects of the evaluation process (Blevis et al., 2012; Yoo and Kim, 2014; Bogicevic et al., 2019). For instance, through mental imagery, customers can 'experience' the product in various contexts, imagine using it in their daily lives, and anticipate the satisfaction it might bring. This imaginative engagement can significantly impact their satisfaction with the digital configuration process, their confidence in purchase decisions, and ultimately, their satisfaction with the final product.

Mental imagery is particularly interesting in this context because it taps into the customer's cognitive and emotional processes, offering a rich area for research and application. Understanding how to stimulate and leverage mental imagery can lead to more effective digital interfaces and product presentations. Moreover, mental imagery's role extends beyond mere product visualisation. It can influence customer attitudes, intentions, and behaviours by developing a deeper emotional connection with the product (Renner *et al.*, 2019). This emotional engagement is crucial in digital environments, where the physical distance from the product might otherwise lead to a more detached and rational decision-making process.

1.5 Cognitive Effort Investment in Mental Imagery

Mental imagery plays a crucial role in the product evaluation process, particularly in the context of digital product customisation. As users engage with product configurators and make design choices, they rely on mental imagery to visualise and assess the potential outcomes of their decisions. However, generating and maintaining these mental images requires cognitive effort, which can influence the user's overall experience and satisfaction with the customisation process (Overmars and Poels, 2015). Kirby and Kosslyn (1990) established the key priorities of mental imagery and suggested that mental images are only maintained through cognitive effort and rapidly fade without it. This insight highlights the importance of understanding the cognitive effort invested in mental imagery during digital product customisation. By exploring how users allocate cognitive resources to generate and sustain mental images, we can gain a deeper understanding of the factors that shape user engagement and decision-making in this context. However, despite the potential significance of cognitive effort investment in mental imagery, there has been limited research specifically addressing this aspect of digital product customisation. Most studies have focused on the role of mental imagery in facilitating product evaluation and decision-making (Dahl and Hoeffler, 2004; Zhao, Hoeffler and Dahl, 2009; Zhao, Dahl and Hoeffler, 2014) or the role of product visual presentation in augmenting mental imagery processing (Yoo and Kim, 2014; Maier and Dost, 2018; Kim *et al.*, 2020), the specific cognitive effort required to generate

and maintain mental images during the customisation process has not been adequately addressed. A previous study by Hildebrand et al. (2014) considered and highlighted the important role of mental simulation in product customisation. However, it did not investigate the specific cognitive challenges associated with the modular nature of digital product customisation. Although the study's findings are valuable, they remain similar to those of previous research in terms of the general influence of mental simulation on product evaluation and decision-making. The study does not provide novel insights into the cognitive effort required to create and maintain mental images in the modular context of digital product customisation, where users must generate initial mental representations of the customised product and continuously update these images as they explore different options and configurations. The cognitive effort demanded by this iterative mental imagery process is distinct from that in traditional product evaluation and decision-making scenarios. To fully understand the role of cognitive effort investment in mental imagery during digital product customisation, current research needs to consider the unique demands of generating, maintaining, and continuously updating mental images as users navigate through various customisation options. By examining how users manage the cognitive load associated with utilising their mental images throughout the modular customisation process, the current research can uncover distinct challenges and opportunities for optimising digital product customisation systems.

Cognitive effort invested in decision-making is subject to a wide range of influencing factors, including design decisions and system usability. As such, this research will draw on established research knowledge and practices from across a range of disciplines to explore the challenges and opportunities associated with balancing user autonomy of the process, investigate users' decision-making processes, examine the role of visual mental imagery, and identify gaps in current understanding of cognitive processes and user experience with configurators. In this way, this research focuses on examining the cognitive effort invested in mental imagery during the digital product configuration process. This aims to provide valuable insights that can offer a deeper understanding of how users navigate the product evaluation process in a digital environment, and how the efficacy of the process may lead to the satisfaction of individual needs and preferences. Ultimately it is hoped that this work can help develop

more user-friendly digital product customisation processes that results in products that better meet the needs and preferences of individual users that can be utilised and kept for longer.

1.6 Research Aim and Objectives

The research reported in this thesis aims to investigate the digital product customisation process in order to propose a theoretical approach that enhances user satisfaction with both digital design outcomes and the decision-making process. The specific objectives of the research are:

Objectives:

- *To understand users' decision journey and their expectations and concerns when conducting product customisation in the virtual environment.*

- *To analyse the distribution of users' cognitive effort in the digital product configuration process, specifically how they utilise mental imagery when evaluating the digitally configured product.*

- *To propose a new construct to investigate and further understand users' cognitive effort in mental imagery during the digital product configuration process.*

1.7 Structure of the Thesis

The summary of the chapters in this thesis is as follows, and as shown in *Figure 1-7:*

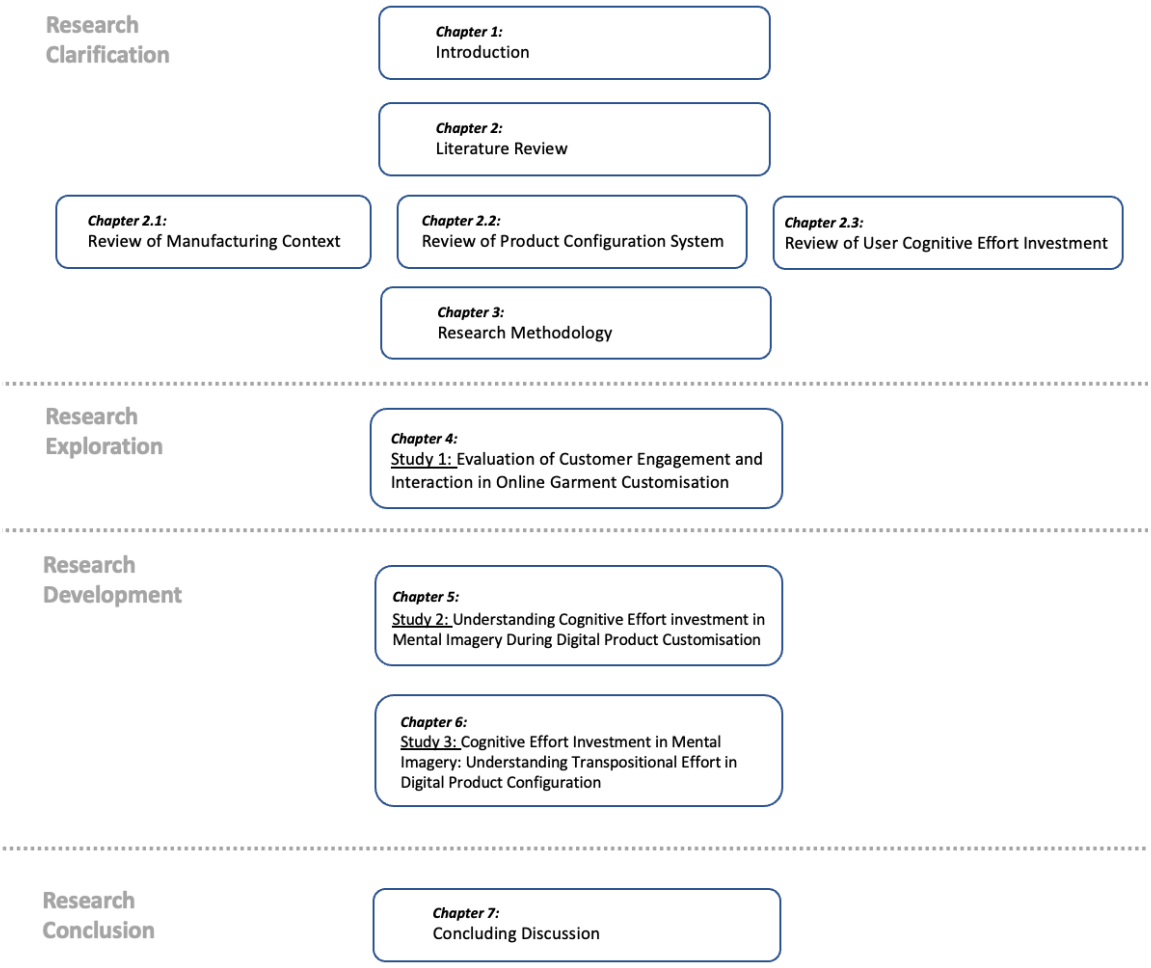


Figure 1-7. Thesis Structure

Chapter 1 is the introductory chapter that sets the context of this research, providing a brief introduction to product customisation, the application of product configurators, and the challenges and opportunities they present. This chapter outlines the research aims and objectives and positions the research within its broader context.

Chapter 2 describes the key concepts underpinning this research and their positions in existing academic literature and industry implementation. The chapter further establishes connections between existing and proposed concepts.

Chapter 3 presents the research methodology adopted in this research. Positioned as Design Science Research (DSR), it addresses human behavioural and motivational factors through advances in technology systems. Adopting the Design Research Methodology (DRM) framework, this research uses a mix of qualitative exploration and quantitative analysis for validating research hypotheses and the proposed concepts.

Chapter 4 highlights the findings from the first study in the research exploration stage. This chapter evaluates user engagement and interaction to understand customers' expectations and concerns when conducting customisation in the virtual environment. Using the case of tailored shirts, the chapter further examines how the remote digital environment impacts users' engagement with product function, form, and fit.

Chapters 5 and 6 present the main research development of the thesis through two studies. Building on the key findings around users' mental imagery in the product configuration process, the research further explores users' cognitive effort investment in mental imagery and its impact on the efficacy of the digital product configuration process. ***Chapter 7*** summarises the conclusion of this research, along with research contributions, implications, limitations and directions for further research.

2. LITERATURE REVIEW

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This chapter offers an exploration of the relevant literature related to digital product customisation. In the constantly evolving landscape of modern industry and product innovation, it is critical to understand the development process, sustainability considerations, and technological advancements driving change. This review aims to outline the complex and cross-disciplinary phenomenon of user interaction with digital product customisation, providing a comprehensive overview of the critical areas, including the academic origins, current practices, and future directions of this field.

The focus of this literature review begins within manufacturing contexts, exploring how technological advancements have enabled the possibility of mass customisation. This entails the feasibility of producing customised products at scale, and balancing efficiency with customer demands while considering environmental and social responsibilities. By comparing current production models, the review further examines the capabilities, challenges, and limitations of mass customisation, as well as its impact on streamlining the product development process and thereby enhancing customer experience.

The narrative then transitions to a focused examination of product configuration systems— the enablers of digital product customisation. This section delves into the evolution of product configurators, outlining current practices that facilitate the customisation process and detailing their features, capabilities, and limitations. By analysing state-of-the-art product configuration and its developmental direction, the review aims to understand how these systems are revolutionising the way products are designed and experienced by users.

Building on the discussion of product configuration systems, this review further explores user interaction and engagement within these digital environments. It focuses on the most significant work already accomplished in this area, analysing how digital platforms enhance the user experience during product customisation. The review examines strategies employed to improve user interface and interaction design, thereby increasing user satisfaction and engagement. Furthermore, it addresses the psychological aspects of product customisation, particularly cognitive effort and mental imagery. This

section investigates how cognitive processes involved in envisioning digitally configured products influence user decisions and satisfaction levels. By understanding the investment in cognitive effort and the strategies of mental imagery users employ during the product configuration process, this section offers insights into and identifies gaps in the existing literature, laying a foundational understanding that supports the thesis's investigations into digital product customisation.

2.1 Review of Manufacturing Context

The progression of manufacturing techniques has led to the development of three primary models: *custom-made production*, where products are tailored to individual specifications; *mass production*, which focuses on the efficient production of large quantities of standardised products; and *mass customisation*, a hybrid approach that combines the efficiency of mass production with the personalisation of custom-made items. The following section aims to investigate each of these methodologies, exploring their distinct features, strengths, and weaknesses. By examining these approaches in detail, this section will analyse their impact on the modern market, which is increasingly influenced by customer preferences and demands. Through this comparison, this section aims to illuminate how each manufacturing model caters to different market segments, balancing between cost-efficiency, scalability, and the desire for personalisation, thereby shaping the consumption patterns and competitive dynamics of today's customer-driven market.

2.1.1 Custom-Made Production

Custom-made production, often referred to as bespoke manufacturing, prioritises the creation of items that are specifically designed to meet the unique requirements and tastes of each customer (Gilmore and Pine, 2007). This method is traditionally linked with superior craftsmanship and a sense of exclusivity, as custom-made products are generally more costly and require a longer production time compared to items that are mass-produced (Pine, 1993). Despite these increased expenses, the demand for custom-made goods remains strong in several sectors, notably within the realms of luxury

fashion, bespoke furniture, and artisanal products. In these domains, the premium placed on distinctiveness and personalisation by customers is significant (Kapferer and Bastien, 2012).

The appeal of custom-made production lies not only in its ability to deliver unparalleled personalisation but also in its emphasis on quality and the meticulous attention to detail afforded by skilled artisans and craftsmen (Kapferer and Bastien, 2012). This approach enables customers to be directly involved in the creation process, from initial design to final product, developing a deeper connection between the buyer and the item. As a result, custom-made production not only caters to the desire for individuality among customers but also enhances the overall purchasing experience, reinforcing the value of craftsmanship in today's increasingly automated world (Marsh, 2012; Hu, 2013). The participation of customers in the creation process, from initial design through to the final product, creates a deeper connection to the item, enhancing the purchasing experience and reinforcing the value of unique craftsmanship ((Bhaduri and Stanforth, 2017; Fink and Geldman, 2017; Diefenbach *et al.*, 2018). Diefenbach et al. (2018) delve deeper into customer participation, exploring the commercial value and product attachment. Their study, conducted across various product domains, illustrates that both self-design and self-creation both equally promotes product attachment. This finding indicating the significant impact of customer involvement on emotional attachment and commercial value of the products.

2.1.2 Mass Production

Mass production, frequently attributed to Henry Ford and his revolutionary practices in the automotive industry, represents a manufacturing methodology dedicated to the generation of standardised products in large volumes, aiming to minimise the cost per unit (Williams, Haslam and Williams, 1992; Duguay, Landry and Pasin, 1997). This approach is fundamentally defined by the principle of economies of scale, a concept that highlights how increased production levels can lead to significant cost savings, thereby reducing the price of each individual unit (Atack, 1985; Chandler, 1986). The adoption of mass production techniques has become prevalent across numerous sectors, from consumer electronics to fast-moving consumer goods, primarily because of its unparalleled efficiency and cost-saving potential

(Alptekinoğlu and Corbett, 2008). This broad applicability underscores a transition towards more sophisticated manufacturing model that leverage technological advancements to promote economic growth and competitiveness (Duguay, Landry and Pasin, 1997; Hu, 2013).

Despite its widespread implementation and the economic benefits it brings, mass production is not without its drawbacks (Williams *et al.*, 2014). One of the main criticisms levelled against this approach concerns its tendency to overlook the diverse needs and preferences of individual customers (Duguay, Landry and Pasin, 1997; Alptekinoğlu and Corbett, 2008). By focusing on the creation of uniform products, mass production often leads to a market saturated with similar offerings, which can limit choices for customers seeking personalised or niche products (Wang *et al.*, 2017). Furthermore, this emphasis on standardisation and efficiency can sometimes result in compromises on product quality and innovation, as the drive to reduce costs and simplify manufacturing processes takes priority (Radder and Louw, 1999; Williams *et al.*, 2014). As a consequence, while mass production continues to play a critical role in the global economy, facilitating access to affordable goods for a broad audience, it also prompts an ongoing debate about the balance between cost-effectiveness and the fulfilment of diverse customer desires (Marsh, 2012; Williams *et al.*, 2014).

In addition to the concerns regarding customer choice and product homogeneity, the environmental and sustainability impacts of mass production remain a significant area of criticism (Marsh, 2012; Hu, 2013; Williams *et al.*, 2014). The large-scale, standardised approach of mass production demands an extensive use of resources, including raw materials and energy, leading to a considerable environmental footprint (Williams *et al.*, 2014). This process often results in overproduction, creating waste and excess inventory that might not find use (Duguay, Landry and Pasin, 1997; Marsh, 2012; Williams *et al.*, 2014). Moreover, the drive to lower costs can sometimes lead to practices that sidestep environmental regulations, causing pollution that affects air and water quality and contributes to broader environmental damage, such as habitat destruction and biodiversity loss (Kent, 2021). Additionally, the focus on volume and cost reduction can undermine product quality, creating a disposability culture and

a cycle of continuous consumption that poses challenges to both environmental and economic sustainability (Boër *et al.*, 2018; Gembarski *et al.*, 2018; Dissanayake, 2020).

Today, the fashion industry stands as one of the major polluters, grappling with the negative impacts of mass production (Saxena and Raja, 2014; Henninger, Alevizou and Oates, 2016; Kent, 2021). In response to these challenges, there's a growing movement towards alternative manufacturing practices that prioritize environmental stewardship and resource efficiency (Dissanayake and Weerasinghe, 2022). The circular economy, for instance, is being pursued to address these issues by promoting the reuse, recycling, and reduction of materials throughout the production lifecycle (Moorhouse and Moorhouse, 2017; Shirvanimoghaddam *et al.*, 2020; Dissanayake and Weerasinghe, 2022). Meanwhile, innovations in manufacturing strategies, such as mass customisation, illustrate how further advancement of technologies and growing customer desires to purchase sustainable products will make mass customisation a viable sustainable business model (Boër *et al.*, 2018; Gembarski *et al.*, 2018). As customer awareness around environmental issues grows, there's an escalating demand on the industry to adopt practices that are in line with environmental responsibility and conservation principles (Kaiser *et al.*, 2014; Matthews, Rothenberg and Gopalakrishnan, 2019; McNeill and Snowdon, 2019). This shift underscores a critical moment in manufacturing, particularly within the fashion sector, where the longstanding benefits of mass production are reconsidered against the pressing need for sustainable development and ecological preservation (Sumner, 2019; Kent, 2021; Dissanayake and Weerasinghe, 2022).

2.1.3 Mass Customisation

Mass customisation represents a strategic approach that enables companies to offer products and services tailored to the unique preferences of individual customers, all the while maintaining the efficiencies and cost advantages associated with mass production (Pine 1993, Piller and Tseng, 2010). This innovative method has garnered significant attention from both the academic world and the industry, as it offers a solution to the growing customer demand for personalised products without compromising on cost or scale (Gerards *et al.*, 2011; Kuksa, Skinner, Kent, *et al.*, 2023). Moreover, the

sustainable aspects of mass customisation present a compelling case for its broader adoption. Aligning production more closely with actual customer demand not only minimises waste associated with overproduction but also promotes more sustainable consumption patterns through longer product lifecycles (Hu, 2013; Wang *et al.*, 2017; Piller and Wang, 2018; Pine, 2018). Products designed and produced under the mass customisation model are more likely to be valued and retained by customers for extended periods, thus reducing the environmental footprint associated with frequent replacements (Boër *et al.*, 2018; Gembarski *et al.*, 2018).

Originating as a countermeasure to the rigidity of mass production, which traditionally favours standardisation and economies of scale at the expense of individual customer preferences, mass customisation has emerged as a vital response to the increasing call for personalisation (Pine, 1993, 2018; Dellaert and Stremersch, 2005; Turner, 2018). Nowadays, this strategy evolved significantly since its inception. The development of digital technologies, including Computer-aided Design (CAD) and additive manufacturing, has played a crucial role in facilitating the widespread adoption of mass customisation strategies (Yuan and Huh, 2018; Kuksa, Skinner, Fisher, *et al.*, 2023). These technological advancements have made it feasible to tailor products to individual preferences efficiently, bridging the gap between bespoke craftsmanship and mass production scalability (Radder and Louw, 1999; Alptekinoğlu and Corbett, 2008; Wang *et al.*, 2017). On the other hand, this evolution also reflects a shift from highly standardised process to offering customer with more choices, implicating deeper levels of personalisation and understanding the individual customer at one-on-one levels (Duguay, Landry and Pasin, 1997; Alptekinoğlu and Corbett, 2008; Marsh, 2012; Fisher, Kuksa and Kent, 2023).

The adoption of mass customisation spans a diverse adoption in different industries, from automotive and fashion to customer electronics and furniture (Hvam, Mortensen and Riis, 2008; Piller and Wang, 2018; J. Pallant, Sands and Karpen, 2020). The process of customisation involves considerations of sectoral variations, organisational positioning, product or service type, and the complexity of customisation (Ozdemir, Verlinden and Cascini, 2022). Therefore, each of these sectors encounters unique challenges in implementing mass customisation, such as maintaining production efficiency, managing increased complexity in supply chain logistics, and ensuring a seamless customer

experience (Abbasi *et al.*, 2013). The successful adoption of mass customisation extends beyond just offering customised products and services; it involves efficient processes and a customer-centric design. Therefore, the journey towards fully realising the potential of mass customisation is challenging. The complexity of managing a wide array of customer preferences requires sophisticated systems for design, production planning, and logistics (Felfernig, Bagley and Tiihonen, 2014).

The aim of mass customisation is to produce products that more exactly meet customer requirements through a producer-led approach, adapting standard products to meet customer specifications (Thallmaier, 2015; J. L. Pallant, Sands and Karpen, 2020; J. Pallant, Sands and Karpen, 2020). The current practice of mass customisation operates on a spectrum of customer input, from scenarios where the producer entirely controls the customisation process to those where the customer is deeply involved in creating a unique product (Wang, Piller and Wang, 2018). As such, recent literature has explored the critical role of customer engagement and co-creation in the mass customisation process (Bleier, de Keyser and Verleye, 2017; Oertzen, Odekerken-Schröder and Mager, 2020; Özdemir *et al.*, 2020; Tran and Vu, 2021). Previous studies also emphasised the importance of integrating customer feedback and preferences directly into the product development cycle, leveraging digital platforms to enhance the customisation experience (Jiang, Balasubramanian and Lambert, 2014; Sjøbakk *et al.*, 2018; Tan *et al.*, 2020; Yavari *et al.*, 2021; Kuksa, Fisher and Kent, 2023; Kuksa, Skinner, Fisher, *et al.*, 2023).

Therefore, in recent years, the notion of mass customisation has evolved towards a new concept of mass personalisation (Wang *et al.*, 2017; Zheng *et al.*, 2017; Boër *et al.*, 2018; Aheleroff *et al.*, 2019; Ozdemir, Verlinden and Cascini, 2022). This progression aims to shift from highly modular-based customisation to fully personalised products and services, facilitated by Industry 4.0 technologies such as the Internet of Things (IoT), cyber-physical systems, and advanced data analytics (Wang et al., 2017). Advancements in technologies has also opened new business opportunities, further enhanced the flexibility and responsiveness of production processes, especially for Small and Medium-sized Enterprises (SMEs), by reducing barriers to entry and enabling specialisation in mass customisation (Torn and Vaneker, 2019). This transition from mass customisation to personalisation addresses some of the inherent limitations of mass customisation by enabling direct customer involvement in the design

phase, thereby not only meeting, but anticipating customer needs (Kent, Kuksa and Fisher, 2023a). The transition reflects a broader trend towards more individualised customer experiences, highlighting the ongoing evolution of customer-centric business strategies in response to changing market dynamics and technological advancements (Deloitte Digital, 2019). The continued exploration of this concept in academic and industry circles is essential to overcoming the operational and technological challenges inherent in the implementation of mass customisation, thereby unlocking its full potential to transform manufacturing practices and customer experiences.

2.1.4 Comparative Analysis

The comparative analysis of mass production, mass customisation, and custom-made production reveals distinct strengths and weaknesses in their ability to meet customer demands as shown in *Figure 2-1* and *Figure 2-2*. Mass production stands out for its unparalleled cost efficiency and scalability, making it possible to produce vast quantities of goods at a lower per-unit cost (Alptekinoğlu and Corbett, 2008). This model's success is grounded in economies of scale, which benefit customers through lower prices and companies through higher production efficiency. However, its primary limitation lies in its one-size-fits-all approach, which often neglects the diverse preferences and needs of individual customers (Hu, 2013). As a result, while mass-produced goods are accessible and affordable, they lack the personal touch of configurability that many customers seek.

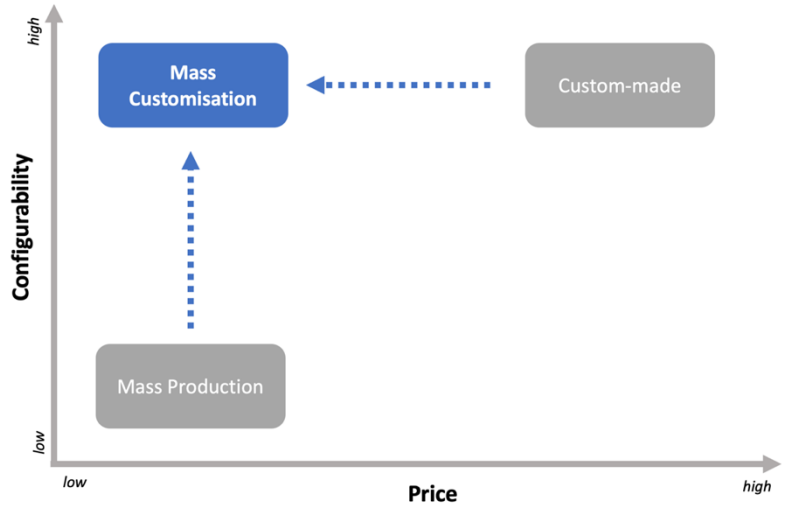


Figure 2-1. Configurability and Price

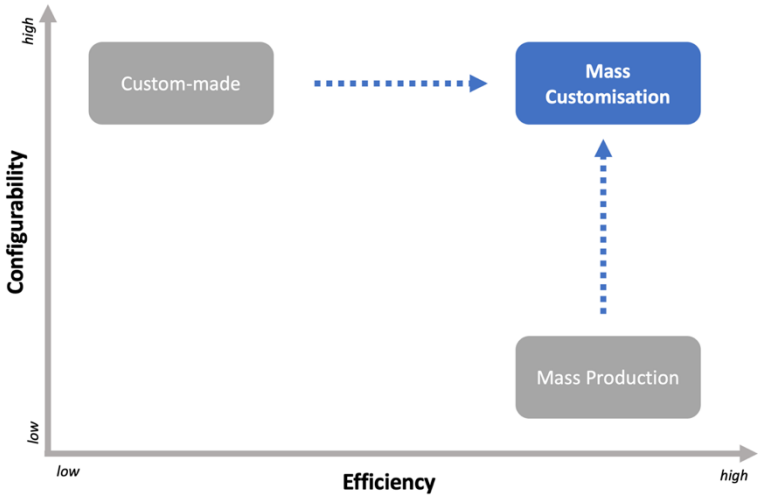


Figure 2-2. Configurability and Efficiency

In contrast, custom-made production, also known as bespoke manufacturing, excels in providing a high degree of personalisation. This model allows for products to be made according to specific customer specifications, ensuring that each item is unique and tailored to individual tastes and requirements. The bespoke nature of custom-made goods typically results in superior quality and a sense of exclusivity, attributes highly valued in certain markets such as luxury goods and artisanal products (Prentice and Loureiro, 2018). However, these benefits come at a cost, both in terms of price and time. Custom-made products are usually more expensive due to the intensive labour and craftsmanship involved, and the production process is slower, limiting the ability to meet demand quickly.

Mass customisation emerges as a hybrid approach, seeking to marry the efficiency and affordability of mass production with the personalisation and uniqueness of custom-made production (Boër *et al.*, 2018). By leveraging advances in technology, mass customisation allows for individualised products to be created with the same efficiency and cost-effectiveness as mass-produced items. This approach offers customers the opportunity to participate in the design process, selecting features, colours, and styles that reflect their personal needs and preferences without the high cost associated with bespoke items. While mass customisation addresses many of the limitations of the other two models, it also faces its own set of challenges, including maintaining production efficiency among increased complexity

and ensuring that customisation options remain meaningful and manageable for customers (Felfernig, Bagley and Tiihonen, 2014).

2.1.5 Benefits of Mass Customisation

Mass customisation offers several benefits to businesses, including:

1. Enhanced customer satisfaction: By providing tailored products and services, companies can better cater to individual preferences, resulting in increased customer satisfaction and loyalty.

2. Economies of scope: Mass customisation enables companies to leverage economies of scope, reducing costs associated with producing a wide variety of products.

3. Environmental sustainability: Customised products can potentially reduce waste and resource consumption, as they are made to order and often have a longer useful life.

2.1.6 Challenges of Mass Customisation

Despite its benefits, mass customisation presents several challenges, including:

1. Complexity in production and supply chain management: The shift from mass production to mass customisation increases the complexity of production processes and supply chain management, requiring businesses to develop new capabilities and invest in advanced technologies.

2. Balancing efficiency and flexibility: Companies must strike a balance between maintaining efficiency in production and providing customised offerings, which can be a difficult and resource-intensive task.

3. Customer involvement: Mass customisation requires active customer participation in the design process, which can be time-consuming and demanding for both customers and businesses.

2.2 Review of Product Configuration System

Traditional customisation methods of custom-made usually require a complex and time-consuming process, including in-store appointments and maybe several re-visiting sessions. Even today, the involvement of digital technology can be limited in the process of creating a customised product and this makes customisation a labour intensive and typically expensive process (Felfernig, Bagley and Tiihonen, 2014; Schillaci, 2018a). However, increasingly over the past decade companies are turning to mass customisation strategies to meet the growing demand for personalised products and services since the discovery in e-commerce that additional revenue can be generated from online product customisations (Ozdemir, Verlinden and Cascini, 2022; Pech and Vrchota, 2022; Kuksa, Skinner, Fisher, *et al.*, 2023). Central to enable these strategies digitally are product configuration systems, which enable end-users to design products to their specific needs and preferences (Blzaek, 2018; Schillaci, 2018b).

A product configurator is a software tool that allows users to design products by selecting from a set of predefined options and features. As defined by Hvam et al. (2008), product configuration systems are "knowledge-based software applications that support the specification of the product by restricting how predefined entities (physical or non-physical) and their properties (fixed or variable) may be combined" (Hvam, Mortensen and Riis, 2008). Product configuration systems play a crucial role in enabling mass customisation, as they allow companies to offer a wide range of product variants while maintaining efficiency and cost-effectiveness in production (Zhang *et al.*, 2016; Blzaek, 2018). By empowering end-users to co-design their products, configurators help bridge the gap between individual user needs and the efficiencies of mass production (Gerards *et al.*, 2011; Piller and Wang, 2018).

The importance of product configuration systems extends beyond their ability to facilitate mass customisation. They also contribute to improved customer satisfaction, reduced lead times, and increased sales (Piller and Wang, 2018). By providing a user-friendly interface for product customisation, configurators enhance the customer experience and create a sense of co-creation and ownership (Roberts, Palmer and Hughes, 2022; Kent, Kuksa and Fisher, 2023b). Furthermore, by automating the product specification process, configurators help reduce errors and accelerate the sales process (Trentin, Perin and Forza, 2014; Sandrin *et al.*, 2017). The following section will provide a systematic and critical analysis of the existing research on product configuration systems.

2.2.1 Evolution of Product Configuration Systems

Early product configurators emerged in the 1980s and 1990s as rule-based expert systems. These systems were designed to capture and apply the knowledge of domain experts to guide users through the product configuration process. One of the earliest examples is R1/XCON, a configurator developed by Digital Equipment Corporation in the late 1970s to configure computer systems (McDermott, 1982). R1/XCON used a set of rules to validate customer orders and generate manufacturing instructions, reducing errors and improving efficiency, which was widely recognised as one of the first commercially successful delivery of valid and completely configured systems (Felfernig, Bagley and Tiihonen, 2014). The early rule-based configurators laid the foundation for the development of more advanced systems. However, they were often complex, requiring significant expertise to develop and maintain the underlying rule bases (Piller and Tseng, 2010; Haug, Hvam and Mortensen, 2011). They were also primarily used for internal purposes, such as sales support and manufacturing, rather than being directly accessible to end-users (Haug, Hvam and Mortensen, 2011; Zhang *et al.*, 2016). In the late 1990s and early 2000s, web-based configurators began to emerge, leveraging the growing popularity of the internet to reach a wider audience (Blzaek, 2018).

Over the past two decades, rapid advancements in technology have greatly influenced the development and capabilities of product configuration systems (Blazek and Pilsl, 2018; Blzaek, 2018; Schillaci, 2018b). The widespread adoption of web technologies and the rise of e-commerce have made

configurators more accessible and user-friendly. Web-based configurators now offer rich visual interfaces, real-time feedback, and integration with back-end systems (Trentin, Perin and Forza, 2014; Sandrin *et al.*, 2017). Advances in CAD and Computer-aided Manufacturing (CAM) have also had a significant impact on product configurators. The integration of CAD and CAM systems with configurators has enabled the automatic generation of product models, drawings, and manufacturing instructions based on user-specified parameters (Avella and Albano, 2018; Blazek *et al.*, 2018). This integration has streamlined the product development process and reduced lead times.

The parametric nature of CAD models has enabled their integration with product configurators. By linking the configurator's rule base to the CAD model, changes made by the user during the configuration process can be automatically reflected in the digital representation of the product (Felfernig, Bagley and Tiihonen, 2014; Buchenberg, 2018). This integration has greatly enhanced the visualisation capabilities of configurators, allowing users to see a realistic simulation of their customised product in real-time (Avella and Albano, 2018; Schillaci, 2018b). CAM systems, which use digital models to generate instructions for manufacturing processes such as CNC (Computer Numerical Control) machining, have also been integrated with product configurators (Felfernig, Bagley and Tiihonen, 2014). This integration allows for the automatic generation of manufacturing instructions based on the user's configuration choices, streamlining the production process and reducing lead times (Felfernig, Bagley and Tiihonen, 2014). The advancements in CAD and CAM integration have greatly expanded the capabilities of product configurators, enabling them to handle more complex product structures and provide a more seamless transition from design visualisation to manufacturing.

2.2.2 Types of Product Configurators

Product configurators can be categorised based on various criteria, such as the level of customisation they offer, the technology they employ, or the target audience they serve. This section focuses on two main types of product configurators based on their target users: Business-to-Business (B2B) and Business-to-Consumer (B2C) configurators.

B2B product configurators are designed for use in industrial settings, where the user is another business rather than an individual customer (Haug, Hvam and Mortensen, 2011; Blzaek, 2018). These configurators are often used for complex, high-value products such as machinery, equipment, or industrial components (Hvam, Mortensen and Riis, 2008; Shafiee, Hvam and Mortensen, 2017). B2B configurators typically offer a higher degree of customisation and flexibility compared to B2C configurators, as the products they configure are often tailored to the specific needs of each customer (Haug, Hvam and Mortensen, 2011). Examples of B2B product configurators can be found in industries such as industrial machinery, aerospace, and automotive components. Companies such as Siemens, ABB, and Bosch Rexroth use configurators to help their customers design and specify complex industrial products.

Key characteristics of B2B product configurators include:

Complexity: B2B configurators often deal with products that have a large number of components, options, and constraints. They must be able to handle complex rule sets and dependencies to ensure that the configured product is viable and meets the user's requirements (Hvam, Mortensen and Riis, 2008).

Integration: B2B configurators are often integrated with other enterprise systems, such as CAD, CAM, ERP (Enterprise Resource Planning), and PLM (Product Lifecycle Management). This integration enables the seamless transfer of data between systems, reducing errors and improving efficiency (Haug, Hvam and Mortensen, 2011).

Collaboration: B2B configurators often support collaborative design processes, allowing multiple stakeholders (e.g., sales, engineering, and manufacturing) to provide input and feedback during the configuration process (Felfernig, Bagley and Tiihonen, 2014).

Customisation: B2B configurators typically offer a high degree of customisation, allowing users to specify unique requirements and constraints. This may include the ability to upload custom

specifications, or to request modifications to standard product options (Haug, Hvam and Mortensen, 2011).

B2C product configurators are designed for use by individual customers, typically in an e-commerce setting. These configurators are used for a wide range of consumer products, from apparel and footwear to furniture and electronics (Schillaci, 2018b). Examples of B2C product configurators can be found across many industries. Companies such as Nike, Levi's, and Ikea offer configurators that allow customers to personalise products like shoes, jeans, and furniture to their individual preferences. B2C configurators generally offer a more limited range of options compared to B2B configurators, as they are designed to be user-friendly and accessible to a non-technical audience (Wang, Mo and Tseng, 2019).

Key characteristics of B2C product configurators include:

Visualisation: B2C configurators often place a strong emphasis on visualisation, using high-quality images, 3D models, and real-time rendering to help users visualise their customised products (Avella and Albano, 2018). This is particularly important for products where appearance is a key selling point, such as clothing or home décor (Bellemare, 2010; Blzaek, 2018).

User experience: B2C configurators are designed to be user-friendly and intuitive, with simple interfaces and clear guidance through the configuration process. They often use techniques such as progressive disclosure and default options to help customers make choices without being overwhelmed (Piller and Wang, 2018).

Limited options: B2C configurators typically offer a more limited range of options compared to B2B configurators, focusing on key product attributes such as colour, size, or material. This helps to keep the configuration process simple and accessible for customers (Gerards *et al.*, 2011).

Personalisation: B2C configurators often emphasise personalisation, allowing customers to add unique text, images, or designs to their products. This can include features such as monogramming, engraving, or print-on-demand (Abbasi *et al.*, 2013).

2.2.3 Implementation of Product Configurators

This research will focus primarily on B2C product configurators, as they are more directly related to the end-user experience and the concept of co-creation. B2C Product configurators have been implemented across a wide range of industries, from consumer goods to industrial products. Configurator Database (http://www.configurator-database.com/) (Media, 2018), a comprehensive online resource that catalogues and analyses real-world examples of product configurators, could help to gain a better understanding of the current state of product configurator implementations. The Configurator Database (Media, 2018), launched in 2007, currently contains over 1,400 examples of online product configurators from various industries *(Figure 2-3)*. By analysing the information from this database, we can identify key trends, best practices, and challenges in the implementation of product configurators.

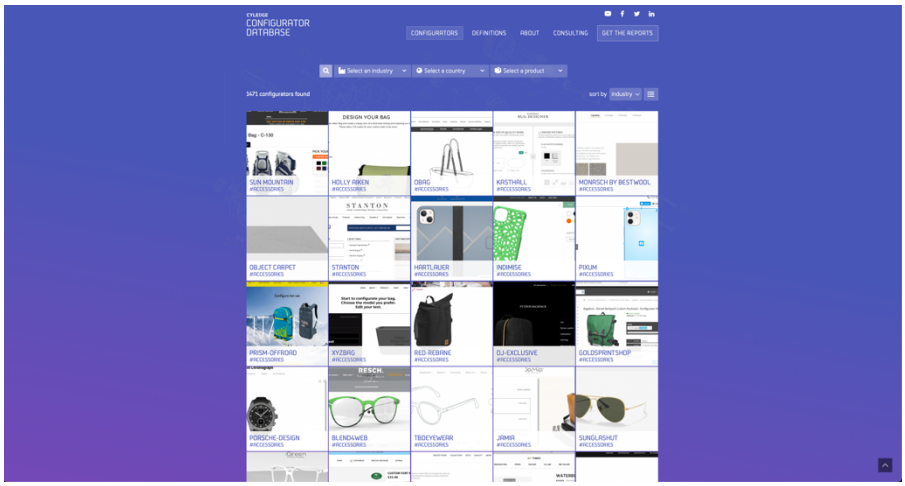


Figure 2-3: Configurator Database (http://www.configurator-database.com/)

The Configurator Database organises product configurators into 16 main industries, ranging from apparel and footwear to industrial machinery and vehicles (Media, 2018). This diversity of industries demonstrates the wide applicability of product configuration strategies across different market

segments and product types. Some of the most popular industries for successful implementation of product configurators, according to the Configurator Database, include:

Apparel and footwear: Configurators in this industry allow customers to personalise clothing and shoes by selecting colours, materials, and other design options. Examples include Nike's NIKEiD configurator for customising sneakers and Levi's Curve ID configurator for personalising jeans.

Interior and Furniture: Configurators in this industry allow customers to customise furniture pieces and home decor items to their specific needs and preferences. Examples include IKEA's online configurators for customising kitchen cabinets and wardrobes, and Moooi's configurator for personalising lighting fixtures.

Vehicles and automotive: Configurators in this industry allow customers to customise cars, motorcycles, and other vehicles by selecting options such as colours, interiors, and accessories. Examples include BMW's configurator for customising MINI Cooper cars and Harley-Davidson's configurator for personalising motorcycles.

Consumer electronics: Configurators in this industry allow customers to personalise electronic devices such as computers, smartphones, and cameras. Examples include Dell's configurator for customising laptops and Motorola's Moto Maker configurator for personalising smartphones.

The Configurator Database also reveals some emerging industries for product configurators, such as food and beverages (e.g., mymuesli's configurator for customizing cereals), and sports equipment (e.g., HEAD's configurator for personalising tennis rackets). The diversity of industries represented in the Configurator Database highlights the potential for product configuration strategies to create value and differentiation across a wide range of markets and product categories.

2.2.4 User Interaction and Experience

The success of a product configurator largely depends on its ability to provide a seamless and engaging user experience (Abbasi *et al.*, 2013; Zhang *et al.*, 2016). There are three key aspects of user interaction and experience in B2C product configurators: usability and choice navigation, visualisation techniques, and the shifting role of the end-user as a co-creator.

Usability is a critical factor in the success of B2C product configurators. A configurator that is difficult to use or navigate can lead to customer frustration and abandonment (Bakås *et al.*, 2018). On the other hand, a well-designed configurator can enhance the customer experience and increase satisfactions (Trentin, Perin and Forza, 2014; Sandrin *et al.*, 2017). The configurator interface should be simple, intuitive, and easy to understand. Complex or confusing interfaces can overwhelm users and lead to abandonment (Blecker, Bernd KALUZA and Gerold KREUTLER, 2004; Dellaert and Stremersch, 2005). Meanwhile, the configurator should provide clear guidance and feedback throughout the configuration process. This can include features such as progress indicators, error messages, and recommendations (Trentin, Perin and Forza, 2014; Sandrin *et al.*, 2017).

Choice navigation refers to the way in which options are presented and structured within the configurator (Bakås *et al.*, 2018). Effective choice navigation can help users find the options they want and make decisions more easily. Established configurators usually designed around attribute-based navigation, where options are organised based on product attributes, such as colour, size, or material (Abbasi *et al.*, 2013; Sabioni *et al.*, 2021). Tool for filtering and sorting options are usually provided which can help users navigate large option spaces more efficiently. Studies have shown that effective usability and choice navigation can have a significant impact on configurator performance. For example, Trentin et al. (2014) found that configurator capabilities such as focused navigation and flexible navigation had a positive impact on user satisfaction and perceived benefits. Similarly, Hildebrand et al. (2014) found that providing users with a starting solution and allowing them to customise it led to higher satisfaction and purchase intentions compared to a pure self-design approach.

Visualisation is another critical aspect of the user experience in B2C product configurators. Effective visualisation can help users understand the options available to them, evaluate different configurations, and envision the final product (Sandrin *et al.*, 2017; Avella and Albano, 2018). Static 2D images can be used to represent different product options or configurations. This is a simple and widely used approach, but it may not provide a realistic or interactive representation of the product (Blzaek, 2018). On the other hand, 3D models can provide a more realistic and interactive representation of the product, allowing users to rotate, zoom, and view the product from different angles. 3D models can be rendered in real-time based on user selections, providing immediate feedback on the configured product (Blzaek, 2018). Advanced rendering techniques can be used to create highly realistic images of the configured product, including accurate textures, lighting, and shadows. This can help users visualise the final product more accurately and increase their confidence in the purchase decision (Sandrin *et al.*, 2017). Established research has shown that effective visualisation can have a positive impact on the user experience and configurator performance. For example, Parlangeli et al. (2019) found that the ability to visualise the configured product was a key factor in user satisfaction and willingness to pay. Similarly, Avella and Albano (2018) found that the use of 3D models and Augmented Reality (AR) technologies in a configurator increased user engagement and satisfaction compared to traditional 2D approaches.

One of the most significant impacts of product configurators on the user experience is the shifting role of the end-user from a passive recipient of products to an active co-creator. By allowing users to customise products to their own preferences and needs, configurators enable a new level of user involvement and empowerment in the design process (Abbasi *et al.*, 2013; Zhang *et al.*, 2016; Sandrin *et al.*, 2017). This shift towards user co-creation has several important implications: Firstly, by allowing users to customise products to their own preferences, configurators enable a high degree of personalisation (Abbasi *et al.*, 2013). This can lead to increased user satisfaction, as the configured product is tailored to their specific needs and tastes (Piller and Wang, 2018). Secondly, by providing users with the tools to customise products, configurators can also enable user innovation (Thallmaier, 2015). Users may create novel or unexpected configurations that can inspire new product ideas or variations (Mandolfo, Chen and Noci, 2020). And finally, the process of co-creation can lead to

increased emotional attachment to the configured product (Mugge, Schoormans and Schiffersteinb, 2009). Users may feel a sense of ownership and pride in the product they have helped to create, leading to higher feelings of accomplishment and uniqueness compared to users who bought standard mass-produced products (Mugge, Schoormans and Schiffersteinb, 2009).

2.2.5 Distinguishing Co-design from Customisation

Co-design, also known as participatory design, is an approach that involves all stakeholders—including employees, partners, customers, citizens, and end users—in the design process to ensure the results meet their needs and are usable (Steen, Manschot and Koning, 2011). A notable example of successful co-design implementation in the commercial sector is Lego's approach. Lego has effectively integrated user-generated designs into their product development cycle (Isa and Liem, 2021). Through platforms like Lego Ideas, users can submit their designs, which, if popular enough, may be produced and sold as official Lego sets. This process not only engages users creatively but also feeds directly back into the product selling cycle, demonstrating how co-design can be successfully incorporated into a business model (Isa and Liem, 2021). While co-design shares some similarities with the customisation processes discussed in this thesis, particularly in its emphasis on user involvement, and can lead to innovative product development (Thallmaier, 2015), it has been deliberately excluded from the scope of this review for several reasons:

Focus on individual user interaction: This research primarily investigates the interaction between individual users and digital product configurators. Co-design, in contrast, often involves collaborative processes with multiple stakeholders, which is beyond the scope of this study.

Emphasis on cognitive processes: This research places significant emphasis on understanding the cognitive processes, particularly mental imagery, involved in individual users' customisation decisions. Co-design methodologies, while valuable, do not typically investigate these specific cognitive aspects.

Configurator-mediated customisation: The study concentrates on customisation processes mediated by digital product configurators, which represent a specific subset of customisation tools. Co-design can cover a much wider range of design methodologies and tools (Steen, 2013).

Distinction in customisation approach: While the Lego example demonstrates a successful integration of co-design into product development, it differs from the immediate, individual customisation process that this thesis focuses on. In digital product configurators, users customise products for their immediate purchase, whereas co-design often involves a longer-term, collaborative process that may or may not result in a purchasable product.

While acknowledging the value and relevance of co-design in the broader field of user-involved design processes, this literature review maintains a focused scope on digital product customisation in e-commerce settings. This focused approach allows for a deeper exploration of the specific cognitive processes, user experiences, and technological aspects relevant to digital product configurators.

2.2.6 Challenges, Gaps and Opportunities

While product configurators have come a long way in enabling mass customisation and enhancing the user experience, there are significant challenges and gaps that need to be addressed. At the same time, these challenges present opportunities for further research and development in the field of product configuration.

The fundamental challenge came from the shift of role from end-user to the product co-creator. In the unguided virtual environment, the B2C configuration system is an essential aspect of supporting online product customisation, creating a link between the retailer and end user to determine how to implement customisation (Zhang *et al.*, 2016). Not all users may have the skills, knowledge, or motivation to engage in co-creation activities (Fürstner, Anišić and Takács, 2012). The configuration process can be complicated and confusing for general users with insufficient knowledge of the configurator and product structure (Abbasi *et al.*, 2013). The predominant approach to product configurators is parameter-based

selection, where all the available options are presented to users, and they make decisions individually by following a list of pre-defined product attributes (Gerards *et al.*, 2011). However, as the number of options and constraints increases, the complexity of the configuration task grows exponentially. Even with a well-designed configurator, users may still struggle to find the options they want, understand the implications of their choices, or make confident decisions (Piller and Tseng, 2010). The increasing complexity of the product structure could cause choice overload, and the negative cognitive and behavioural outcomes caused by choice overload are supported by both theoretical and empirical evidence, especially in consumer and marketing research (Mosteller, Donthu and Eroglu, 2014; Nettelhorst *et al.*, 2017; Shafiee, Hvam and Mortensen, 2017; Wang, Mo and Tseng, 2019; Sabioni *et al.*, 2021).

Increased product configuration complexity leading to choice overload requires academia and industry to find solutions that can lead to a better user experience in choice navigation. In addition to the most basic parameter-based configurator, recent research focusing on optimising customisation systems has presented two further directions of approach: Customisation via Starting Solutions (CvSS), and need-based selection (Hildebrand, Häubl and Herrmann, 2014; Wang, Mo and Tseng, 2019; Sabioni *et al.*, 2021).

Providing users with a starting point (i.e. a pre-specified product inspiration) has been identified as a principle recognising that not all users are interested in fully exploiting the potential of customisation (Hildebrand, Häubl and Herrmann, 2014). This approach has a number of industrial applications and has been categorised by Hildebrand et al. (2014) as CvSS. The aim of this configuration approach is to reduce the perceived complexity of the decision process compared to the traditional parameter-based selection, without compromising users' autonomy to further alter all the attributes of the product to their needs and preferences. Empirical evidence suggests that, compared to parameter-based configuration, CvSS can increase users' satisfaction with their product choices, enhance users' mental simulation of product use, and further enable the purchase of a product with more features and higher price (Hildebrand, Häubl and Herrmann, 2014).

A need-based configuration system follows the idea of transferring the basic choice navigation to a service process – in other words, customising the customisation process (Wang, Zhao and Wan, 2020). This approach mimics the behaviour of a salesperson and requires users to share their needs and requirements; then, the input is transferred by algorithms into a product configuration (Wang, Zhao and Wan, 2020). Several conceptual designs have been proposed by academics, and empirical evidence indicates that compared to parameter-based configurations, a need-based approach can provide a better choice navigation process for the user to find suitable product features, and the configuration process is efficient and enjoyable (Gerards *et al.*, 2011; Sabioni *et al.*, 2021). However, it is also noticed that it is more costly and time-consuming to develop a need-based configurator (Piller and Tseng, 2010; Gerards *et al.*, 2011). While the concept is still in the early stage with minimal industry application, the few established configurators that have adopted this approach are limited to the motor vehicle industry and apply only to users' functional needs (Wang, Zhao and Wan, 2020).

2.2.7 Configurators in the Fashion Industry

Despite widespread adoption, the quality of established configurators in the fashion industry is not consistent. The adoption of product configurators ranges from basic text-based descriptions to sophisticated 3D visualisation tools, reflecting diverse approaches and technological capabilities within the sector (Blzaek, 2018; Schillaci, 2018b). Many fashion retailers still rely on basic text description-based or technical drawing-based configurators. While these simpler tools can provide customisation options, they often fall short in delivering an engaging and immersive user experience (*Figure 2-4*).

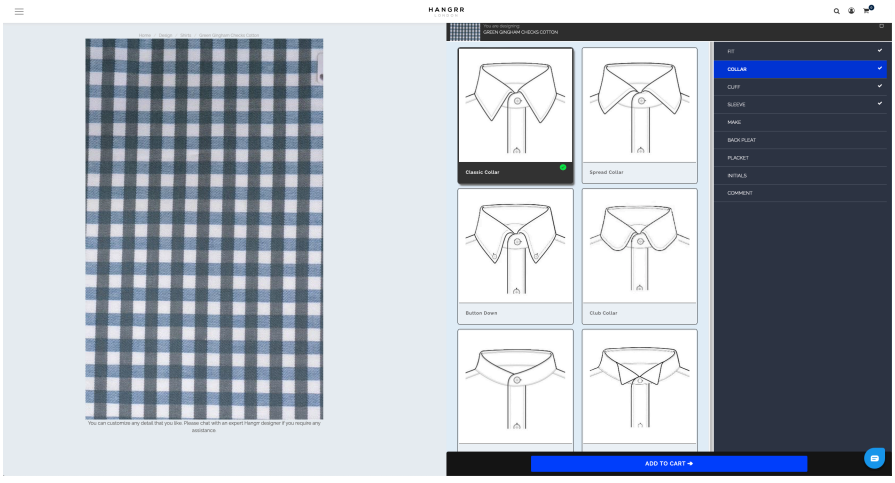


Figure 2-4. Suit Configurator without simulation by HANGRR. (https://hangrr.com/design/customize)

The fashion industry faces several specific challenges in implementing effective product configurators (Bellemare, 2010). One of the primary hurdles is the accurate visual representation of fashion items in a digital environment . Unlike products with rigid structures, clothing is inherently fluid and dynamic, making it difficult to accurately depict fabric textures, drape, and fit on a digital platform (Porterfield and Lamar, 2017). The way a garment hangs on a body, the subtle interplay of light and shadow on different fabrics, and the variation in appearance across different body types are all complex elements to capture digitally (Mert *et al.*, 2018). Another significant challenge lies in ensuring accurate sizing and fit through digital simulations (Liu *et al.*, 2017; Porterfield and Lamar, 2017; Kuzmichev and Cheng, 2020). The discrepancy between users' body measurements and standard sizing systems continues to be a major hurdle in fashion e-commerce, often resulting in high return rates (Pookulangara *et al.*, 2021). The human body's diverse shapes and proportions make it difficult to translate traditional sizing methods into a digital format that consistently provides a good fit for all users.

Meanwhile, the development and implementation of sophisticated product configurators require significant investment, both in terms of financial resources and technological expertise (Felfernig, Bagley and Tiihonen, 2014). This high initial cost can be a barrier for many fashion retailers, especially smaller businesses. As configurators are often viewed as supplementary sales tools rather than mandatory features, fashion retailers must clearly define their contribution to the retail process to justify such investments (Buchenberg, 2018).

Inconsistencies in the quality and sophistication of product configurators are not limited to industry applications but are also present in academic research. In many academic studies, the utilisation of product configurators is often conceptual or limited to basic functionalities for experimental purposes (Hildebrand, Häubl and Herrmann, 2014; Zheng *et al.*, 2017; Wang, Mo and Tseng, 2019; Wang, Zhao and Wan, 2020). This presents a significant gap in the literature, as these simplified research tools may not accurately reflect the current state of configurator development in the industry. This discrepancy can further lead to challenges in translating research findings to real-world applications. The gap between academic prototypes and industry-standard configurators poses challenges for the empirical

investigation of actual configurator use in e-commerce. The inability to reflect up-to-date developments in the industry within academic research settings can limit the validity of studies and potentially lead to conclusions that may not fully apply to real-world scenarios. This gap further emphasis the need to conduct empirical investigation to the actual use of the configurator, to ensure that research on product configurators remains relevant and applicable to current practices.

2.2.8 Conclusion

This section has explored the current state of knowledge on product configuration systems, with a particular focus on B2C configurators and the user experience. By examining the evolution of product configurators, the different types of configurators, and the key aspects of user interaction and experience, several important findings and trends in this field are identified.

However, this review has highlighted a significant gap in the current literature on product configurators. While much of the existing research has focused on the technical aspects of configurator design and implementation, there has been relatively little attention paid to the user perspective and the empirical understanding of the configuration process. Recent research by Kuksa et al. (2023) highlighted that there is a clear need for further research to better understand customisation and personalisation from a user-centric perspective in order to improve product configuration. Most of the current research on configurators approaches the topic from a technical perspective, emphasis has been on the technical mechanisms, data analytics and business advantages to improve the digital systems that enable configuration (Kuksa et al. 2023). But there has been less attention paid to the actual user experience - what are the touch points, pain points and delights as users navigate customisation options? How do factors like the design of the configurator interface impact cognitive load, confidence in choices, satisfaction with the final product? To fully realise the potential of product configurators and to create truly user-centred solutions, it is essential to also consider the user perspective and to empirically investigate how users actually interact with and experience these systems (Kuksa, Fisher, and Kent 2023, Kuksa et al. 2023).

Additionally, the customisation literature could benefit from a more multidisciplinary approach incorporating perspectives from different field (Kuksa et al. 2023). For example, sociology and cultural studies can investigate on the symbolic meaning of personalised products and how they are used to construct individual and social identities. The human-computer interaction field can inform the design of more user-centred and effective configuration systems. Knowledge form behavioural and psychology field can help explain user decision making patterns and strategies. More integrative research bridging these disciplines could significantly advance our understanding (Kuksa et al. 2023).

2.3 Review of User Cognitive Effort Investment

The review on product configuration systems has highlighted the significant progress made in the development and implementation of these systems across various industries. However, it has also revealed a critical gap in the current research: the lack of a user-centred perspective and empirical understanding of the configuration process. To fully realise the potential of product configurators and create solutions that effectively meet user needs and preferences, it is essential to investigate the factors that influence the user experience and outcomes of product configuration. One key aspect of this user experience is the cognitive effort invested by customers during the configuration process. The following section will review this topic from established literature, exploring the concepts of customer engagement, cognitive effort, and mental imagery in the context of digital product customisation.

2.3.1 Customer Engagement

The concept of customer engagement is gaining attention in both industry and academic communities. While its importance is universally recognised, the specific dynamics and implications can vary based on the industry in question. Engagement, in this context, is the quality of the experience that emphasises the interaction's positive aspects (Lalmas, O'Brien and Yom-Tov, 2014). Specifically, it refers to the emotional, cognitive, and behavioural connections a customer forms with a product (O'Brien, 2010). When developing interactive systems, one of the primary goals is to engage with the user and create

engaging technologies (Lehmann *et al.*, 2012; Ravnløkke, 2023). Within the garment industry, engagement often resonates with offline channels. Brand identity, in this sector, plays a critical role, influencing and shaping customer interactions and experiences (Prentice and Loureiro, 2018)). In the context of product customisation, customer engagement can be a decisive factor in the decision journey and purchase intention and could lead to the establishment of an emotional bond with the product over an extended period of time (Mugge, Schoormans and Schiffersteinb, 2009). In the product customisation process, the customer becomes the co-creator, and the co-created value is also a way to communicate the ownership of the product. The endowment effect explains the formation of this ownership—I built it; therefore, I own it. I own it; therefore, it is superb (Damm *et al.*, 2013).

The role of customers in product customisation processes has evolved, highlighting the concept of co-creation in customer engagement. Historically, co-creation was understood from a producer-led perspective, focusing on its benefits to business profitability (Prentice and Loureiro, 2018). However, integrating customer knowledge and creativity in product development and brand extension reflects a deeper customer orientation in business strategies (Guzel, Sezen and Alniacik, 2020; Tran and Vu, 2021). As the customisation process offers more choices, tailoring to individual needs and preferences, co-creation is now seen as a collaborative process where customers are active contributors (Kent, Kuksa and Fisher, 2023b). There's a growing need to explore co-creation from a customer-driven approach, understanding the role of motivational and volitional engagement (Mandolfo, Chen and Noci, 2020). Ozdemir et al. (2020) pointed out that one reason mass customisation may not be successful in practice is due to the lack of customer engagement with both the customised products and the customisation process itself. This underscores the critical role of customer engagement in driving service innovation and the importance of understanding both the positive and negative outcomes of such engagements. Recent research by Kuksa *et al.* (2023) indicates that less attention has been given to a customer-driven approach in understanding customisation and co-creation. Other research also highlights the potential for further study on how businesses can better tailor their offerings to individual customer needs (Bleier, de Keyser and Verleye, 2017; Roberts, Palmer and Hughes, 2022).

A study conducted by the Delft University of Technology examined customers' emotional bonding with personalised products (Mugge, Schoormans and Schiffersteinb, 2009); a customer's level of engagement in the personalisation process was associated with the self-expressive value of the product. As customers move from being mere recipients to active participants in the design process, their level of engagement significantly impacts their involvement and the perceived value of the customised product (Zine *et al.*, 2014). In exploring customer engagement and decision-making in e-commerce, this thesis draws upon Cardozo's (1965) concept of mental effort involved in choosing and making decisions. While the modalities of shopping have evolved from physical to digital realms, the mental processes involved in evaluating options and making purchasing decisions remain fundamentally similar. Cardozo's distinctions help emphasis how even though physical effort is no longer a barrier, the cognitive challenges of decision-making continue to shape customer experiences and outcomes in online settings.

2.3.2 Cognitive Effort

In the purchasing scenario, efforts may be expended in multiple forms, including the physical effort involved in driving to a store and searching for a product or the financial effort required to obtain a product (Cardozo, 1965). When presented with multiple choices, the effort involved in evaluating a set of alternatives is recognised as the cognitive effort (Garbarino and Edell, 1997). The significant influence of cognitive effort on human decision-making behaviour attracts broad interest from different fields, including psychology, human factors and consumer research (Feldon *et al.*, 2019; Westbrook *et al.*, 2020; Blaise *et al.*, 2021; Wu, Ferguson and Inzlicht, 2023; Tankelevitch *et al.*, 2024). Although cognitive effort as a concept lacks a unified definition (Westbrook and Braver, 2015), from the perspective of decision theory, cognitive effort is often defined as the cost of thinking or decision making that requires mental resources to gather information, research and investigate different options to make the decision (Shugan, 1980; Garbarino and Edell, 1997). This independent construct can be used to justify a decision, impact decision-making quality, increase decision accuracy and confidence and reduce decision-making conflict and uncertainties (Park and Hill, 2018).

Cognitive effort investment is a critical topic spanning multiple research fields, exploring the tension and paradox between minimising and embracing effort. Psychologically, cognitive effort is traditionally viewed as inherently aversive. Humans and animals demonstrate a fundamental drive to avoid effort, associating it with physiological stress and discomfort (Wu, Ferguson and Inzlicht, 2023). Cognitive Load Theory further underscores this aversion by categorising cognitive load into intrinsic, extraneous, and germane types, with extraneous load being particularly detrimental to learning and motivation (Feldon *et al.*, 2019). From a human-factors perspective, managing cognitive load is crucial for optimising performance and user satisfaction (Harmon-Jones *et al.*, 2024). Research has identified objective measures of cognitive load, such as pupil size, fixation duration, and saccade amplitude, which correlate with task difficulty and user experience (Wals and Wichary, 2023). These metrics provide valuable insights into the cognitive demands of various tasks and interfaces.

Studies from the perspective of Human–Computer Interactions (HCI) mostly associate cognitive effort with task performance (Bailey and Iqbal, 2008; Maior, Wilson and Sharples, 2018). This involves finding the right place to perform an action, deciding on the necessity of the action, and interpreting the results of the action (Maior, Wilson and Sharples, 2018). Therefore, the interpretation of a user's cognitive effort investment reflects the efficiency of the task, which is highly associated with the user's experience during the system navigation (Luong *et al.*, 2019). Using efficiency as the key variation of cognitive effort was proposed by cognitive effort metrics, implemented by users' self-reporting on frustration, time spent and task complexity (Hong, Thong and Tam, 2004; Mosteller, Donthu and Eroglu, 2014). This sometimes results in the use of "effort" in a very broad and non-specific way, such as "using this site required too much effort" or "how much effort did you put into it". By reducing cognitive effort to a single measure, important details and distinctions between the different influential factors of cognitive effort may be lost, and in some cases limit the determination of cognitive effort to task difficulty.

It is generally assumed that a user's cognitive capacity is limited, and cognitive resources are a decision cost that needs to be reduced (Westbrook and Braver, 2015). As the invested cognitive effort increases, the complexity of the task accordingly increases, and this can be complicated and confusing for users in an unguided environment. This is further supported by actions, such as a decision-maker avoiding a

particular choice process due to its complexity requiring too much effort (Hong, Thong and Tam, 2004). However, little is known beyond this principle, and what causes someone to withhold their effort during engagement is subjective and therefore difficult to predict (Westbrook and Braver, 2015). In attempting to compute the concept in psychology and neuroscience fields, previous studies have often been restricted by limited aspects, such as time and attention (Bettman, Johnson and Payne, 1990; Longo and Barrett, 2010; Westbrook and Braver, 2015). In addition, the subjective nature of cognitive effort makes it difficult to formalise, which can be directed by numerous influencing factors (Longo and Barrett, 2010). The clarification of influencing factors is a non-monotonic discussion, where further factors may be added, grouped or deleted under different circumstances (Longo and Barrett, 2010). Moreover, the dynamic construct of cognitive effort can change depending on an individual's response to specific scenarios, whereby arguments have pointed to effortful tasks motivating and drawing greater engagement (Lala and Chakraborty, 2015).

However, established research also reveals that cognitive effort, while often avoided, can be valued in certain scenarios. Concepts such as the IKEA effect (Norton, Mochon and Ariely, 2012) demonstrate that individuals frequently attribute higher value to outcomes achieved through greater effort, perceiving these results as more rewarding (Inzlicht, Shenhav and Olivola, 2018). This positive valuation occurs because effortful activities can enhance perceived self-efficacy and task engagement, thereby counteracting the aversiveness typically associated with cognitive exertion (Devine and Otto, 2021). Human-factors research also acknowledges the paradoxical nature of cognitive effort. While reducing necessary cognitive load is crucial, presenting meaningful challenges can boost motivation and satisfaction. For example, providing progress information can decrease effort aversion by making tasks appear more manageable and enjoyable (Devine and Otto, 2021). Consequently, cognitive effort emerges as both a cost to be minimised and a potential source of motivation, highlighting the complex relationship between effort and user experience in design contexts (Feldon *et al.*, 2019). Therefore, established studies argues that the design of tasks and user interfaces must strike a delicate balance between effort and reward to maintain user engagement without overwhelming cognitive resources (Devine and Otto, 2021; Skaramagkas *et al.*, 2023; Harmon-Jones *et al.*, 2024). This balance is essential in creating effective and satisfying user experiences across various domains, from educational

technologies to consumer products. Understanding the complexity of cognitive effort investment can inform the development of more intuitive and engaging designs that optimise user performance while minimising unnecessary cognitive exertion.

The complexity of the overall cognitive effort invested by a user expands in e-commerce, where the task is subject to wider influencing factors, such as purchasing decisions and system usability. A number of recent studies have explored the relationship between cognitive effort and consumer behaviour in online shopping contexts. Park et al. (2015) found that higher cognitive effort expenditure during the online shopping process can reduce post-purchase regret, but the effect is moderated by the justification of the effort. Park and Hill (2018) extended this finding, showing that unnecessary effort did not impact regret, while insufficient unjustified effort increased regret. Additionally, Niza Braga and Jacinto (2022) discovered that customers associate online shopping with resource-saving goals and expect online shopping decisions to demand fewer cognitive resources compared to shopping in physical stores. This low-effort expectation can lead customers to depend more on heuristic cues, such as brand, while decreasing their systematic evaluation of other product details. These recent studies demonstrate key advances in understanding of the effort expended during online shopping, however they have all primarily focused on the impact of purchasing decisions on cognitive effort investment, without explicitly addressing the role of system usability.

In the reviewed literature, cognitive effort is generally defined as the mental resources, such as time, attention, and motivation, that customers invest in the decision-making process (Park, Hill and Bonds-Raacke, 2015; Park and Hill, 2018; Niza Braga and Jacinto, 2022). These studies primarily rely on self-reported measures to assess cognitive effort investment. For example, Park et al. (2015) and Niza Braga and Jacinto (2022) asked participants to rate how much time, attention, motivation, and effort they usually invest or expect to invest in online shopping decisions using Likert scales. While these studies provide valuable insights into the role of cognitive effort in online shopping behaviour, their assessment methods may not fully capture the complexity and multidimensional nature of cognitive effort investment in e-commerce. Meanwhile, in the research context of digital product customisation,

with its modular construct and frequent purchase decisions, presents unique challenges for understanding cognitive effort investment.

This research argues that to gain a deeper understanding of the disruption and efficacy of cognitive effort in e-commerce, particularly in the context of digital product customisation, it is necessary to break down cognitive effort investment into its constituent elements (Longo and Barrett, 2010). By examining the specific factors that drive users' decision-making processes, researchers can develop a more comprehensive understanding of how cognitive effort investment affects user behaviour and outcomes in the complex scenario of digital product customisation (Longo and Barrett, 2010). This approach aligns with the limitations identified in the existing literature, where cognitive effort is often treated as a unidimensional construct and assessed using broad measures. By deconstructing cognitive effort investment and exploring its underlying components, the current study aims to contribute to a more detailed understanding of how users allocate mental resources in e-commerce contexts, particularly in the domain of digital product customisation. This understanding can inform the development of more effective configuration systems and strategies that optimise user experience and decision-making processes.

2.3.3 Mental Imagery

Mental imagery, or visual mental imagery, can be most simply defined as “seeing with the mind’s eye” (Kirby and Kosslyn, 1990). Mental imagery involves a complex network of brain areas, including the frontal cortex and primary visual cortex, which allows individuals to create conscious sensory experiences in their mind, simulating real-world objects, scenarios, or experiences (Pearson, 2019). Recent advances in measuring and decoding mental imagery using brain imaging techniques (e.g., fMRI) allow researchers to objectively assess the content and strength of mental images (Pearson, 2019; Shen *et al.*, 2019; Wals and Wichary, 2023). However, the term “mental imagery” has been implemented in several ways, depending on the research domain. The term is derived from concepts such as “visualisation” (Dahl and Hoeffler, 2004; Zhao, Hoeffler and Dahl, 2009; Zhao, Dahl and Hoeffler, 2014) and “imagination” (M. Folkmann, 2010; M. N. Folkmann, 2010; Tully, 2012), while other similar

terms have been established, such as “mental simulation” (Escalas, 2004) or “consumption vision” (Phillips, Olson and Baumgartner, 1995; Phillips, 1996). Therefore, it is necessary to define the range of phenomena being addressed in this study. The ability to imagine and generate mental images that reflect experiences is recognised as a basic form of cognition that plays a central role in many human behaviours, such as navigation, memory or problem solving (Kirby and Kosslyn, 1990). It enables the generation, interpretation and manipulation of information that makes mental imagery become one of the central cognitive inputs of the design process (Dahl, Chattopadhyay and Gorn, 1999). This ability is used to envision different outcomes and scenarios, aiding in decision-making processes (Pearson, 2019). Engineers and designers have identified the importance of visual thinking techniques and thinking visually during design tasks to synthesise ideas and evaluate effects (Dahl, 1992).

In consumer research, mental imagery has received considerable interest from the field of marketing (Escalas, 2004; Bogicevic *et al.*, 2019; Heller *et al.*, 2019; Kim *et al.*, 2020). The concept has been further identified as a visual image of product-related behaviours and their consequences, which consist of mental images that enable customers to experience using the product vicariously (Phillips, Olson and Baumgartner, 1995). The formation of these mental images of future consumption situations, and these mental visions, can influence purchase decision making (Phillips, 1996). Previous research has established that imagery vividness and strength vary among individuals, from completely absent to photo-like (Pearson, 2019). This variability in mental imagery capability can have significant implications for how customers visualise and evaluate products in e-commerce settings (Gonçalves *et al.*, 2018; Park and Yoo, 2020). Understanding individual differences in mental imagery can help tailor marketing strategies to different customer segments. Personalised marketing approaches can leverage strong imagers' ability to vividly picture products, enhancing engagement and purchase intent.

Mental imagery can act as a "motivational amplifier," enhancing engagement in planned behaviours by allowing individuals to pre-experience the emotional consequences of future activities (Renner *et al.*, 2019). Empirical studies have shown that customers who experience mental imagery as the result of seeing an advertisement show a significantly more positive attitude towards the ad and a higher rate of recall of the advertised information (Dahl, 1992). Studies have also found that mental imagery involving

a target product can be used to make abstract features of products more concrete, increasing perceived value and influencing preferences (Renner *et al.*, 2019). It also leads to a higher evaluation of that product, and more positive emotions and fewer critical thoughts are generated (Escalas, 2004). These principles guided TV advertising campaigns in the early 21st century where viewers were asked to imagine themselves using the product, and high-quality imagery was used to assist online customers visualise the product (Escalas, 2004).

The established research also consistently demonstrates that mental imagery plays a crucial role in facilitating virtual product experiences and decision-making processes in online shopping environments (Yoo and Kim, 2014; Overmars and Poels, 2015). The vividness of mental imagery plays a crucial role in its effectiveness. Customers who could vividly imagine the activities reported higher anticipated rewards (Renner *et al.*, 2019). In consumer behaviour, guided mental imagery can enhance motivation and engagement in product usage scenarios, influencing purchase decisions and user experiences (Adaval, Saluja and Jiang, 2019; Park and Yoo, 2020). For example, the use of vivid mental imagery can help customers better imagine themselves using a product, leading to higher levels of engagement and a stronger desire to purchase (Kim *et al.*, 2020). Therefore, recent studies have shown that the concreteness of online product presentations (e.g., dynamic vs. static images) influences the level of mental imagery processing and subsequent customer evaluations (Yoo and Kim, 2014; Maier and Dost, 2018). Moreover, mental imagery evoked by sensory experiences positively affects anticipatory emotions, perceived ownership, and decision satisfaction, ultimately influencing behavioural intentions (Kim *et al.*, 2020). Gender differences have also been observed in the way mental imagery influences decision-making processes, with men relying more on anticipatory emotions and women on cognitive evaluations (Kim *et al.*, 2020).

However, the categorisation of mental imagery types varies across studies, with some focusing on sensory modalities (MacInnis and Price, 1987), others on dimensions such as elaboration and quality (Pearson, Clifford and Tong, 2008). Previous studies have also established different types of imagery and their applicability and potential benefits. For example, Zhao, Hoeffler and Dahl (Zhao, Hoeffler and Dahl, 2009) found that self-related visualisations led to higher evaluations of incremental new products,

while other related visualisations facilitated higher evaluations of very new products. The different categorisation methods suggests that mental imagery can be categorised based on its context focus and impact on product evaluations, and the existing categorisations may not fully capture the unique aspects of mental imagery in the context of digital product customisation. Considering a new categorisation method for mental imagery in digital product customisation could help address the unique challenges and effort costs associated with this context.

In the design process, mental imagery is crucial for creating accurate visual representations. The ability to create and manipulate mental images enables designers to understand and resolve complex design problems, enhancing their creative processes (Kahlon and Fujii, 2022). Designers often engage in a cycle of creating, evaluating, and refining their visual representations. By visualising modifications and adjustments mentally before making physical changes, designers can explore a wider range of possibilities and optimise their designs more efficiently (Tüfek, 2020). This iterative process benefits significantly from strong mental imagery skills, as it reduces the need for multiple physical prototypes, saving time and resources (Dahl, 1992). However, in the digital product customisation where general users taking the role as the designer of their own product, many users often lack strong mental imagery skills due to insufficient knowledge and experience with the customisation process, similar to design students in educational settings (Tüfek, 2020). This limitation can impact their ability to effectively visualise potential outcomes and make informed decisions.

Therefore, the specific case of digital product customisation requires further investigation. This research argues that mental imagery may be seen not only as a decision-making tool but also as an effort cost element due to its modular construction. While mental imagery aids in evaluating customised products, the cognitive effort required to generate and process these mental images can be considered a cost across the decision-making journey. As technology continues to play a larger role in the user experiences, understanding cognitive effort investment in users' mental processes becomes increasingly important, particularly in complex decision-making scenarios (Yusoff and Salim, 2020). The effort required may vary depending on the complexity of the customisation process and the individual's ability to generate mental images. However, the cost associated with the evaluation of digitally

customised products remains unknown. The effort cost associated with generating and processing mental images during the customisation process adds a new dimension to consider how mental imagery is utilised and could provide valuable insights for researchers and help practitioners design more effective digital product customisation systems.

2.4 Chapter Summary

This literature review has explored the complex and diverse nature of digital product customisation, focusing on three key areas: the manufacturing context, product configuration systems, and user cognitive effort investment. By examining the evolution and current state of these domains, this review has provided a comprehensive understanding of the factors that shape the user experience and outcomes of digital product customisation.

The review began by comparing the three primary manufacturing models: custom-made production, mass production, and mass customisation. While custom-made production offers unparalleled personalisation and mass production excels in cost-efficiency and scalability, mass customisation emerges as a hybrid approach that combines the benefits of both models. The adoption of mass customisation strategies across various industries highlights the growing demand for personalised products and the potential for this approach to create value and differentiation in competitive markets.

Next, the review focused on product configuration systems, the enablers of digital product customisation. By exploring the evolution, types, and implementation of these systems, the review identified key trends and best practices in the field. However, it also revealed a critical gap in the current research: the lack of a user-centred perspective and empirical understanding of the configuration process. To fully realise the potential of product configurators, it is essential to investigate the factors that influence the user experience and outcomes of product configuration.

One key aspect of this user experience is the cognitive effort invested by customers during the configuration process. The review explored the concepts of customer engagement, cognitive effort, and mental imagery in the context of digital product customisation. While customer engagement plays a crucial role in driving the perceived value and emotional connection to customised products, the cognitive effort required to navigate complex configuration processes requires a deeper understanding of its disruption. Mental imagery emerges as a tool for facilitating product evaluation and decision-making, it also represents an effort cost that needs to be considered in the design of effective configuration systems.

The literature review has highlighted several key gaps in our understanding of cognitive effort investment in mental imagery during digital product customisation, particularly in the context of the fashion industry. While existing research has provided valuable insights into user experiences with configurators and the role of mental imagery in decision-making, there remains a need for a more comprehensive and systematic investigation of these processes. The next chapter will present an overview of the methodological approach adopted to address these gaps and explore the research objectives.

3. METHODOLOGY

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3.1 Design Science Research Overview

This research adopts the Design Science Research (DSR) paradigm (Dresch, Lacerda and Antunes, 2015), situating itself at the intersection of technological advancements and the exploration of human behavioural and motivational dynamics. According to Dresch et al. (2015), DSR is distinguished by its pragmatic approach to problem-solving, which leverages established knowledge to transform current conditions and address issues with innovative solutions aimed at enhancing outcomes. Unlike other research paradigms that primarily focus on understanding and describing the world as it is, DSR is primarily concerned with how the world ought to be, applying a constructive lens to identify and solve problems. By combining the rigor of scientific methods with the creativity of design thinking, DSR seeks

to develop artifacts, such as constructs, models, methods, and instantiations, that can effectively bridge the gap between theory and practice (Dresch, Lacerda and Antunes, 2015).

To identify further research approaches and methods for systematic research planning, the Design Research Methodology (DRM) framework by Blessing and Chakrabarti (2009) was adopted *(Figure 3-1)*. The DRM framework provides guidelines for understanding the established operation model, identifying challenges and gaps from the users' perspective and evaluating potential solutions in the user contexts. The framework encourages consistent reflection on the applied approach, considering the specific study objectives, tools, test materials and feedback mechanisms required to produce the best available solution to the defined problem (Calderon, 2010). By reducing knowledge gaps, unwanted complexity and unnecessary steps, the research hypotheses can be more effectively and efficiently tested.

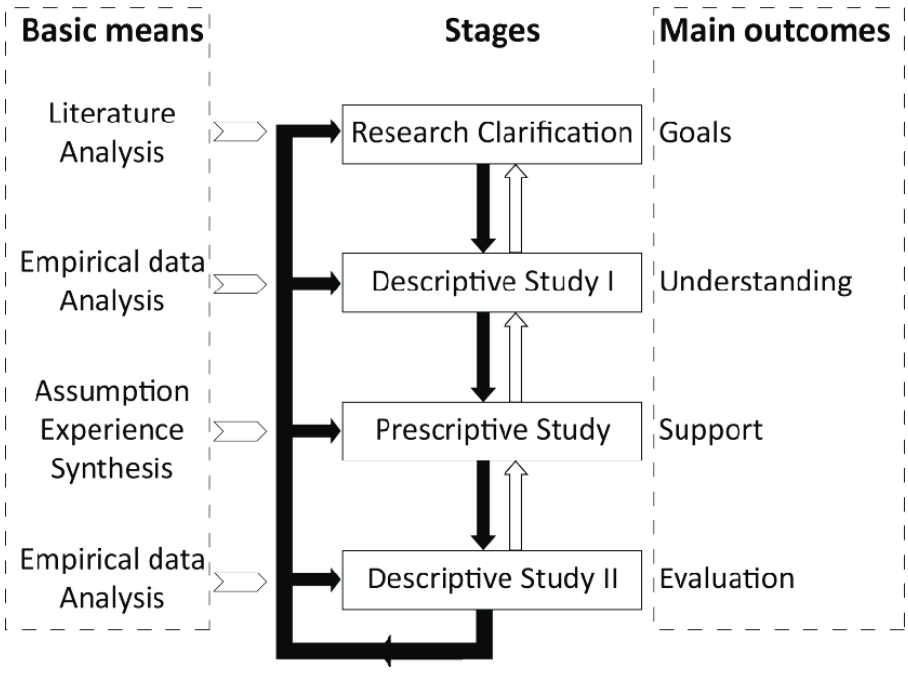


Figure 3-1. Design Research Methodology (DRM) framework by Blessing and Chakrabarti (2009)

3.2 Research Stages

This research applies the DRM framework to investigate the design of product configurators, aiming to generate prescriptive knowledge in the form of design principles and guidelines that can guide the development of user-centric and engaging configuration systems. This study aims to contribute to both the theoretical understanding of user behaviour in digital customisation environments and the practical implementation of effective product configurator solutions. Based on the DRM approach, this research was designed with four key stages as shown in *Figure 3-2*.

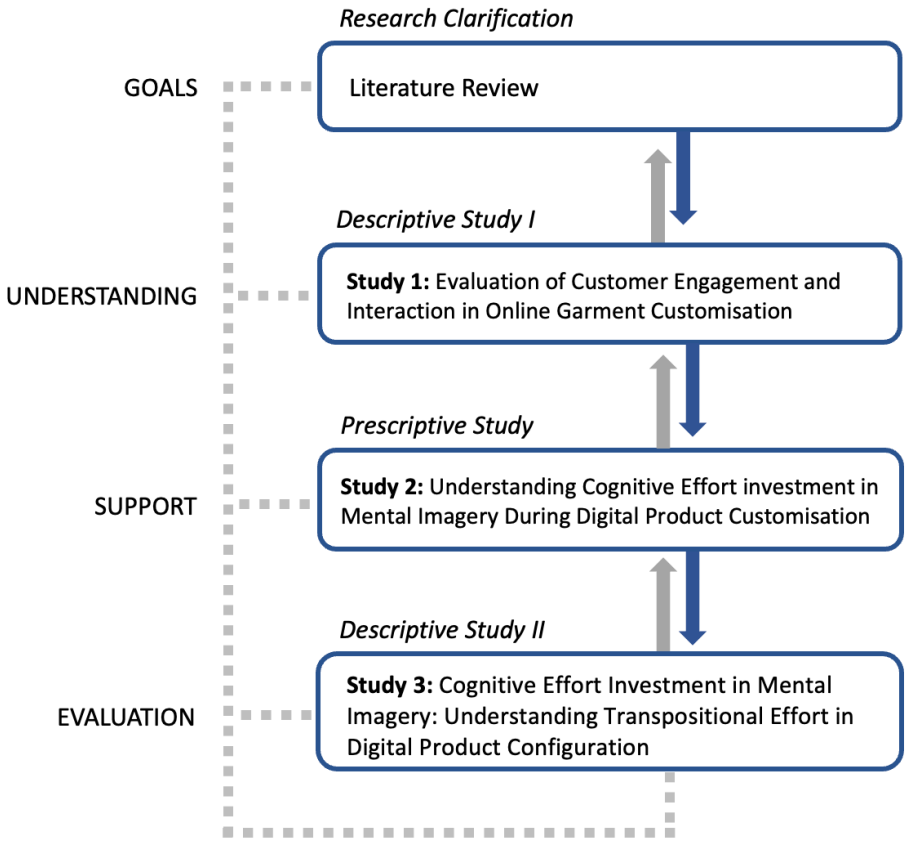


Figure 3-2. Design Research Stages

3.2.1 Research Clarification

A literature review was conducted in the research clarification stage to explore the technical developments in the past decade addressing manufacturing, product configuration system as well as customer and user engagement in the field of consumer research and human-computer interaction.

This stage aims to help establish the broader goals of the research, identifying gaps and opportunities in the field. This review covered a wide range of theoretical frameworks and empirical studies related to digital product customisation, user engagement, and decision-making processes, drawing from diverse fields such as consumer behaviour, psychology and human-computer interaction. By synthesising insights from prior studies and identifying key theoretical constructs and models, this stage laid the foundational understanding of the problem domain and informed the subsequent stages of the research.

The literature review has revealed that while mass customisation and product configuration systems have made significant advancements in enabling personalised products, there is a critical gap in understanding the user experience and cognitive processes involved in digital product customisation. Key findings highlight the importance of customer engagement, the multidimensional nature of cognitive effort investment, and the role of mental imagery in shaping user satisfaction and decision-making. The review emphasises the need for a user-centric perspective that considers the unique challenges and demands of the digital customisation context, particularly in relation to cognitive effort and mental imagery. By addressing these gaps, we can inform the development of more effective and engaging product configuration systems that optimize user experiences and drive successful mass customisation strategies.

The research clarification stage offered a comprehensive understanding of both the practical and theoretical aspects of manufacturing context, product configuration system, and user cognitive effort investment. By identifying the key gaps in the literature and opportunities in established practices, the aims and objectives of the research were set, and the subsequent study designed. This initial phase was crucial in grounding the research within existing theoretical frameworks and industry practices, ensuring that the study built upon prior knowledge while also addressing novel challenges and opportunities in the field. The detailed literature review can be found in Chapter 2.

3.2.2 Descriptive Study I

In the descriptive study I stage, the research focuses on evaluating customers' engagement and interaction in the online garment customisation process. This study aims to establish a detailed understanding of users' experiences and identify specific challenges and opportunities within digital garment customisation. Online configurators have enabled widespread product customisation using personal devices, allowing for a more interactive and immersive experience through virtual simulation. This has opened up new opportunities for various sectors, including the fashion industry. However, the garment customisation process in an unguided digital environment can be complicated and confusing for customers to navigate. To gain a deep understanding of users' experiences, challenges, and preferences in the context of digital garment customisation, this study investigates established online garment customisation methods. The aim is to understand how the remote digital environment impacts customers' engagement with garment function, form, and fit. By examining these aspects, the study sets the stage for the following prescriptive study phase, where targeted solutions can be proposed to enhance user engagement and satisfaction.

In this study, 25 participants (n=25) were asked to customise a shirt using an online configurator. This approach allowed for the collection of rich, context-specific data on users' decision-making processes and emotional responses toward a digitally configured product. In-depth interviews were conducted with 11 participants (n=11) with previous garment customisation experience to capture participants' experiences, thoughts, and feelings throughout the customisation journey. The results of this study indicate that while participants generally had a positive experience in configuring the appearance of the garment, their inability to visualise the customised garment on their own body led to reduced satisfaction with, and sense of ownership of, the designed digital outcome. This finding highlights a significant challenge in the current state of online garment customisation: the lack of effective tools or techniques to help customers visualise and evaluate the fit and drape of the customised garment on their unique body shape and size.

The insights gained from this descriptive study I stage provide a solid foundation for understanding the key factors influencing customer engagement and satisfaction in digital garment customisation. By identifying the specific pain points and opportunities in the current online customisation process, this study informs the development of targeted interventions for further understanding and investigation in the following prescriptive study phase. Moreover, the findings from this study have broader implications for the field of digital product customisation. The challenges and opportunities identified in the context of online garment customisation can be translated to other product categories and industries where virtual simulation and configuration play a crucial role in customer engagement and decision-making. A detailed description of the study design, methodology and results are elaborated in Chapter 4.

3.2.3 Prescriptive Study

In the prescriptive study phase, the research delves deeper into investigating users' utilisation of mental imagery during the customisation process. This study aims to provide targeted solutions and recommendations to improve user experience based on insights from previous stages. Building on the insights gained from the descriptive study I stage, which highlighted the challenges customers face in visualising and evaluating customised garments in a digital environment, this phase focuses on understanding how mental imagery influences users' cognitive effort investment and overall satisfaction with the configuration experience.

To investigate the relationship between mental imagery and cognitive effort investment in the customisation process, data were collected through a combination of survey questionnaires and contextual inquiry with 31 participants (n=31). The survey questionnaires assessed users' mental imagery abilities, including the vividness of their mental images and the frequency with which they engage in mental imagery in daily life. Contextual inquiry, on the other hand, provided an in-depth understanding of users' decision-making processes and strategies when configuring product attributes in an online configurator.

Interestingly, the study found no significant correlation between the vividness of mental imagery or the frequency of its use in daily life and the effort users invested in mental imagery during the digital product configuration process. This suggests that users' inherent mental imagery abilities may not directly determine the level of cognitive effort they invest in the customisation task. Furthermore, the study identified three distinct types of visualisations that users employ during the customisation process: product-related, user-related, and scenario-related visualisations. The findings suggest that encouraging users to engage in all three types of visualisations could lead to a more comprehensive evaluation of the customised product and enhance their overall satisfaction with the designed outcome. The study also indicates that expending more effort in mental imagery during the customisation process could positively influence users' confidence and satisfaction with the designed outcome. This implies that configurators should be designed to facilitate and support users' mental imagery processes, providing them with the necessary tools and information to create vivid and accurate mental representations of their customised products.

The insights gained from this prescriptive study phase contribute to a deeper understanding of how users navigate digital product customisation and provide direct guidance for improving the configuration experience. By leveraging the findings on the types of visualisations users employ and the impact of cognitive effort investment on satisfaction, designers and developers can create configurators that better align with users' mental models and decision-making processes. This, in turn, will enable the development of products that more closely meet users' expectations, leading to increased enjoyment, utilisation, and product longevity. Moreover, the prescriptive study phase highlights the potential for using cognitive effort investment in mental imagery as a metric for evaluating the efficacy of the configuration experience. By systematically measuring users' cognitive effort investment and assessing its correlation with key outcomes such as satisfaction, researchers and practitioners can gain valuable insights into the effectiveness of different configurator designs and features. A detailed description of the study design, methodology and results are elaborated in Chapter 5.

3.2.4 Descriptive Study II

In the final phase of the research, descriptive study II, the focus shifts to validating the proposed construct and assessing its impact on user engagement and satisfaction in real-world settings. This study aims to confirm the findings from earlier stages and evaluate the practical application of the new construct in real-world environments. This stage marks a significant milestone in the research process, as it formally introduces and defines the new construct, Transpositional Effort. Building upon the insights gained from the prescriptive study phase, which highlighted the importance of mental imagery in the customisation process, Transpositional Effort encapsulates the cognitive effort invested by users in mental imagery during product configuration.

To validate the proposed construct and evaluate its effectiveness in addressing the identified challenges in understanding and optimising users' cognitive processes during product customisation, a mixed-method survey was conducted. The study gathered both quantitative data (n=400) and qualitative data (n=212) on users' experiences with two different configurators. This approach allowed for a comprehensive examination of how Transpositional Effort influences user satisfaction and the overall success of the customisation process. The results of the study provide compelling evidence for the significance of Transpositional Effort in shaping user experiences with configurators. The findings reveal that users who expended the most cognitive effort in mental imagery during the configuration process were also the most satisfied with their designed outcomes. This suggests that encouraging and facilitating users' investment in mental imagery can lead to more positive and fulfilling customisation experiences.

The insights gained from this descriptive study II contribute to the broader knowledge base in user experience design and mass customisation, offering actionable recommendations for configurator design and development, while also providing a foundation for future research and development in this rapidly evolving domain. By considering Transpositional Effort as a key factor in the customisation process, designers and developers can create configurators that better support and encourage users' investment in mental imagery, ultimately leading to more satisfying and successful customisation

experiences. A detailed description of the study design, methodology and results are elaborated in Chapter 6.

3.3 Research Methods

This research is inherently interdisciplinary, drawing upon theories, methods, and practices from various fields, including design, psychology, human-computer interaction, and consumer behaviour. Working across disciplines requires a careful selection and integration of research methods that can effectively address the complexities of the research problem at hand (Kuksa, Skinner, Kent, *et al.*, 2023). By combining insights and approaches from different domains, this research aims to develop a comprehensive understanding of users' cognitive processes and experiences in digital product customisation, and to generate actionable knowledge for enhancing configurator design and user satisfaction.

This research employs a mixed methods approach across all three empirical studies. The choice of a mixed methods approach for this research is well-supported by Creswell's (2022) work on research design, offering a comprehensive exploration of user experiences and cognitive processes in digital product customisation. This methodology integrates quantitative and qualitative methods, allowing for complementarity and triangulation, which enhances the validity and reliability of findings through cross-verification from multiple data sources (Creswell, 2022). The quantitative component, represented by survey questionnaires, was chosen for its ability to efficiently collect data from a large and diverse sample (Brace, 2008). By utilising established measures and scales, these questionnaires provide a broad overview of user behaviour patterns, preferences, and demographic variations (Lavrakas, 2008). This method is critical for establishing a statistical foundation that quantifies user interactions with configuration systems, allowing for an objective understanding of user behaviour in the digital customisation process.

Complementing the quantitative approach, qualitative methods including semi-structured interviews and contextual inquiries provide depth to the findings (Flick, 2014). Semi-structured interviews investigate the personal experiences and perceptions of users, uncovering the motivations and challenges that lie beneath the surface data provided by surveys. This method's flexible nature facilitates an exploration of topics that emerge during conversations, offering a richer and more detailed perspective on individual user experiences (Seidman, 2006). Contextual inquiry further enhances the qualitative insights by observing users in their natural or simulated interaction environments, capturing real-time decision-making processes and interactions (Morales, 2020).

This mixed-methods strategy is particularly valuable when addressing complex research questions that cannot be fully answered by a single methodological approach. In the context of digital product customisation, quantitative methods measure aspects like task completion time or satisfaction ratings, while qualitative methods explore the emotional and cognitive dimensions of the user experience. Creswell (2022) emphasises the importance of thoughtful sequencing and integration of methods, suggesting that qualitative interviews could inform the design of quantitative surveys, or quantitative results could be further explored through qualitative follow-ups. By combining approaches, researchers can mitigate the limitations of individual methods and leverage their respective strengths (Creswell, 2022). Ultimately, this mixed-methods approach enhances the practical implications of the research, providing both statistical evidence and rich narratives to inform design decisions and improve user experiences in digital product customisation. The combination of these qualitative methods with quantitative data creates a robust framework for understanding the complex dynamics of user engagement and satisfaction in digital customisation.

In this research, self-reporting methods such as surveys and interviews have been primarily employed to gather data on users' experiences and cognitive processes during digital product customisation. This approach was chosen over alternatives such as think-aloud protocols, cursor tracking, and eye tracking for several compelling reasons.

Self-reporting provides a unique gateway to the internal cognitive processes that are essential for understanding how users utilise mental imagery in customisation—a central focus of this study. Unlike behavioural measures that capture only observable actions, self-reporting delves into users' thought processes and mental strategies directly from their perspectives (Skaramagkas *et al.*, 2023). This depth of insight is critical when exploring complex phenomena that are not outwardly visible, providing a layer of understanding that purely observational methods cannot offer (Saris, 2014).

Moreover, self-reporting methods enable users to engage with the customisation task uninterrupted, preserving the naturalness of their interactions with the digital tool (Morales, 2020). Think-aloud protocols, in contrast, could disrupt this natural flow, as they require users to verbalise their thoughts during the task, potentially altering their genuine responses (Morales, 2020). Furthermore, the retrospective nature of self-reporting allows participants to reflect on their entire experience post-task. This reflective process often uncovers more significant insights into their cognitive strategies and decision-making processes, which might not be evident in real-time data collection (Flick, 2014).

The practicality of self-reporting methods, especially in collecting data from a broad and diverse sample, is also a significant advantage (Brace, 2008). The COVID-19 pandemic introduced additional constraints, such as limits on in-person research activities and the necessity for remote data collection, making self-reporting particularly suitable. These methods facilitated extensive data gathering in a manner both safe and adaptable to participants' varying circumstances.

Through pilot studies, cursor tracking was also tested; however, it revealed significant limitations that affected its utility. The digital product customisation interface used in this study primarily involves activities on a single page, often with multiple pop-up tabs. This design caused the data collected through cursor tracking—and similarly through eye tracking—to be mixed and overlapping, making it difficult to accurately discern user focus and intentions. The cursor and eye movements on a dynamic, multi-element interface could not provide clear, actionable data, reinforcing the decision to rely more heavily on self-reporting (Wang *et al.*, 2021).

Looking forward, while this study primarily utilised self-reporting due to its numerous benefits and the practical constraints imposed by the pandemic, future research might explore the integration of improved observational methods. These could include advanced tracking technologies that better handle complex interfaces, potentially providing complementary data that would enrich the strength and comprehensiveness of the findings.

3.3.1 Mixed Methods Approach: Qualitative + Quantitative

The mixed methods approach, central to this research, integrates qualitative and quantitative methodologies across three distinct studies, drawing upon the foundational works of Creswell (2014). Creswell proposes this integration as a strategy to maximise the efficacy of both methodological approaches: qualitative data provides depth and context while quantitative data offers expansion and generalisability (Creswell, 2014). The qualitative component of the research facilitates an in-depth exploration of users' experiences, perceptions, and decision-making processes within digital product customisation contexts. This approach uncovers rich, contextual insights that shape users' engagement with configurators and their satisfaction with digital design outcomes (Adams, Lunt, and Cairns, 2008; Flick, 2014). On the other hand, the quantitative component systematically measures and analyses key variables such as users' mental imagery abilities, cognitive effort investment, and satisfaction levels. This allows for the identification of patterns, relationships, and trends that can be generalised across the broader population of configurator users (Nunnally and Farkas, 2016). By employing Crewell's mixed-methods framework, this research achieves a comprehensive understanding of the complex phenomena, ensuring that findings are both empirically robust and deeply informative, thereby generating actionable insights for the field of digital product customisation.

3.3.2 Survey Questionnaire

Survey questionnaires are employed in all three studies, primarily for the purpose of gathering quantitative data. The use of survey questionnaires allows for the efficient collection of data from a large sample of participants, providing a broad overview of the key variables of interest (Lavrakas, 2008;

Saris, 2014). The questionnaires include closed-ended questions, enabling the capture of numerical data that can be statistically analysed to identify patterns, relationships, and trends (Thomas, 2022).

In Study 1 (Descriptive Study I), survey questionnaires are used to gather data on users' experiences, challenges, and preferences in the context of digital garment customisation. In Study 2 (Prescriptive Study), survey questionnaires are employed to assess users' mental imagery abilities, including the vividness of their mental images and the frequency with which they engage in mental imagery in daily life. These data provide valuable insights into the individual differences in mental imagery abilities among configurator users and help to explore the relationship between these abilities and cognitive effort investment in the customisation process. In Study 3 (Descriptive Study II), survey questionnaires are utilised to collect quantitative data on users' experiences with two different configurators, focusing on their cognitive effort investment in mental imagery (Transpositional Effort) and their satisfaction with the designed outcomes. The quantitative data collected through these questionnaires enable the validation of the proposed construct of Transpositional Effort and the assessment of its impact on user engagement and satisfaction in real-world settings.

In Study 3 (Descriptive Study II), the survey questionnaire includes open-ended questions to gather qualitative data on users' experiences and design decision process with two different configurators. These open-ended questions provide an opportunity for users to express their thoughts, feelings, and reflections on the customisation process in their own words, offering a more detailed and detailed understanding of their cognitive effort investment in mental imagery and their satisfaction with the designed outcomes (Brace, 2008; Saris, 2014). The qualitative data collected through open-ended questions complement the quantitative data obtained through closed-ended questions in the survey questionnaire, providing a more comprehensive and holistic understanding of users' experiences in digital product customisation.

3.3.3 Semi-structured Interview and Contextual Inquiry

Semi-structured interviews are employed in Study 1 (Descriptive Study I) to gain a deep, qualitative understanding of users' decision-making processes, strategies, and experiences in the context of digital garment customisation. These interviews follow a flexible and open-ended format, allowing participants to express their thoughts, feelings, and experiences in their own words, while still maintaining a focus on the key topics and themes of study (Thomas, 2022). The semi-structured nature of the interviews enables the researcher to adapt the questioning based on participants' responses, probing for further clarification or exploring emergent ideas as necessary (Gill *et al.*, 2008; Wilson, 2013). This approach facilitates a detailed understanding of users' experiences, providing valuable insights into the factors that influence their engagement and satisfaction with the configurator and the designed outcome (Wilson, 2013). The qualitative data collected through semi-structured interviews complement the quantitative data obtained through survey questionnaires in Study 1, offering a more comprehensive and contextual understanding of users' experiences in digital garment customisation.

Contextual inquiry is employed in Study 2 (Prescriptive Study) to investigate users' decision making and their utilisation of mental imagery during the customisation process (Robinson, Lanius and Weber, 2018; Morales, 2020). By observing and probing participants as they configure product attributes in an online configurator, researchers can gain valuable insights into the details of mental visualisations utilised, as well as the cognitive strategies and challenges encountered during the customisation process. This method allows for the capture of rich, context-specific data that can inform the development of targeted interventions to enhance users' engagement, interaction and satisfaction in digital product customisation (Morales, 2020).

3.4 Chapter Summary

This chapter has outlined the research methodology employed in this study, which is situated within the Design Science Research (DSR) paradigm and follows the Design Research Methodology (DRM)

framework. The research is driven by an empirical approach to problem-solving, aiming to generate knowledge that can inform the design and development of effective product configurators and enhance user satisfaction in the domain of digital product customisation.

The research progresses through four main stages: Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II. In the Research Clarification stage, a comprehensive literature review and a comparison study were conducted to establish a solid foundation for the research, identifying key gaps and opportunities in both theory and practice. The Descriptive Study I stage involved an evaluation of customers' engagement and interaction in the online garment customisation process, providing a deep understanding of users' experiences, challenges, and preferences in the context of digital product customisation.

In the Prescriptive Study stage, the research delved deeper into investigating users' utilisation of mental imagery during the customisation process, exploring the relationship between mental imagery and cognitive effort investment in the configuration experience. The insights gained from this stage informed the development of a new construct, Transpositional Effort, which encapsulates the cognitive effort invested by users in mental imagery during product configuration. Finally, in the Descriptive Study II stage, the proposed construct of Transpositional Effort was validated and assessed for its impact on user engagement and satisfaction in real-world settings. This stage provided a comprehensive evaluation of the effectiveness of the proposed construct and its potential to address the identified challenges in understanding and optimising users' cognitive processes during product customisation.

Throughout the research, a mixed methods approach was employed, combining qualitative and quantitative research techniques to achieve a holistic understanding of the research problem. Survey questionnaires served as a primary tool across all three studies, gathering quantitative data on users' experiences, mental imagery abilities, cognitive effort investment, and satisfaction levels. Semi-structured Interviews and contextual inquiry were employed in specific studies to gain a deeper, qualitative understanding of users' decision-making processes, strategies, and experiences in the context of digital product customisation.

The integration of these research methods across the different phases of the study allowed for the generation of robust, reliable, and actionable insights that can inform the design and development of effective product configurators and enhance user satisfaction in the domain of mass customisation. By leveraging the strengths of each method and combining insights from various disciplines, this research aims to bridge the gap between theory and practice, contributing to the broader knowledge base in design science, user experience design, and digital product customisation.

In conclusion, the research methodology outlined in this chapter provides a comprehensive and systematic approach to investigating users' cognitive processes and experiences in digital product customisation, with the ultimate goal of generating actionable knowledge that can drive innovation and improvement in the design and development of product configurators. The insights and recommendations gathered from this research have the potential to significantly impact the field of mass customisation, enabling businesses to create more user-centric and engaging customisation experiences that meet the evolving needs and expectations of product end-users in the digital age.

The next chapter will present Study One, which delves into the evaluation of user engagement and interaction in online product customisation. By investigating customers' decision journeys and emotional responses during online product customisation, Study One seeks to provide a deeper understanding of the user experience. Through this empirical investigation, the study aims to address the gaps in the current literature and contribute to a more comprehensive understanding of digital product customisation from a user-centric perspective.

4. STUDY ONE

EVALUATION OF CUSTOMER ENGAGEMENT AND INTERACTION IN ONLINE GARMENT CUSTOMISATION

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4.1 Introduction

The literature review reported in chapter 2 has revealed a significant gap in understanding the user experience and cognitive processes involved in digital product customisation. While previous studies have focused on the technical aspects of product configuration systems and the benefits of mass customisation, there is a growing need for a user-centric perspective that considers the unique challenges and demands of the digital customisation context. In particular, the review has highlighted the importance of customer engagement, cognitive processing in shaping user satisfaction and decision-making processes.

To address these gaps and gain a deeper understanding of user experiences in digital product customisation, this chapter presents the first study. This study aims to collect empirical evidence on user engagement and interaction in a real-world digital customisation setting. By focusing on the fashion industry, specifically online garment customisation, the study aims to answer the following research question: ***How do customers engage and interact with online customisation platforms, and what are their expectations and concerns when conducting customisation in the virtual environment?***

The fashion industry serves as an ideal case example for understanding digital product customisation due to several factors. First, garment is a highly personal product category, where individual preferences and self-expression play a significant role in purchase decisions. Second, the modular nature of garment design and the wide range of available options make it a complex customisation context that can provide valuable insights into user decision making process. Third, the fashion industry has been at the forefront of adopting digital customisation technologies, with many brands and retailers offering online customisation platforms, making it a rich and relevant setting for empirical investigation. Meanwhile, one critical aspect of customised garments is achieving the right fit, especially challenging in a fully digital environment where physical try-ons are not possible. Studies have shown that customer satisfaction in online garment shopping is influenced by how closely the virtual models resemble their

own body shape. This insight underscores the importance of using body-related visualisation technology in the digital customisation process.

To investigate this further, this first study delves into the impact of the remote digital environment on customer engagement with garment function, form, and fit. The study aims to provide a foundation for understanding the user experience in digital product customisation by exploring customers' decision journeys and emotional responses during the process. Furthermore, by positioning this study as an initial understanding stage, this study supports the work started in the literature review to further explore and address the first research objective of this thesis which aims "to understand users' decision journey and their expectations and concerns when conducting product customisation in the virtual environment".

4.2 Research Design

This study employs a mixed methods approach to understand customer's expectations and concerns when conducting garment customisation in the virtual environment. Two activities were undertaken in the study: (1) a simulated garment customisation process using an online configurator tool and survey and (2) and in-depth interview. User engagement and interaction is a complex construct. To ensure the reliability and validity of the collected data, the study utilised subjective measures, including self-report questionnaires with rating scales and semi-structured interviews, and objective measures like web analytics and screen captures. Full details of the study, including *Participant Information Sheet*, *Survey Questionnaires*, *Interview Schedule*, and *Codebook*, are included in ***Appendix I: Study One***. All participants participated voluntarily and provided their written informed consent to participate in this study. The study was approved by the Imperial College London Joint Research Compliance Office, register number **20IC6002**.

The mixed approach of the questionnaire and interview facilitates a comprehensive examination of customer engagement and interaction in online garment customisation, capturing both quantitative and qualitative aspects across multiple dimensions. The questionnaire comprises 21 questions designed to gather quantitative data about the online garment customisation experience. It incorporates

demographic enquiries such as gender, age, knowledge about shirts, and wearing habits. Participants' prior customisation experiences are assessed through yes/no questions. The primary section of the questionnaire employs a 5-point Likert scale to evaluate key variables, including a participant's ability to visualise themselves wearing a shirt, their satisfaction with how the shirt will appear on them, and their confidence in their design choice reflecting their personal image. Other variables including user autonomy, effort investment, emotional attachment, ownership, purchase likelihood, and concerns about the inability to physically try on garments. Furthermore, 5-point semantic differential scales are used to rate the overall customisation experience and sentiments towards the finalised product.

The interview, on the other hand, delves into qualitative insights regarding the customer's decision-making process. Topics include intended usage, desired options, evaluation of fit and sizing, past customisation experiences, the role in co-creation, and the overall customisation experience. Its semi-structured nature permits personalised follow-up questions, offering a deeper exploration of thought processes, decision-making criteria, and perceptions.

An established configurator will be essential for simulating a typical digital customisation process. In the search for an appropriate configurator, several characteristics were considered. The configurable item should be common in daily life and appropriate for the general consumer audience. The configurator should function with smooth user flow and clear navigation with high-quality, realistic product simulation materials to eliminate potential user experience issues that could negatively impact the configuration process.

A shirt was used as the customisation item for this study. When searching for an appropriate configurator, a shirt was chosen because of the following characteristics: (1) A shirt is a common garment that requires a tailored silhouette to fit the body well; (2) shirts are highly flexible in style, with established, configurable options; and (3) shirts are usually made with woven, non-stretchy fabrics, such as cotton.

To simulate the online garment customisation process, the shirt configurator developed by Tailor Store Sweden AB (tailorstore.co.uk) was used in this study (*Figure 4-1*). The configurator provides a visualised shirt customisation process, which includes a series of comprehensive form and function options. The configurator is believed to represent an up-to-date online garment customisation process. The configurator contains ten configurable categories, with 28 sub-option touchpoints. Within the 28 options, seven options (25%) are designed for functional decisions, such as collar stiffness and pockets; 19 options (67.9%) exist for altering garment form, including fabrics, placket and cuff styles. There are only two options (7.1%) for configuring garment fit: back details and back yoke.



Figure 4-1: Shirt Configurator by Tailor Store Sweden AB, via tailorstore.co.uk. (https://www.tailorstore.co.uk/shirt-designer#4YyICO8DnzXA6E76lAMKn8NqCLI0kBwkrHJTllGYHew56txj5L)

Participants were asked to join a remote-control session in which all on-screen activities during the simulation would be recorded for data analysis. Completion of a short survey regarding the decision journey was required, and a small number of participants were selected for an in-depth interview based on their past experience with garment customisation to further identify detailed customer interactions within the customisation process. The participants were recruited through social media advertisements (i.e., Facebook, Instagram) and snowball sampling. At the end of the survey, participants with previous experience in garment customisation were asked if they would be willing to be contacted for an in-depth interview.

4.3 Data Analysis

A total of 25 participants (n = 25) were recruited to participate in this user study. The participants were 18–35 years old. A preliminary analysis showed that 12 participants (48%) had experience in garment customisation and 11 of which participated in the in-depth interviews, however, none of them had ever used an online garment configuration tool.

The study employed a mixed-method approach for data analysis. Pearson correlation coefficients were used to analyse the correlations among variables. The qualitative data were first analysed using a deductive coding cycle, based on theories and constructs identified in this study. The first cycle resulted in six codes, including *Co-creation*, *Customisation Process*, *Virtual Simulation*, *Body Visualisation*, *Fit Evaluation*, and *Decision Journey*. The study then employed an inductive cycle to identify new themes that emerged, as well as recurring patterns from the qualitative data. A total of 19 codes were generated and identified during this second inductive cycle. These codes were further categorised into themes that emerged. Four themes were identified in the analysis, which include *Customisation Process*, *Challenges with Fit Visualisation*, *Need for Fit Optimisation*, and *Design Decision Challenges*. The complete coding system, covering both deductive and inductive codes along with detailed descriptions, is available in the *Appendix I - D: Study One – Codebook*.

The average time spent on the shirt configuration session was 15 minutes and 10 seconds. Interestingly, Pearson correlations (r) indicate that there was no significant statistical correlation between the time spent in the session and the customer's subjective (self-reported) effort invested (r = 0.085). On average, participants spent 10.3% of the time on options related to garment function (25% of total options), 84.1% on configuring garment form (67.9%) and only 5.3% of the time on garment fit (7.1%) decisions.

The following sub-sections present the full data analysis, broken down into three individual categories: firstly, experiences with the customisation process overall; secondly, the evaluation of fit in the virtual environment; and thirdly, impacts of product visualisation. Each section begins by delving into the

relevant qualitative findings, followed by supportive exploration of the quantitative data where relevant. The qualitative findings reference specific codes from the interview transcriptions in italics and note the number of 'instances' representing the occurrences of the code throughout all discussions.

4.3.1 Customisation Process

The configurator presents customers with a wide range of options available, each choice leading to a unique design possibility. The centre of a customer's engagement in digital garment customisation is the interaction with the configurator. Therefore, the discussion of the ease, flexibility, and accuracy of the *Customisation Process* (54 instances) emerges not only as critical constructs in the study but also as a recurring theme in the interview conversations. During the customisation process, the customer's position shifted from a passive buyer to a product co-creator, as agreed by 21 out of 25 participants. This is also evidenced from the qualitative interviews, with many making references to *Co-Creation* (28 instances), indicating the process felt like collaborating with the system like a co-designer, with statements such as: *"It's kind of like you work with this website to create a product, you're actually working together as a sort of like your colleague. And then you're doing things together to make a product."*

Participants expressed *excitement about the expanded customisation capabilities* through online platforms (3 instances). One commented, *"It was a really good experience. I feel like I half made that shirt."* This enthusiasm for digital customisation was further evidenced when discussing the *sense of control and the self-expressive creative process* (4 instances). Another participant stated, "*I have all the control of every single detail. So, when I design every single part of the shirt, I do feel like, 'Oh, that final product belongs to me in a way."*

Supporting these qualitative insights, relevant quantitative data from the survey is shown in *Table 4-1*. This revealed that a significant majority of participants believed the process was enjoyable, with 92% agreeing (m = 4.36). Additionally, 82% felt they could complete all the steps independently (m = 4.24). In terms of attachment to their creations, 44% of participants agreed that they developed a sense of

ownership over the digital design post-customisation (m = 3.24). 72% believed they would be more emotionally attached to this shirt (m = 3.96), and 84% believed they would keep this shirt longer (m = 4.36) than a shirt they hadn't customised.

Table 4-1: Key Survey Question Reponses

Survey Question	Positive Responses	Mean	SD
(Design Attributes) All the available options are equally important to create the shirt.	72%	3.88	0.86
(User Autonomy) I am able to complete all the steps independently.	80%	4.24	1.03
(Effort Investment) I have given a lot of thought when I'm creating this shirt.	72%	3.84	0.97
(Simulation Quality) The digital simulation of the shirt is in high quality and realistic.	84%	4.16	0.88
(Visualisation Ability) I am able to visualise myself wearing the shirt.	32%	2.80	1.10
(Design Confidence) I am confident my design of this shirt fits my image.	72%	3.72	0.92
(Design Satisfaction) I am satisfied with this shirt design will look good on me.	42%	3.24	0.95
(Design Ownership) I feel like I already own this shirt now I have spent time customising it.	44%	3.24	0.99
(Emotional Attachment) I believe I will be more emotionally attached to this shirt.	72%	3.96	1.15
(Long-Term Hold) I believe I will keep this shirt longer than one without customising it.	84%	4.36	0.93

Note. n = 25. Positive Responses = Strongly agree (Score 5 out of 5) + Somewhat agree (Score 4 out of 5)
Mean on 5-point scale. SD = Standard Deviation.

However, some challenges also emerged in the design decision journey. While the list of options provides freedom to customers, some specifically mentioned that they were *overwhelmed by options* (6 instances): *"When you have too many choices, it's really hard to lock down to one."* Compared to the in-store customisation experience, some people felt less confident due to a *lack of fashion design expertise* (3 instances). Others expressed *confusion over construction details* (4 instances), and one specifically mentioned *hesitance to choose unconventional options* (1 instance) with their unguided decisions: *"I am not sure what I'm doing. I don't know if it's good or not. If I just design it and I wear it to a dinner, it turns out that I am the most outstanding guy wearing a not suitable shirt on that occasion, it might be awkward and embarrassing."*

4.3.2 Fit Evaluation

Fit stands as a major concern in the domain of online garment customisation. The suitability of a garment, beyond its aesthetic design, is heavily weighted on its fit. The majority of current in-store

customisations, especially traditional tailoring, prioritise achieving a perfect fit. Therefore, this makes fit evaluation a critical aspect of garment customisation and where the most challenges emerge. This is further evidenced from the in-depth interview, where discussion on *Fit Evaluation*, related to assessing fit and sizing through the virtual experience, was the most discussed topic (61 instances). Participants emphasised the significance of assessing fit and sizing through the virtual interface: *"I want my waist to be a bit tighter... but if you button up you probably can't breathe easily."* Statements like this indicated the priority on comfort, and statements such as *"It's very hard for me to find a perfect fit shirt for me because of my silhouette."* indicated the expectation for customers to achieve a perfect fit in garment customisation.

From a garment construction perspective, especially for the product type of shirt utilised in this study, the qualitative data further reveal specific concerns when it comes to fitting a shirt in the digital environment. The focus on *accurate chest and waist circumference fit* was the most discussed during the in-depth interview (7 instances). One participant stated: *"I usually require a larger chest size shirt and it's quite a unique figure for choosing from standard sizing, and to get what I want to look like."* Meanwhile, participants also stressed the importance of *proper sleeve length* for fitting a shirt (4 instances): *"I'm quite tall so I've got really long arms, but I'm really slim as well. So, if I buy a slim-fit shirt, the sleeves are really tight."* Lastly, some mentioned that they faced challenges with the *shoulder width* when fitting a shirt: *"The shoulder might be a bit too wide for me, so. It is a bit difficult sometimes to find a perfect size, maybe for women who are quite tall."*

Another interesting point mentioned in the discussion was the *need for fit intended for specific activities* (2 instances). A participant said: *"You should move around with your arms and if this shirt is not a really good cut, you find it becomes shorter and you don't feel really comfortable with your arms and chest."* This highlighted that customers have distinct preferences and priorities when it comes to fit, ranging from comfort considerations to ensuring suitability for specific activities or occasions.

4.3.3 Visualisation

Visualisation plays a critical role in the digital product configurator. It bridges the gap between digital interfaces and tangible products, allowing users to foresee the final outcome of their design choices. To assess a configurator, the quality and realism of the virtual simulation could be one of the most direct ways to judge if this is a state-of-the-art configurator. For garments, the ability to visualise them in terms of colours, textures, and designs on a virtual simulation greatly enhances the customisation experience.

Participants shared varied insights regarding their experiences with the digital simulation of shirts. Feedback on *seeing garments on virtual body models* was a dominant theme in the in-depth interviews (43 instances). Some participants specifically mentioned their *difficulty in envisioning the final product* on themselves (5 instances): *"Sometimes I just don't know how it really looks on me"*. Challenges related to assessing fit on the physical body were also highlighted, with one participant remarking, *"For me, I'm quite specific. I'm quite tall, so I think if you put my body figure on it, my arms are kind of pretty long, longer than most ladies out there, I guess. So, it would be nice for me to see actually how that looks on the arm."* The tactile experience was a recurring theme, emphasised (8 instances), with participants stressing the importance of feeling a garment's material and texture: *"I think the only problem is the fabric. I cannot feel the fabric. The only thing I still need to try is the texture of the fabric."* Such feedback underscores the challenges of digital customisation in delivering a comprehensive visualisation experience. Additionally, concerns over dissatisfaction with the final product were voiced (2 instances): *"There is also the fear that you do all that and it's still not right, and that you tailor everything and it's still not what you imagined."*

Complementing the qualitative feedback, the relevant quantitative data is shown in *Table 4-2*, analysing the correlations amongst variables measured in the survey. This data illustrated that 84% of participants believed the digital simulation of the shirt was of high quality and realistic (m = 4.26). However, only 32% were able to easily visualise themselves wearing the shirt (m = 2.8). Crucially, the study found a significant correlation between customers' ability to visualise the garment on their body and their

confidence in the digitally designed product (m = 3.72, r = 0.462) as well as their satisfaction (m = 3.24, r = 0.738).

Table 4-2: Correlations Among Variables

	VA	DC	DS	DO	EA
Visualisation Ability	-	0.462*	0.738***	0.192	0.216
Design Confidence		-	0.536**	0.162	0.255
Design Satisfaction			-	0.576**	0.155
Design Ownership				-	0.254
Emotional Attachment					-

Note. n = 25. VA = Visualisation Ability. DC = Design Confidence. DS = Design Satisfaction. DO = Design Ownership. EA = Emotional Attachment. *p < .05; **p < .01; ***p < .001

4.4 Discussion

The data analysis from this study underscores three main themes that are central to the experience of digital garment customisation. First, the journey customers take in making decisions significantly affects their overall satisfaction. Second, analysing garment fit within a digital platform presents a notable challenge, with the necessity for precise fit-assessment tools being crucial for customer trust. Third, while quality visual simulation is important, however, it must be coupled with the customer's ability to visualise the garment on themselves to ensure true satisfaction. These themes are closely connected, as mental visualisation not only assists in evaluating fit but also is key to the customisation process, leading users through their choices. Thus, the configurator's design is critical, acting as both an enabler of personalisation and a connector between the digital and physical customer experiences. *Table 4-3* provides a comprehensive overview of the current state of digital garment customisation identified in this study, pinpointing its strengths, identifying areas of improvement, and suggesting potential solutions.

Table 4-3: Digital Garment Customisation: Strengths, Gaps, and Recommendations

Aspect	Strengths	Limitation/Gap	Recommendation
Customisation Process	Flexibility in options promotes personalisation. High level of enthusiasm for customisation	Less fashion-savvy customers struggle with overwhelming options	Enhance user guidance for a more seamless customisation experience
Body Visualisation	High-quality and realistic simulation of the garment	Desire among customers to view garments on their specific body type, rather than a standard model	Integrate advanced technologies such as body scanning or augmented reality to provide tailored fit predictions
Fit Evaluation	*No strengths identified*	Existing digital tools may lack the capability to reflect real-world fittings accurately, leading to discrepancies in fit representation	Fit prediction tools should adapt to diverse body types and precisely predict actual fit to meet customer expectations
Tactile Experience	Quality imagery and detailed description of fabric materials	Intangibility causes concerns over inability to properly evaluate fabrics and quality	Innovations like augmented reality, 3D simulations, or haptic feedback to enhance the visualisation experience

This study demonstrates its value by providing empirical data of customer's expectations and concerns when conducting garment customisation in the virtual environment. The example configurator used in this study has provided a useful reference as a baseline in configurator development due to its successful implementation of garment form–related configurable options and a high level of appearance-design interaction. The results could also contribute to the digitalisation movement of garment production, providing guidance to the industry on how to incorporate technology-oriented customisation in operation models.

4.5 Conclusions

Study one evaluated customers' engagement and interaction with the online garment customisation process using a user study with an established online garment configurator. A primary finding from the data analysis is that despite a positive experience in configuring garment appearance, customers' inability to visualise the customised garment on their body could result in less satisfaction with, and sense of ownership of, the designed digital outcome. As the study revealed, while there are undeniable benefits of the product configurator, including the empowerment of customers as co-creators and the joy of the customisation process, there are also pressing challenges to address. Key challenges among these are the balance of offering choice without overwhelming users, the critical role of fit evaluation in a virtual environment, and the tangible-intangible divide those digital systems often struggle with - especially concerning fabric feel and quality in the context of garments such as shirts. Meanwhile, customers' desire for a realistic body visualisation, coupled with accurate fit optimisation, identifies a number of areas for further investigation which will be important for developing effective garment customisation experiences. Most critically, there is a pressing need to investigate strategies to enable the effective remote evaluation of garment fit and function.

Meanwhile, the study highlighted that visualisation or mental imagery plays a critical role in the customer’s decision-making process. The following studies explore how users utilise mental imagery in their experiences with digital product configuration to understand more about the role this plays in satisfaction with the digitally designed outcome. This investigation should consider the psychological aspect of mental imagery in the context of digital product customisation, including how individuals differ in their ability to generate and manipulate mental images of the product they are configuring. By integrating findings from cognitive psychology with user experience design, future research could identify strategies to enhance the product configuration experience, potentially through advanced visualisation technologies. This could contribute to the development of more intuitive and satisfying digital customisation platforms.

5. STUDY TWO

UNDERSTANDING COGNITIVE EFFORT INVESTMENT IN MENTAL IMAGERY DURING DIGITAL PRODUCT CUSTOMISATION

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5.1 Introduction

There remains a significant gap in understanding how to address user issues regarding product fit and meeting specific expectations with digital product customisation. This gap often leads to high product return rates and contributes to environmental waste. To address this, a deeper exploration into the online product configuration process is essential, aiming to tailor the customisation experience more precisely to individual user needs. Integrating interdisciplinary research, especially from psychology, could offer critical insights into user decision-making processes, thereby enhancing product customisation effectiveness and developing the creation of products that align more closely with user expectations. The findings from study one suggests that mental imagery plays a critical role in the decision-making process during digital product configuration. The ability to generate and manipulate mental images of the product being configured could significantly influence user satisfaction with the final digitally designed outcome. To further explore this concept and build upon these results, this second study delves deeper into the specific aspects of mental imagery that contribute to a more engaging and satisfying user experience.

In the digital realm of product configuration, where users cannot physically touch the product, the process relies heavily on mental resources to gather and evaluate information, known as cognitive effort in decision-making. This cognitive effort plays a crucial role in increasing decision confidence and reducing post-decision regret, but it's influenced by various factors including design decisions and system usability. Additionally, in a remote digital environment, the challenge is heightened due to the discrepancies between virtual representations and the physical product, especially in terms of materials and sizing. Users often rely on visual mental imagery during product evaluation, a process of 'thinking in pictures' or 'seeing with the mind's eye.' Understanding the cognitive effort invested in this mental imagery is key to comprehending how users navigate product evaluation in a digital environment.

To investigate this further, this second study aims to explore users' cognitive effort distribution in digital product evaluation and answer the following research question: ***What specific aspects of mental***

imagery contribute to a more engaging and satisfying user experience in digital product customisation? This is investigated by exploring different types of mental imagery used by users during the digital customisation process, examining how the use of mental imagery evolves throughout the customisation journey, and assessing whether there is a correlation between mental imagery ability and decision-making effectiveness in digital product customisation. This addresses the second research objective of this thesis "to analyse the distribution of users' cognitive effort in the digital product configuration process, specifically how they utilise mental imagery when evaluating the digitally configured product" and builds on the findings from the first study to develop a deeper understanding of these critical aspects of customisation.

5.2 Methods and Procedure

The study implemented a mixed method of qualitative and quantitative approaches to investigate users' cognitive effort investment on mental imagery in the digital product customisation process. There were two parts to the activities conducted in this study: (1) A survey to identify the participant's mental imagery ability, including the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973) and the Spontaneous Use of Imagery Scale (SUIS) (Reisberg, Pearson and Kosslyn, 2003); (2) A task to complete a shirt design using a configuration system + interview. Each participant was required to participate in both activities to complete the study, taking approximately 45 minutes per session. In total 31 participants were engaged, and the study structure and procedure are described in *Figure 5-1*. Full details of the study, including *Participant Information Sheet*, *Survey Questionnaires*, *Interview Schedule*, and *Codebook*, are included in ***Appendix II: Study Two***. All participants participated voluntarily and provided their written informed consent to participate in this study. The study was approved by the Imperial College London Research Governance and Integrity Team, register number **21IC6745**.

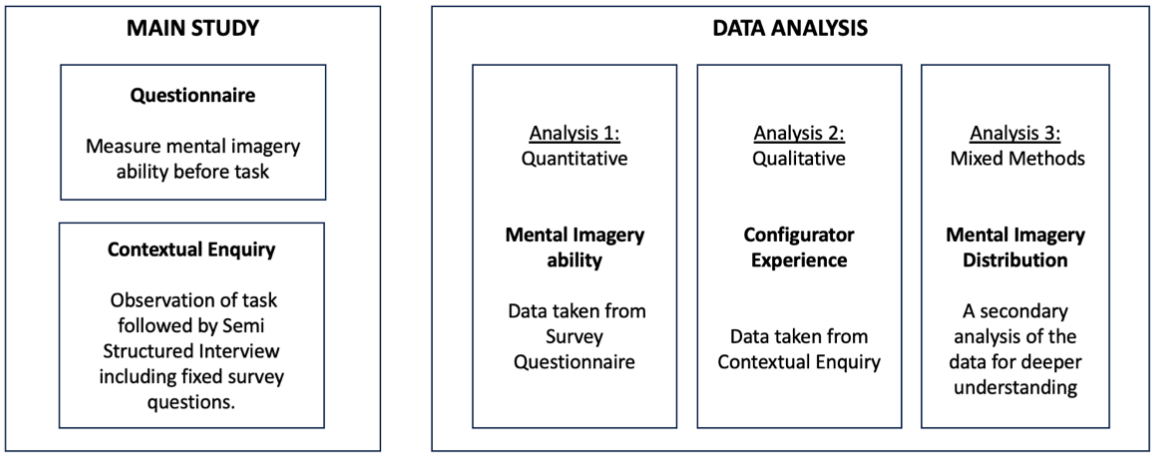


Figure 5-1: Research Structure and Procedure

5.3 Survey Questionnaires

Scientific investigations have well established that people have different abilities to use mental imagery (Kosslyn *et al.*, 1984; Cui *et al.*, 2007; Andrade *et al.*, 2014). One of the earliest supports to this notion can trace back to Galton (Galton, 2004), who identified vividness as a critical measure of mental imagery abilities. Numerous self-report measures have since been developed and revised to identify strengths and weaknesses in imagery, including multi-sensory scales such as Betts' (Betts, 1909) 150-item Questionnaire Upon Mental Imagery, which later was modified by Sheehan (Sheehan, 1967) into a 35-item shortened version. Plymouth Sensory Imagery Questionnaire also recognised the imagery across sensory modalities and expanded sensory factors with more up-to-date scenarios (Andrade *et al.*, 2014).

Although multi-sensory measures could establish a more comprehensive understanding of an individual's mental imagery ability, senses such as sound, taste and smell may not necessarily be utilised in the study scenario of digital product customisation. Therefore, this study adopted the VVIQ (Marks, 1973), one of the most commonly used scales focusing on visual imagery. The questionnaire consists of four scenes, including a relative or friend, the rising sun, a shop and a landscape. Participants will rate all 16 scenarios based on the vividness of the triggered mental imagery using a five-point scale, from 'perfectly clear and vivid' to 'no image at all'. The total score will range from 16 to 80, with a lower score indicates a stronger imagery ability.

Another identified factor to explore in this study is the tendency to use visual mental imagery in daily life. SUIS (Reisberg, Pearson and Kosslyn, 2003) is a 12-item questionnaire focusing only on visual imagery frequency and likelihood. The participant will respond to daily life scenarios using a five-point scale indicating how appropriate the description is, from 'always completely appropriate' to 'never appropriate'. A previous study identified that the SUIS total score is related to higher levels of visual imagery ability measured through VVIQ (Nelis *et al.*, 2014). Incorporating both the SUIS and VVIQ offers a comprehensive approach in this study. While SUIS assesses the frequency of visual imagery in daily scenarios, VVIQ evaluates the vividness and clarity of these visualisations. Together, these two scales enable a more thorough examination of individual mental imagery abilities by connecting the frequency of visualisation with the clarity and detail of these images, enhancing our insight into users' cognitive processes in the digital customisation process.

5.4 Contextual Inquiry

An established configurator is essential to simulate the current digital customisation process in this study. When searching for an appropriate configurator, several characteristics were considered. The configurable item should be common in daily life and appropriate for the general consumer audience. In addition, it should be flexible in style with established configurable options. To represent a comprehensive customisation process, the configurable attributes should cover all three product characteristics: form, function and fit. The configurator should function with smooth user flow and clear navigation with high-quality, realistic product simulation materials to eliminate potential user experience issues that could negatively impact the configuration process.

The shirt configurator developed by Tailor Store Sweden AB (Tailorstore.co.uk) was selected in this study, as shown in *Figure 5-2*. The configurator provides a visualised configuration process and is believed to represent an up-to-date digital customisation process with photo-realistic product simulation, a series of comprehensive options responding to product form, fit and function, including 10 configurable categories with 28 sub-options.



Figure 5-2: Shirt Configurator by Tailor Store Sweden AB, via tailorstore.co.uk. (https://www.tailorstore.com/shirt-designer#4YyUl21AXDOR2hHr8foKwQXKjR3tlflxfkv6ag8PdOwUByS58d)

To determine how users utilise mental imagery in the configuration process, it is necessary to understand their in-depth thinking process and the structure underlying each decision. This study conducted contextual inquiries to uncover these interaction details that are habitual and invisible (Liaqat *et al.*, 2018). As a practical User Experience (UX) research methodology, contextual inquiries are widely implemented in the HCI field. They occur in the context of a particular process, combining observation and interviews to gain a more in-depth understanding of the process (Robinson, Lanius and Weber, 2018). While the traditional model of contextual inquiry involves interruption in the task process, the interruption with question answering may impact the overall effort investment in the user decision journey. Therefore, this study adopted passive inquiry, where participants perform their tasks without engagement from the researcher, and all questions regarding the participants' interaction are raised after the task is completed (Morales, 2020).

Participants were asked to join a remote-control session to design their shirts using the configurator during the study. Two pilot studies were conducted to obtain a basic understanding of the configuration flow. The pilot studies also identified key moments that may indicate internally focused thinking, including taking long pauses, skipping steps, revising decisions and constantly comparing options. Interview questions were keyed to the above moments and after each configurable category. All the

onscreen activities were recorded and replayed during the interview to help the participant recall the process.

The interview explores participants' design choices and their use of mental imagery. Questions are centred around their decision-making strategy, particularly when imagining the product in various scenarios. Participants are also asked to rate their satisfaction with how the shirt will appear on them, and their confidence in their design choice reflecting their personal image. In analysing the data, the study focuses on understanding the cognitive effort involved in visualisation and decision-making. This includes examining patterns in how design choices are navigated, the utilisation of mental imagery, and linking these aspects to their satisfaction with both the end-designed product and the customisation process. Additionally, behavioural observations during the design process are incorporated into the analysis, offering a comprehensive view of the user's experience in digital product customisation.

5.5 Data Analysis

5.5.1 Recruitment and Demographics

A total of 35 undergraduate and postgraduate students were initially recruited to participate in this study, but 4 participants were ruled out due to the incompletion of tasks. Of the remaining 31 participants, 18 were female and 13 were male, ranging from 18 to 40 years. All of the participants were screened for English proficiency. Participants with English as a second language and Mandarin Chinese as their first language had the option to conduct the interview in the language of their choice. The task and interview sessions were conducted in the laboratory or via remote video chat. All interviews were audio-recorded and transcribed.

5.5.2 Quantitative Data: Mental Imagery Ability

The abilities of each participant to utilise mental imagery and their tendency to use visual mental imagery were assessed through VVIQ and SUIS (See *Table 5-1*). Cronbach’s alpha in this study was

0.82 for VVIQ and 0.73 for SUIS, indicating an acceptable internal consistency for both questionnaires. The Pearson correlation coefficients indicated that participants with a high level of image vividness are likely to have a higher tendency to use visual mental imagery in their daily life (r=0.476, p<.01).

Table 5-1: VVIQ & SUIS Descriptive Statistics

Questionnaire	α	Mean	Max	Min	SD
Vividness of Visual Imagery Questionnaire (VVIQ)	0.82	60.52	74	46	7.04
Spontaneous Use of Imagery Scale (SUIS)	0.73	44.45	53	31	6.15

Note. N = 31. VVIQ scores range from 16 to 80. SUIS scores range from 12 to 60. SD = Standard Deviation.

5.5.3 Qualitative Data: Configurator Experience

The qualitative data were first analysed using a deductive coding cycle, based on theories and constructs identified in this study. The first cycle resulted in ten codes, including *Pre-Task Imagery*, *Post-Task Imagery*, *Product Fit, Form and Function*, *Design and Process Satisfaction* and different *Types of Visualisations* utilised by the user. The study then employed an inductive cycle to identify new themes that emerged, as well as recurring patterns from the qualitative data. A total of 14 codes were generated and identified during this second inductive cycle. These codes were further categorised into themes that emerged. Four themes were identified in the analysis, which include *Visualisation Process*, *Decision-Making Strategy*, *Design Process*, and *Problems and Challenges*. The complete coding system, with both deductive and inductive codes along with detailed descriptions, is available in the *Appendix II - D: Study Two - Codebook*.

The following sub-sections detail a qualitative analysis collected from empirical data through contextual inquiry. The characteristics of the visualisation process are examined initially. Then followed by an assessment of decision-making strategies influenced by mental images. The report further exploring how imagery shapes the design process. The final part of the analysis focuses on user-reported satisfaction, evaluating the overall problem and challenges during customisation process. The qualitative findings reference specific codes from the interview transcriptions in italics and note the number of 'instances' representing the occurrences of the code throughout all discussions.

5.5.4 Visualisation Process

The qualitative data analysis reveals critical insights into the visualisation process users engage in during the digital product customisation journey. Users utilise a variety of mental imagery techniques throughout their product configuration experiences, which based on the recurring patterns identified in the inductive coding cycle, these visualisations can be summarised into several distinct types.

Holistic Visualisation *(14 instances)*: This type of visualisation emerges mainly in two phases. Initially, as participants form early expectations about the style of the product, and later, when they review the finalised design. A common sentiment among users was a desire for a zoomed-out perspective to better understand the overall look of the product from a distance. One user expressed this desire clearly, saying, *"I wanted to zoom out and see the full shirt before deciding on buttons."* This need for a comprehensive view underscores the importance of seeing the product as a whole during various stages of the customisation process.

Tactile Visualisation *(6 instances)*: Given the intangible nature of digital artifacts, participants reported using mental simulations to imagine tactile aspects such as fabric weight, texture, and drape. Users often relied on text descriptions and visual aesthetics to trigger these mental simulations, filling in the gaps where physical touch wasn't possible. As one user put it, *“I tried to imagine the texture, like how crisp the cotton would feel.”* This indicates how users mentally simulate the physical attributes of products, such as texture and material quality, to overcome the limitations of digital experiences.

Self-Visualisation *(15 instances)*: In this study, given the nature of the product being analysed, self-visualisation emerges as a useful tool. It enables users to mentally project the product's aesthetics onto their own bodies, a process that typically unfolds later in their decision-making journey, especially with products they find more appealing. A user described this process: *"I pictured wearing this shirt with jeans and sneakers."*

Mirrored *(4 instances) vs****. Third-Person Visualisation*** *(3 instances)*: Users mentally visualize wearing items from both a first-person mirrored perspective and a third-person external viewpoint. These different perspectives serve varying functions, with the mirrored view often used to consider fit and coordination, and the third-person view used to project social impressions. A user describing the mirrored perspective said, *"It was like seeing myself in the shirt through a mirror,"* indicating an introspective approach to visualisation. Conversely, for the third-person perspective, another user mentioned, *"I envisioned how the back yoke detail might look to others,"* reflecting a concern for external perceptions.

Environmental Visualisation *(6 instances)*: Users also imagine wearing products in specific environments or settings. One participant described this as, *"I imagined wearing this while walking through the park."* This type of visualisation places the product within a broader context, influencing the decision-making process.

Memory-based Visualisation *(7 instances)*: The participants past experiences and memories also play a role in the visualisation process. For instance, one user recalled, *"The fabric print reminded me of a shirt I used to own."* This demonstrates how users connect current products with past experiences, influencing their perceptions and choices.

5.5.5 Decision Making Strategy

During the analysis focusing on users' decision-making during product customisation, the qualitative data indicated that participants employed a combination of *Comparative Evaluation*, *Attribute Filtering*, and considerations of *Product Form, Fit, and Function*. These approaches emphasis the detailed and highly personalised characteristics of users' decision-making processes.

Comparative Evaluation (13 instances) was a notable strategy, where participants engaged in detailed comparison between options. For example, one participant described their method: *"I clicked between the two nearest colours to see which blue worked best against the tan base."* This approach reflects a

deep analysis to evaluate the subtle differences. Meanwhile, many participants also adopted *Attribute Filtering (8 instances)*, a method involving the elimination of less relevant options based on personal preferences. As one participant put it, *"First I removed any patterns because I don't wear patterns usually, then looked closer at the solid colours only."* This strategy allowed for a more focused exploration by narrowing down the choices.

Along with these approaches, considerations of *Product Form (24 instances), Fit (37 instances), and Function (19 instances)* also played a critical role in the decision-making process. Participants made specific comments about the aesthetic aspects, as captured in the quote: *"I will first decide what the clothing looks like, then think about the materials and fabrics that would go with this style, and then proceed to further associate it with my existing clothes at home."* Similarly, the fit of the product was an important consideration, particularly for the study case of tailored shirt of how it complemented the individual's body type, as expressed by a participant: *"I do have curves, so I like fitted shapes, but since I was also thinking of this as a casual shirt, it's nice to have some space and volume in the fit."* The functionality of the product also played a significant role, with participants considering practical aspects, such as in the statement: *"I think of its certain functionality. I think we can put a square towel if we need it. Then when the clothes are very transparent, the pocket can cover it."*

5.5.6 Understanding the Customisation Design Process

The study further reveals how users navigate through their configuration journeys in a nonlinear and adaptive manner. A notable theme observed was the tendency to *Change in Direction (16 instances)* during the process. This was often characterised by shifts from casual to formal styles or vice versa, reflecting emerging preferences. For instance, one participant noted, *"I started laidback but moved more business-formal realizing that aesthetic suits my professional identity more."* This illustrates how users' initial concepts can evolve as they engage with the task. Another significant observation was the tendency to *Revisit and Adjust Previous Selections (9 instances)*. This revision often occurred when users identified a misalignment between their initial vision and the actual implementation. One participant exemplifies this: *"Seeing the overall shirt, I decided the accent colour was too loud, so I*

toned it down." These examples illustrate a dynamic and ongoing process of adjustment, where users consistently refine their choices in response to changing insights and preferences. These adaptive approach in the customisation process is closely linked to decision-making strategies. Users engage in an open-ended exploration to identify misfits and re-adjust their choices. Detailed comparisons are made to pinpoint specific areas for refinement, and a holistic integration of vision prompts broader adjustments.

Central to the customisation design process is the role of mental imagery. The study identified two key phases: Pre-Task and Post-Task Imagery. During the *Pre-Task Imagery* phase *(14 instances)*, participants form initial mental images and design ideas before starting the task. This phase is critical for setting the groundwork for customisation, as illustrated by a participant who reconsidered their colour choice upon visualising themselves: *"Initially, I thought about white, but when I put on white, I felt like a hotel waiter. So, I thought choosing a slightly darker colour might be better."* This example underscores the importance of mental visualisation in refining initial ideas. In contrast, the *Post-Task Imagery* phase *(13 instances)* involves reflecting on the designs after completion. Participants evaluate their outcomes and consider further modifications, as highlighted by another participant: "*In the final step, I thought the design looked pretty good. I even reconsidered if long sleeves might look better, so I went back to check that option."* This phase shows how task completion influences participants to review and potentially revise their initial concepts, demonstrating the dynamic and evolving nature of mental imagery throughout the creative process.

5.5.7 User Perceptions and Satisfaction

In the analysis of user satisfaction within the customisation process, the study highlights two main areas: Design Satisfaction and Process Satisfaction. *Design Satisfaction (19 instances)* refers to the users' feedback on their satisfaction with the final customised product. An example is illustrated by a user's reaction to the outcome of their design, *"I didn't expect the blue sleeves to turn out the way they did – the design makes it resemble formal women's workwear."* This indicates the variety of responses users had towards the final aesthetic and functional aspects of their customized products. *Process*

Satisfaction (11 instances), on the other hand, deals with users' experiences during the customisation journey. Many found pleasure in the creative control afforded by the process, as one user expressed, *"I enjoyed being able to choose every detail and make something unique."* This highlights the importance of the customisation experience itself, not just the end product.

While most users expressed moderate to high satisfaction with both their customised designs and the customisation process, several pain points emerged. *Choice overload (9 instances)* was a significant issue, where an abundance of options led to decision paralysis. One participant stating, "*Too many fabrics made it feel overwhelming and exhausting to review them all in detail."* Additionally, some revealed Knowledge Gaps *(8 instances)* as a barrier, where users struggled with understanding specific terms or functionalities. As one participant mentioned, *"I didn't understand the descriptions differentiating the back seam choices."* This indicates a need for clearer, more accessible information. Furthermore, some participant pointed out System Constraints *(14 instances)* in the process, particularly in terms of navigation flow and interface design. One feedback, *"Being unable to toggle between zoom-in and zoom-out views disrupted my sense of the holistic vision,"* highlights the need for more adaptable and user-friendly interfaces.

5.6 Further Analysis: Mental Imagery Distribution

The participants reported various mental images. Previous studies on product evaluation in consumer research categorised mental images on the usage scenario as either 'memory-focused visualisation and imagination-focused visualisation' (MacInnis and Price, 1987) or 'self-related visualisation and other-related visualisation' (Dahl and Hoeffler, 2004). However, using these methods to classify mental images may create a significant imbalance and fail to cover all seven distinct types of visualisations identified in the study. Given the research context of product configuration, where mental images are triggered in multiple steps and serve different purposes in responding to product attributes, this study proposed a new categorisation of types of mental imageries utilised by the user:

***1. Product-related visualisation*:** This consists of mental images that consider details of the product's aesthetic or appearances, such as the colours or texture of the material. This type of mental image usually does not involve the user but focuses on the product itself.

***2. User-related visualisation*:** This involves mental images of a user's direct interaction with the product, including self or others. Take for example the visualisation of a person wearing a shirt. Such mental images provide the evaluation of the fitness of a product to the user's personal preferences.

3. Scenario-related visualisation: This is the visualisation of product usage in a specific scenario. Mental images in this category would include the surrounding environment, for example, which occasion to wear the shirt for or the overall styling.

Meanwhile, a consistent pattern was found in the decision-making process of the participants. Users utilised similar mental images among the product's configurable features under the same category or product characteristic. These configurable attributes can be categorised based on the fundamental product characteristics of form, fit and function and expanded from the study findings into the following *(Table 5-2).*

Table 5-2: Configurable Product Attributes

Product Attribute	Definition	Examples on Shirt
Materials	Determine which materials are appropriate for the product	Fabric
Aesthetic Features	Features can affect the product's apparent usability	Collar, Cuff
Functional Features	Features can affect the product's usability but not aesthetic	Back Yoke, Bottom Cut
Minor Details	Less visible aesthetic details that can't affect product usability	Buttons, Threads

Based on the identified decision-making process and the three types of mental imageries utilised by the user, this study proposed a computational method to measure the cognitive effort invested by a user in mental imagery during the configuration process. A 15-item checklist was designed to analyse the interview transcriptions (See *Table 5-3*). Three dichotomous questions were used to identify which of the three types of mental imageries was utilised by the user during the configuration of product attributes. The results were calculated by the numbers of 'yes' (1) and 'no' (0) on the checklist. Total scores, indicating a user's cognitive effort investment in mental imagery, range from 0 to 15, with a

higher score indicating more mental images was triggered in the user's decision-making process, therefore, a greater amount of cognitive effort was invested in mental imagery when configuring the product. The range of the score from the data collected in the study spanning from the lowest score of 7 to the highest of 13. The average (mean) score is 9.81, and the standard deviation (SD) is 1.83. The following is a breakdown of what the scores might indicate:

Table 5-3: Mental Imagery Utilisation Checklist

Materials		
Did the participant utilise product-related visualisation?	Yes []	No []
Did the participant utilise user-related visualisation?	Yes []	No []
Did the participant utilise scenario-related visualisation?	Yes []	No []
Aesthetic Features		
Did the participant utilise product-related visualisation?	Yes []	No []
Did the participant utilise user-related visualisation?	Yes []	No []
Did the participant utilise scenario-related visualisation?	Yes []	No []
Functional Features		
Did the participant utilise product-related visualisation?	Yes []	No []
Did the participant utilise user-related visualisation?	Yes []	No []
Did the participant utilise scenario-related visualisation?	Yes []	No []
Minor Details		
Did the participant utilise product-related visualisation?	Yes []	No []
Did the participant utilise user-related visualisation?	Yes []	No []
Did the participant utilise scenario-related visualisation?	Yes []	No []
Review		
Did the participant utilise product-related visualisation?	Yes []	No []
Did the participant utilise user-related visualisation?	Yes []	No []
Did the participant utilise scenario-related visualisation?	Yes []	No []

- 0-5 (Low investment): Scores in this range suggest a minimal use of mental imagery in the decision-making process. Users with these scores may find it challenging to extensively use mental imagery for configuring product attributes or might not rely heavily on visual processes.
- 6-10 (Moderate investment): These scores indicate a moderate level of investment of cognitive effort in mental imagery. Users in this bracket likely utilise mental imagery to a certain extent in their decision-making process, balancing between visualising product attributes and other forms of thinking.

- 11-15 (High investment): High scores reflect a significant reliance on mental imagery. Users scoring in this range extensively use visual or imaginative processes for configuring product attributes. They likely have a strong ability to visualise different aspects of the products vividly in their minds.

The study conducted exploratory analyses comparing participants' total score on cognitive effort investment in mental imagery, with results from the VVIQ, the SUIS and the confidence and satisfaction of the participants with the design outcome. The study found high positive correlations were reported between users' cognitive effort investment in mental imagery and their satisfaction and confidence with the digital design outcome (See *Table 5-4*). Each participant was asked two five-scale questions at the end of the interview to determine their satisfaction and confidence with their digitally customised item. Data revealed that participants with higher satisfaction with their design also had higher confidence that their customised item would meet their needs and preferences. The results also revealed that users who invested more cognitive effort investment in mental imagery in the process positively influenced their satisfaction (r=0.534, p<.01) and confidence (r=0.708, p<.001) with the digital design outcome. However, no correlations were found between participants' cognitive effort investment in mental imagery during the configuration process and their VVIQ (r=0.076) and SUIS scores (r=0.051). This outcome could indicate that compared to users with relatively low mental imagery ability or usage tendency, users with higher abilities or a higher tendency to utilise mental imagery unnecessarily invest more effort in mental imagery when evaluating the product in the virtual environment.

Table 5-4: Correlations Among Variables

	CEMI	VVIQ	SUIS	DC	DS
Cognitive Effort in Mental Imagery	-	0.076	0.051	0.708***	0.534**
VVIQ		-	0.476**	0.194	0.307
SUIS			-	-0.029	0.098
Design Confidence				-	0.590***
Design Satisfaction					-

Note. N = 31. CEMI = Cognitive Effort in Mental Imagery. DC = Design Confidence. DS = Design Satisfaction.

*p < .05; **p < .01; ***p < .001

The study compared the three types of mental imageries utilised by users in the configuration process *(Figure 5-3)*. User-related visualisation was the most widely triggered mental image. The data indicated that for 18 of the 31 participants, most of their mental images during the configuration process were user-related, which on average took 36.6% of the user's total cognitive effort investment in mental imagery. This was the most utilised mental image for four out of five configurable attributes, with the exemption of product details. Meanwhile, the result indicated that users preferred product-related visualisation when assessing attributes related to minor product details. Scenario-related visualisation was the least utilised mental imagery, though it still took 29.2% of the total cognitive effort investment in mental imagery on average. Overall, most participants triggered all three types of mental imageries in their decision-making process, and there were only two cases where the participants predominantly utilised two types of mental images.

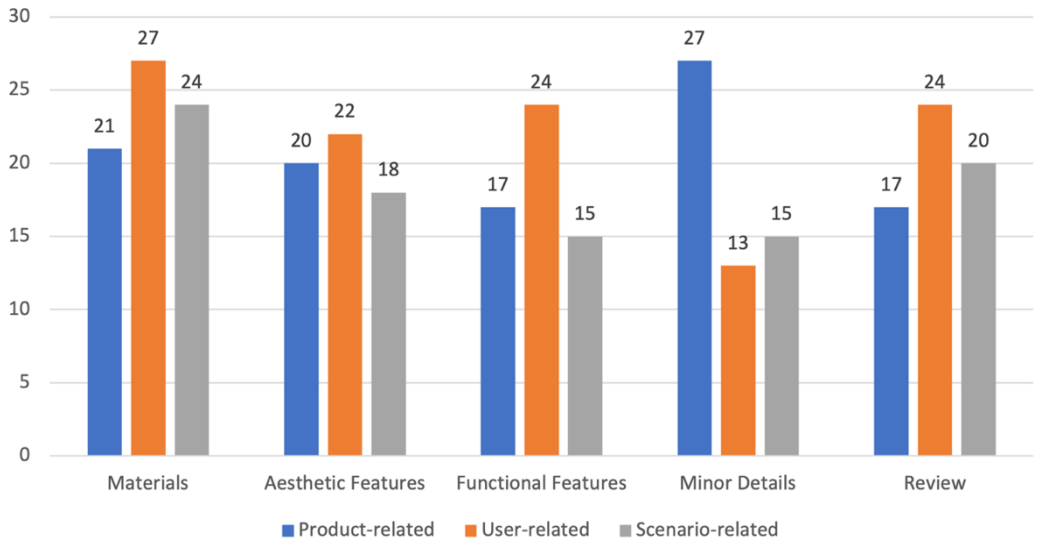


Figure 5-3: Participants' Mental Imagery Distribution in the Customisation Process. N=31.

5.7 Development of the Cognitive Effort Investment in Mental Imagery Measure

Based on the findings from this study, we propose a new measure for cognitive effort investment in mental imagery as a design support tool for digital product configurators. This measure represents the cognitive effort invested by users in mental imagery during the product configuration process.

Format and Content: The cognitive effort investment in mental imagery is conceptualised as a quantifiable measure, presented as a 15-item checklist:

Please consider the following five stages in your decision-making process:

1. **Materials:** Choosing the materials for the product.
2. **Aesthetic Features:** Deciding on the product's look, such as colour and design.
3. **Functional Features:** Determining how the product will work.
4. **Minor Details:** Adding the final small touches to the product.
5. **Review:** Looking over the completed design before finalising it.

These questions will be repeated for each stage of the configuration process:

1. **Product-related Visualisation:**
   Did you have any mental images that only included the product itself?
   Yes [ ] No [ ]
2. **User-related Visualisation:**
   Did you have any mental images of yourself using the product?
   Yes [ ] No [ ]
3. **Scenario-related Visualisation:**
   Did you have any mental images of yourself using the product in specific situations?
   Yes [ ] No [ ]

This checklist assesses the utilisation of three types of mental imagery (product-related, user-related, and scenario-related) across five stages of the configuration process (Materials, Aesthetic Features, Functional Features, Minor Details, and Review). It's important to note that this measure can be adapted based on the specific product type and stages of the configuration process being examined.

Inputs and Development Process: The measure was developed primarily using data from qualitative contextual inquiry into users' decision-making processes during product configuration. The development process involved:

- Identifying patterns in users' mental imagery utilisation through qualitative analysis.
- Categorising these patterns into three distinct types of visualisations.
- Mapping these visualisations onto the stages of the configuration process.
- Creating a scoring system to quantify the cognitive effort invested in mental imagery.

Application: This measure can be used by designers and researchers to:

- Evaluate the effectiveness of product configurators in engaging users' mental imagery.
- Identify areas in the configuration process where users struggle to visualise the product.
- Guide the development of configurator features that support different types of mental imagery.

This design support tool provides a structured approach to understanding and optimising users' cognitive processes during digital product customisation. By focusing on cognitive effort investment in mental imagery, configurator designers can create interfaces that better support users' mental imagery processes, potentially leading to increased user satisfaction and more successful customisation outcomes.

5.8 Conclusions

In assisting users to become part of the product development process, this study investigated the digital product customisation process from a novel perspective, emphasising the efficacy of the decision making involved in the configuration process, instead of the quality of the digital experience. The research used mental imagery as an independent construct to investigate the users' interaction with the digital product, separating it from the effort invested by users in system usability. The work also showed that the cognitive effort in mental imagery could provide a deeper understanding of how mental imagery is used to evaluate products in the virtual environment. In addition to providing a theoretical foundation for cognitive effort investment on mental imagery, users' mental images identified in this study could also direct insight into how to communicate with users more accurately.

The study however highlighted an interesting lack of correlation between participants with a high level of image vividness, and the amount of effort invested in the process. This highlights that different strategies are being used by different users to conduct the transposition from digital to physical. Knowing how users utilise mental imagery could more reliably filter visual materials that respond to the user's needs and preferences, will support the creation of a more user-centred experience, and one that will enable the development of products more likely to be as expected – and therefore enjoyed, utilised and kept for a longer time.

From the mental images reported by the participants that involved the transposition of virtual products to the physical environment, the research identified three types of mental imageries to define a user's cognitive effort investment in mental imagery, namely product-related, user-related and scenario-related visualisation. This study further proposed that the cognitive effort in mental imagery could be quantified. The exploratory data analysis revealed a positive correlation between users' cognitive effort investment in mental imagery and their confidence and satisfaction with the digital design outcome. The results from this study provide a theoretical foundation for the following study, to investigate how cognitive effort investment in mental imagery influences user decision-making. By comparing different product types and configuration methods, the next step would be developing a systematic method of measuring cognitive effort investment in mental imagery. Such a method would enhance our understanding of how users utilise mental imagery in a virtual environment when evaluating a product. This understanding is crucial for providing guidance on implementing cognitive effort investment in mental imagery to improve the digital product customisation process.

6. STUDY THREE

COGNITIVE EFFORT INVESTMENT IN MENTAL IMAGERY: UNDERSTANDING TRANSPOSITIONAL EFFORT IN DIGITAL PRODUCT CONFIGURATION

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6.1 Introduction

Building upon the insights gained from the previous two studies, which explored users' engagement and interaction in the online garment customisation process (Study 1) and investigated the role of mental imagery in the customisation experience (Study 2), this third study aims to further deepen our understanding of the cognitive processes involved in digital product configuration. Study 2 revealed that mental imagery plays a crucial role in users' evaluation and decision-making during the customisation process, with users employing different types of visualisations (product-related, user-related, and scenario-related) to guide their choices. Moreover, the findings suggested that expending more cognitive effort in mental imagery could positively influence users' confidence and satisfaction with the designed outcome.

While Study 2 provided valuable insights into the importance of mental imagery in the customisation experience, it also raised new questions about the detailed structure and measurement of the cognitive effort invested in this process. To address these questions and build upon the previous findings, Study 3 introduces a new construct named Transpositional Effort, which represents the cognitive effort invested by users in utilising mental imagery during product configuration – an act which enables them

to transpose what they are seeing in the virtual environment and imagine how it might suggest in a physical environment. The concept of Transpositional Effort is grounded in the understanding that product configurators must ensure that the choices made by users in the digital space accurately reflect their real-world expectations. In the absence of physical interaction with the product, users rely heavily on mental imagery to guide their decisions and evaluate the digital designed outcomes of their customisation choices. However, the cognitive effort required to generate and manipulate mental images during this process can vary significantly between individuals which requires a deeper understanding.

Meanwhile, building upon the prescriptive study (study two)'s proposed measure for cognitive effort investment in mental imagery, the third study, a descriptive study II, aims to further refine and validate this design support tool. In this phase, the study will evaluate the effectiveness and applicability of the measure in real-world scenarios, gathering empirical evidence to support or modify its structure and content.

By introducing and validating the construct of Transpositional Effort, Study 3 aims to answer the following research question: **How does the cognitive effort invested in mental imagery during product configuration, conceptualised as Transpositional Effort, influence users' satisfaction with the configuration process and the digital designed outcome, and how can this construct be effectively measured and validated in the context of digital product customisation?**

This addresses the third research objective of this thesis “to propose a new construct to investigate and further understand users' cognitive effort in mental imagery during the digital product configuration process”. The study also incorporates different starting points to investigate how providing users with pre-designed starting points could influence their decision journey, as compared to users starting with a blank slate. Study 3 represents the capstone of the research conducted in this thesis, integrating the insights from the previous two studies and introducing Transpositional Effort to provide a more holistic and detailed understanding of the cognitive dimensions of digital product customisation, thereby setting the stage for future research and development in this field.

6.2 Development of Research Hypotheses

This research focuses on configurators employed in the B2C context. The prevalent approach for these contexts is parameter- based selection, which accounts for 97% of configurators (Gerards *et al.*, 2011). This method allows customers to choose product specifications or features from a predefined set of options (Hildebrand, Häubl and Herrmann, 2014). However, when products have very complex structures - such as numerous customisable features, add-ons, accessories, colour and styling options - it can become cognitively demanding for users to evaluate all the possibilities (Nettelhorst *et al.*, 2017). This choice overload can cause stress, confusion, and perceived difficulty in making the optimal choice. Consequently, users may put off the configuration process, make a selection but later feel regret over potential alternatives, or give up on the process entirely out of being overwhelmed by the options (Swait and Adamowicz, 2001; Mosteller, Donthu and Eroglu, 2014; Nettelhorst *et al.*, 2017). To address this, recent research has presented solutions such as Customisation via Starting Solutions (CvSS) (Hildebrand, Häubl and Herrmann, 2014). CvSS, in particular, aims to reduce decision complexity by providing a pre-specified product inspiration, without compromising users' autonomy. Empirical evidence suggested that CvSS can increase satisfaction, enhance mental simulation of product use, and enable the purchase of more feature-rich and higher-priced products (Hildebrand, Häubl and Herrmann, 2014).

This study seeks to compare the real-life experiences of users with two predominant configurator types: the parameter-based approach and CvSS. Specifically, these represent distinct starting points in the configuration process: the parameter-based approach begins with a blank slate, while CvSS introduces users to a pre-designed inspiration (Hildebrand, Häubl and Herrmann, 2014). Through this comparison, the study aims to validate existing empirical findings, and understand more about the decision-making journey and how configurator design influences the user’s experience and utilisation of mental imagery.

The efficacy of the digital product configuration process will be assessed in this study using two key constructs: users' satisfaction with their digital design outcomes (Product Satisfaction) and their

experiences during the decision-making process (Decision Satisfaction). Building upon prior research suggesting that CvSS can enhance users' mental engagement and satisfaction with product choices (Hildebrand, Häubl and Herrmann, 2014), the study formulates the following hypothesis:

H1: *Users given a CvSS configurator will have higher product satisfaction and decision satisfaction than those using a parameter-based configurator.*

H2: *On average, users given a CvSS configurator will invest more cognitive effort in mental imagery than those using a parameter-based configurator.*

Meanwhile, traditional views suggest that people should minimise cognitive effort. However, Park and Hill (2018) indicated that users should devalue the cognitive effort minimisation goal and spend more cognitive effort in some situations, especially when the invested cognitive effort may reduce uncertainty about a product. Therefore, the study hypothesises a positive relationship between users' cognitive effort investment in mental imagery and the efficacy of the process:

H3: *Users' cognitive effort investment in mental imagery positively related to product satisfaction and decision satisfaction.*

6.3 Measuring Cognitive Effort Investment in Mental Imagery

Based on the user's decision-making process, this study aims to introduce a computational method to quantify a user's cognitive effort investment in mental imagery during the product configuration process. To bolster the generalisability of the study's result, this study proposes a universal method to divide the user's decision-making process into two distinct phases:

Design phase: This phase unfolds before the completion of the design.
Review phase: This phase initiates once the user has finalised the design.

A user's cognitive effort investment in mental imagery in the configuration process can then be computed by the total cost of deciding on both decision-making phases. The cost of deciding on each decision-making phase is represented by the user's cognitive effort investment in mental imagery, and, based on the categorisation of the three types of mental imageries utilised: product-related, user-related, and scenario-related visualisation. Using these, user's cognitive effort investment in mental imagery can be computed as:

$$PR(v+e+q) + UR(v+e+q) + SR(v+e+q)$$

where,

PR = Product-related visualisation

UR = User-related visualisation

SR = Scenario-related visualisation

v = Imagery vividness

e = Imagery ease

q = Imagery quantity

Three factors are adopted from established research and taken into account here when computing the cost of deciding: Imagery vividness, ease, and quantity (Fitzgerald Bone and Scholder Ellen, 1992). Vividness refers to the clarity of the mental imagery evoked, indicating the user's ability to form a solid or distinct impression of the scene. Established research recognises vividness as a key dimension of imagery, highlighting the qualitative aspects of the evoked imagery (Cui *et al*., 2007). Ease, on the other hand, addresses the level of difficulty encountered by the user in generating mental images of the scene. The simplicity or challenge in generating imagery has also been identified as a notable dimension in prior studies (Babin and Burns, 1998). Quantity, meanwhile, refers to the number of distinct mental images or elements a user can generate and maintain in their mind simultaneously, reflecting the volume or richness of their mental imagery (Fitzgerald Bone and Scholder Ellen, 1992).

6.4 Study Design and Methodology

To test the hypotheses, this study uses a mixed-method approach to both quantitively (n=400) and qualitatively (n=212) build a larger understanding of mental imagery and cognitive effort in this context. Participants were recruited through online platforms and asked to use an online configurator to design a customised product. They then were asked to complete an online questionnaire including both quantitative measures and open-ended questions about their experiences with the customisation process, and of how they utilised imagery and effort throughout. Full details of the study, including *Participant Information Sheet*, *Survey Questionnaires*, and *Codebook*, are included in ***Appendix III: Study Three***. All participants participated voluntarily and provided their informed consent to participate in this study. The study was approved by the Imperial College London Research Governance and Integrity Team, register number **22IC7864**.

6.4.1 Configurator Selection

An established configurator will be essential for simulating a typical digital customisation process. In the search for an appropriate configurator, several characteristics were considered. The configurable item should be common in daily life and appropriate for the general consumer audience. The configurator should function with smooth user flow and clear navigation with high-quality, realistic product simulation materials to eliminate potential user experience issues that could negatively impact the configuration process. Established product configurators from various industries were considered, including apparel, electronics, office merchandise, motor vehicles and interior design. Several configurator design agencies from Asia, Europe and North America were also contacted for potential collaboration or technical support. The selection process identified the four characteristics which make the configurator suitable for the study: quality of the product simulation, structured product configurable options, target market and product familiarity.

The footwear configurator developed by Nike (nike.com) (nike.com, no date) was selected as one of the most appropriate configurators for this study *(*

Figure 6-1*)*. Nike is one of the most recognised brands internationally, targeting a broad market segmentation. Meanwhile, footwear is a common consumer good with high accessibility. The configurator provides a visualised configuration process and is believed to represent up-to-date digital customisation with photo-realistic Three-Dimensional (3D) product simulation and a series of comprehensive options responding to product aesthetics and materials, including 13 configurable components and many equipped with more than 10 variable options. The large number of configurable components allows users to come up with a unique colour combination. Additionally, the Nike configurator provides users with many pre-designed inspirations to start from, which fits the configuration approach of CvSS. In fact, Nike was identified as one of the first industry application cases for providing users with a starting point for product customisation (Randall et. al., 2005).

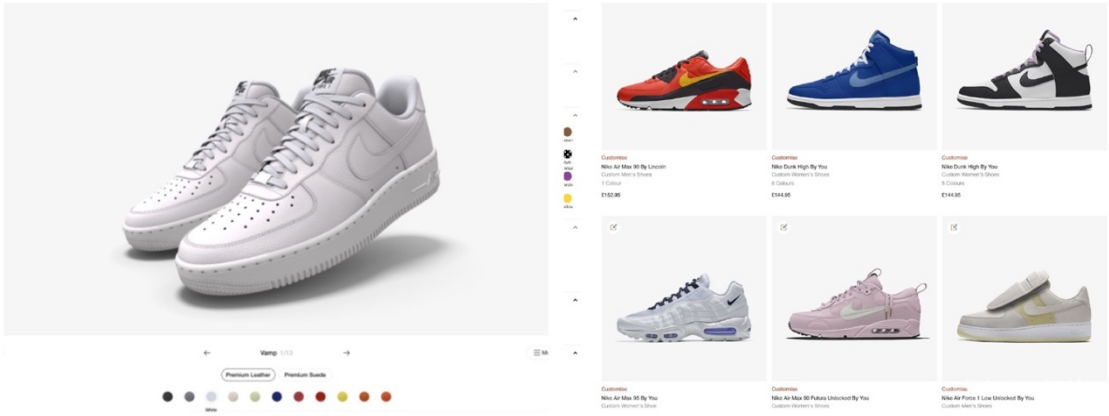


Figure 6-1: Trainer Configurator: Nike by You (https://www.nike.com/w/new-nike-by-you-shoes-3n82yz6ealhzy7ok)
Left: Parameter-based (starting with blank white design) Right: CvSS (starting with a pre-design inspiration)

The Tailor Store Sweden AB's shirt configurator (tailorstore.co.uk) (Tailorstore.co.uk, no date) was selected as the second configurator *(Figure 6-2).* It offers a visually based configuration process and is considered to be a state-of-the-art digital customisation solution. The configurator caters to customers' needs and preferences with photo-realistic product simulation and a broad range of options, especially in terms of fabric, including various colours and patterns. It provides 10 configurable categories with 28 sub-options, providing a comprehensive range of customisation choices. Meanwhile, the configurator also offers users pre-designed items as starting points for inspiration.

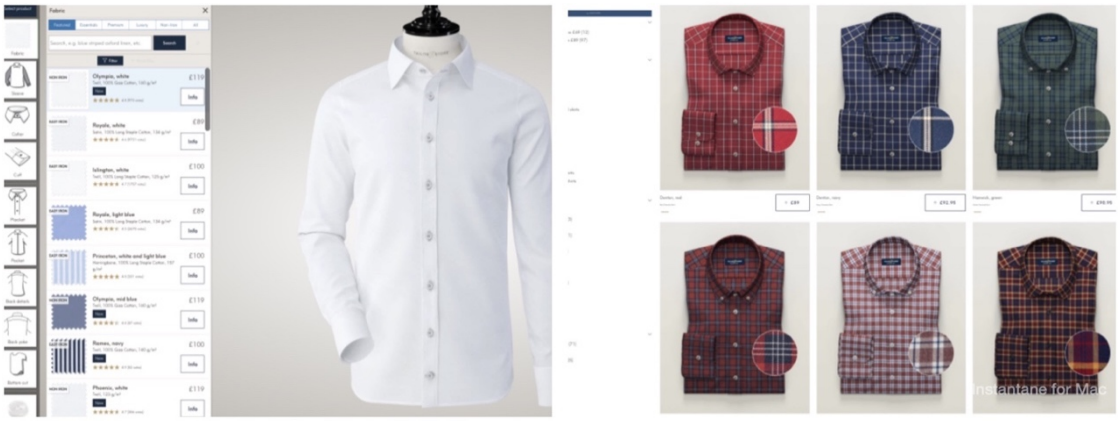


Figure 6-2: Shirt Configurator: Tailor Store (https://www.tailorstore.com/shirt-designer)
Left: Parameter-based (starting with blank white design) Right: CvSS (starting with a pre-design inspiration)

6.5 Questionnaire Development

6.5.1 Quantitative Method

A questionnaire will be included to systematically measure a user's cognitive effort investment in mental imagery during the task of digital product customisation. Other dependent variables - product satisfaction and decision satisfaction - will be introduced in the questionnaire by adopting measures from established research. Cronbach's alpha will be used to assess the developed scale's internal consistency. Pearson correlation coefficients will be applied to analyse the relationship between participants' usage of transpositional effort and their reported efficacy of the process and, thus, verify further the research hypotheses.

The measures for the variables used in the present study were adopted from established research in the fields of product customisation and consumer decision-making. These measures were tested and have demonstrated appropriate reliability in previous research, ensuring the validity of the results obtained in this study. The cost of cognitive effort investment was evaluated using a three-item scale by Hildebrand, Haubl, and Herrmann (2014), which was adapted from Escalas's (2004) Mental Simulation Scale. This scale assessed the factors of imagery vividness, ease, and quantity and showed

good reliability across five studies with a coefficient alpha value of 0.79-0.93. Decision satisfaction was measured using three items adopted from Kim et al. (2020) and Mosteller, Donthu, and Eroglu (2014), with a coefficient alpha value of 0.90-0.93. Finally, the variable of product satisfaction was measured using three items adapted from Homburg, Koschate, and Hoyer (2006) and Hildebrand, Haubl, and Herrmann (2014), with a coefficient alpha value ranging from 0.76 to 0.91.

To ensure adequate statistical power to detect a significant correlation between the variables of interest, a power analysis was conducted. This utilised the Spearman's correlation test, aiming to detect the smallest effect size of interest ($\rho=0.2$) at a power ($1 - \beta$) of 0.8, and a significance level (α) of 0.05, based on a two-sided test (Ballou *et al.*, 2022). The power analysis indicated a minimum unadjusted sample size of 198 for the study. Given the design, which divided the data into two groups for comparison, the required total sample size was subsequently doubled to 396. The final valid sample size in the study was 400, which comfortably exceeding this requirement. This ensured the study was adequately powered to detect meaningful correlations at the expected level.

6.5.2 Qualitative Method

Data for the qualitative analysis consisted of the answers to the five open-response questions. Participants were first asked (1) about their design decision process, and how the exploration of various options influenced their satisfaction with the final design. They were then questioned (2) if there were moments when they felt overwhelmed by the number of choices available, and how this shaped their overall experience.

Further inquiries were made (3) about the effort they invested in visualising their product, with a focus on moments that were particularly challenging. The next question (4) explored how this effort impacted their satisfaction with the final design, and if increased effort in visualisation might have influenced their satisfaction. Finally, an examination was made into (5) how starting with a blank white design or inspiration affected their decision-making process. They were asked to speculate if their experience would have been different had they started with a white design or an inspiration. These structured

questions were designed to generate qualitative data to support the findings from the quantitative analysis.

6.5.3 Participant Recruitment and Experience

The participants were recruited using Prolific.co(Prolific, no date) in exchange for a small fee. Prolific, similar to Amazon Mechanical Turk (MTurk)(Amazon, no date), is a crowdsourcing platform dedicated to online participants recruitment for research purposes. It has a successful track record in various research areas such as economics, psychology, human-computer interaction, and design (Aguinis, Villamor and Ramani, 2021). In addition, Prolific places a strong emphasis on the ethical treatment of participants through its detailed rules and regulations. The platform also has a user-friendly interface and a comprehensive set of features to pre-screen participants. To take part in the study, participants must be 18 years of age or older and fluent in English.

The questionnaire was administered using Qualtrics (Qualtrics, no date) and included an introduction to the study and detailed instructions for the configuration task. Participants were directed to the corresponding configurator via an external link and were required to return to the questionnaire after completing the design task. The validity of the task was assessed using Qualtrics' embedded timer function, which recorded the amount of time the participant spends on the configuration task. Participants were also asked to upload the saved file or a screenshot of their completed design as proof of task completion.

The questionnaire, which follows the configuration task, measures cognitive effort investment in mental imagery and other research variables. The questionnaire's design has been optimised to minimise the number of questions the participant sees and allow for skipping questions based on their answers, reducing the potential for reduced attention due to repetitive questions. At the end of the questionnaire, each participant was assigned a unique code to be entered on the recruitment platform Prolific to confirm their completion of the study.

This study will also conduct a comparative analysis between parameter-based and CvSS configuration approaches in the product configuration process. Half of the participants will be assigned to the parameter-based selection, where they will start configuring from a blank white sneaker, or white shirt, and go through the available configurable options. The other half of the participants will start by choosing one sneaker or shirt from a number of specified designs as the inspiration and their starting point, and they will configure the product by refining the inspiration they choose, with the same configurable options available for parameter-based selection. All participants from the two approaches answered the same survey questionnaire to verify the developed scale and further reveal the decision strategies of the users and the differences in their effort investment between the two approaches.

The study aimed to recruit four hundred participants (N=400) for the entire study, and the participants were equally divided (N=100) and randomly assigned to one or the other configurator (Nike or Tailor Store) and one or the other configuration approach. Among these, half of the participants under each condition (N=50) were invited to further answer qualitative questions. The time required to complete the study was around 30 minutes, including the configuration task and questionnaire, and around 45 minutes for participants answering five additional qualitative questions. Each participant received £6 for participating.

6.6 Pilot Study

To determine the appropriateness of the study design, a pilot study was conducted. This enabled initial validation and refinement of:

- How participants would be recruited.
- How participants would understand the questionnaire.
- How participants would utilise mental imagery in the configuration process.

This pilot study was conducted using contextual inquiries to gather more information about the participants' decision-making process during digital product customisation. Ten participants (n=10) were recruited through MTurk and Prolific and asked to join a Zoom (Zoom Video Communications, no date) session where they would design their Nike trainers while sharing their screens with the researcher. To avoid interrupting their decision-making process, the study adopted a passive inquiry approach, where the participants were allowed to complete their tasks without engagement from the researcher, and all questions were asked after they finished. The participants were located in the United Kingdom and screened for English proficiency. The interviews were audio-recorded and transcribed.

After completing the design task, the participants were asked if they utilised any mental images during their decision-making process. All ten participants answered affirmatively and were then asked to describe the details of their mental images. To uncover the habitual and unconscious mental imagery details, questions were asked using visual aids based on the categorising types of mental images of product-related, user-related, and scenario-related visualisations proposed in previous studies.

The pilot study found that different mental Imagery strategies may be used during the review phase after the design was completed. Half of the participants reported using different mental images during the review phase compared to the design phase, and generally, less mental imagery was used in the review phase. Eight out of ten participants reported using product-related visualisations, five reported using user-related visualisations, and two reported using scenario-related visualisations.

All participants reported that the product simulation was of high quality and realistic and that the configuration process was enjoyable and interesting. One participant mentioned that even though *“not the best at seeing pictures and thing"*, the simulation was still able to help them *“have a rough idea of how I wanted the shoes to look”*. The qualitative data collected through the pilot study confirmed that mental imagery plays a central role in user'' decision-making process and that even those with weaker mental imagery abilities still benefit from transposing the digital product to a physical environment during the configuration process.

The pilot study made several changes to enhance the validity of the study design. Initially, participants were recruited from both MTurk and Prolific. Despite pre-screening requirements for participants located in the United Kingdom, the study discovered that some participants from MTurk were using Virtual Private Network (VPN) to alter their geographic location. Additionally, the recruitment process required participants to sign up for a voice Zoom session at a specific time slot, but some participants requested changes or failed to show up. In contrast, participants from Prolific were able to contact the researcher through an embedded messaging function, reducing the likelihood of participants not showing up.

Based on the feedback from a participant with extensive experience in UX research on crowdsourcing platforms, and their recommendation of Prolific, the decision was made to recruit all main study participants from Prolific. This was due to the higher quality of participants and the user-friendly interface and features. The questionnaire was also revised based on the participants' experience and feedback from the pilot study. Clear and detailed instructions were added to guide participants in accessing the configurator page and completing the task independently. The text description of mental image examples was revised for greater clarity and visual aids were added to questions regarding mental imagery utilisation. The pilot study confirmed that the questionnaire flow was tested and that participants were able to complete the study on their own, with all the introductions, instructions, and descriptions being clear and easy to follow.

6.7 Data Analysis

A total of 512 participants clicked the link to start the questionnaire. Out of this number, 460 completed the entire study task and questionnaire. Among them, 21 failed the attention check, and 12 didn’t complete the study on the correct device, leading to their exclusion from the final sample. Additionally, 27 participants scored 0 when measuring cognitive effort investment in mental imagery, indicating that there was no mental imagery utilised in the product configuration process. This represented 6.32% of the sample population. As the study's aim was to investigate the cognitive effort investment in mental imagery, participants who specified that they didn’t utilise mental imagery were excluded from the

quantitative data analysis (n=12), but their answers to qualitative questions were included in the final sample to help build a more comprehensive view of different experiences.

The final quantitative sample included data from 400 (n=400) participants with a mean age of 33 years, 196 identified as female and 204 as male. The final qualitative sample included responses from 212 (n=212) participants with a mean age of 33 years, 112 identified as female and 100 as male.

6.7.1 Validation

All measures used in the study reported a good level of reliability (*Table 6-1*). The users' investment in transpositional effort - cognitive effort investment in mental imagery, as well as users' product satisfaction and decision satisfaction, were measured after participants completed the configuration task. The details of the survey questionnaires are available in the *Appendix III - B: Study Three – Survey Questionnaires.*

Table 6-1: Descriptive Statistics

Measures	Mean	SD	Scale Reliability (α)
Transpositional Effort	47.46	22.04	.844
Product Satisfaction	16.32	2.97	.771
Decision Satisfaction	17.72	2.42	.731
Efficacy of the Process	32.93	4.73	.802

Note. n = 400. Scale Reliability is reported as Cronbach's α.

6.7.2 Qualitative Coding

The 212 participant responses totalled 47,500 words. The qualitative data were analysed with a deductive coding cycle and an inductive second cycle. The deductive coding cycle was based on theories and constructs identified and adopted in this study, and further categorised based on the objective of each open-response question. This first coding cycle resulted in 15 codes in total, such as Effort Investment, Product Satisfaction, and Perceived Enjoyment.

In the inductive cycle, data were openly coded without a predefined set of codes, and new themes emerged along with recurring patterns from the data. There were 20 codes identified and generated during the inductive second cycle, which included subcodes such as Extent of Exploration, where participants described varying degrees of exploration, and Difficulty Making Decisions, where participants described specific challenges in making decisions. The full coding system with both deductive and inductive codes, along with further detailed descriptions, is available in the *Appendix III - C: Study Three - Codebook*.

6.8 Results

The following section reports the results. These have been split into the three key hypotheses, and each individual factor presented begins by reporting the quantitative findings, and then the qualitative findings most relevant. In this way, the qualitative findings will be reported in a more narrative format with reference to the codes and subcodes identified.

6.8.1 Efficacy of the Configuration Process

The study hypothesised that users given a CvSS configurator would have higher product satisfaction and decision satisfaction than those using a Parameter-based configurator [H1]. However, the quantitative results from this study didn't indicate a significant difference when comparing the two types of configuration processes. In fact, when breaking down the data for the specific product of Nike trainers, users with a parameter-based configurator reported slightly higher satisfaction in both the final designed product (m=17.2) and the decision-making process (m=17.67) than users with a CvSS configurator (m=16.09; m=17.51) *(Table 6-2).*

Configuration Approach	Product Satisfaction	Decision Satisfaction	Efficacy of the Process
CvSS	16.26 (2.93)	17.87 (2.19)	34.13 (4.42)
Parameter-based	16.38 (3.01)	17.57 (2.63)	33.95 (4.95)
Trainers			
CvSS	16.09 (3.05)	17.51 (2.24)	33.60 (4.54)
Parameter-based	17.20 (2.60)	17.67 (2.44)	34.87 (4.42)
Shirts			
CvSS	16.42 (2.82)	18.23 (2.08)	34.65 (4.25)
Parameter-based	15.56 (3.17)	17.46 (2.82)	33.02 (5.30)

Note. The figure represents the mean (SD). The total number of participants n=400. The number of participants assigned to each product type n=200.

Table 6-2: Descriptive Statistics – Efficacy of the Process

The results from the qualitative data reported similar findings, with no significant difference noted by participants in satisfaction with the final designed product (59 instances CvSS; 55 instances Parameter-based) or perceived enjoyment (33 instances CvSS; 32 instances Parameter-based). The qualitative findings further indicated that more people would prefer to use a parameter-based configurator (blank white starting point) compared to using a CvSS configurator (pre-designed inspiration). When asked how the type of configurator influenced their decision-making process, and if their experience would have been different if they had a different starting point, the answers could be categorised as preference for starting with a pre-designed inspiration (73 instances), preference for starting with a blank white design (99 instances), and no preference (36 instances).

In the cases where the user indicated a preference for CvSS, the study further identified three subcodes describing how starting with a pre-designed inspiration could influence to their configuration process: quick and easy process (9 instances), encourage creativity (8 instances) and overwhelming (10 instances). Participants described how a pre-designed inspiration could help them quickly identify what they want (quick and easy process): *"The inspiration is a fantastic tool to start the whole design process. It removes a lot of thinking from the process and will make the design phase quicker." (57d***622, male)*

For some participants, starting with a pre-designed inspiration would influence and encourage them to experiment more with colours and styles (encourage creativity): *"Starting with a plain white design*

*probably led me to choose the safe and familiar style I ended up with. I am not very adventurous, and perhaps if I had been given a more interesting starting point then I would have experimented a bit more with bolder colours and styles." (5ec***1f6, female)*

However, some participants directly pointed out that starting with a blank white design would be overwhelming (overwhelming): *"If I started with a plain white design, I feel like I would have got overwhelmed quickly and found it harder to make decisions." (60f***747, female)*

On the other hand, more participants indicated that they would prefer to start with a blank white design. There were three identified subcodes indicating that starting from a blank white design had influence on creating their final design: user autonomy (6 instances) and perceived ownership (4 instances) and challenging (8 instances). Some specified that they enjoyed the autonomy to create and experiment (user autonomy): *"Starting with a white design was better because it allowed me to create my own visual image of the final product. It enabled me to express my own creativity." (5ba***f70, male)*

For some participants, starting from a blank white design would allow them to create a design with which they had a sense of ownership, and which felt more original (perceived ownership): *"I think having a fresh canvas to work on lets you clearly plot out your ideas. It's also genuinely your own creation." (62a***ef5, male)*

Interestingly, some believed that starting with a pre-designed inspiration would make the decision-making process more challenging (challenging): *"It's just easier to start with a blank canvas and build from there; otherwise, your choices might clash with the design that's already on there, making it more difficult to visualise how it will all look together after you've changed the rest." (5fa***042, female)*

Finally, a number of participants (28 instances) mentioned that the type of configurator and starting point had no influence on their decision-making, with most stating that they already had a design in their mind: *"I don't think my experience would have been different starting from an inspiration, as I had an*

*idea in my head anyway which wouldn't have been any different regardless of where I started." (5cc***e88, female)*

In summary, the data from the study revealed a complex interplay between personal preference and configurator type. Despite the hypothesis and results from previous studies favouring the CvSS configurator, no significant difference in satisfaction was found compared to the parameter-based approach. This suggested that there is no correlation between the type of configurator and the efficacy of the configuration process. Instead, users' preferences for the type of configurator and starting point are subject to a wide range of personal factors.

6.8.2 Cognitive Effort Investment in Mental Imagery

The study hypothesised that users with a CvSS configurator would invest more cognitive effort in mental imagery compared to those using a parameter-based approach [H2]. However, the results showed the opposite, with higher mental imagery investment in the parameter-based group (m=50.32) than in the CvSS group (m=44.61) *(Table 6-3)*. This finding raises several interpretations about how the starting point might influence cognitive effort in mental imagery and the individual differences in mental imagery strategies.

Table 6-3: Descriptive Statistics – Transpositional Effort

Configuration Approach	Design Phase	Review Phase	Transpositional Effort
CvSS	21.67 (12.54)	24.08 (11.98)	45.74 (22.01)
Parameter-based	23.11 (12.12)	26.04 (11.96)	49.15 (21.99)
Trainers			
CvSS	18.59 (12.90)	23.30 (12.00)	41.89 (22.36)
Parameter-based	20.98 (12.81)	26.35 (11.35)	47.33 (22.06)
Shirts			
CvSS	24.75 (11.43)	24.85 (11.97)	49.58 (21.06)
Parameter-based	25.24 (11.03)	25.72 (12.60)	50.96 (21.89)

Note. The figure represents the mean (SD). The total number of participants n=400. The number of participants assigned to each product type n=200.

The quantitative data revealed that users expended more effort during the review phase (m=25.09) than in the design phase (m=22.38). This pattern was consistent regardless of the configuration approach or product type. This observation is supported by qualitative feedback from participants describing their mental imagery strategies: *"I didn't invest much effort into creating mental images of the trainers until the final stage. I have similar trainers, so I was confident they'd suit me. However, at the end, I asked myself, 'are you sure?' and validated my decision by imagining how the trainers would look and feel in my daily life." (5ec…1f6, female)*

When examining the type of mental imagery utilised, a general trend emerged: users tend to invest more effort in user-related (m=18.98) visualisation compared to product-related (m=14.70) and scenario-related visualisation (m=11.37) *(Table 6-4)*, and user-related visualisation ranks highest regardless of the configuration approach or product type *(Figure 6-3).* Users configuring shirts invested more effort in user-related (m=20.10) and scenario-related (m=15.42) visualisation than those configuring trainers (m=17.77; m=12.15) *(Table 6-5).* One participant remarked, *"I tried to imagine how they might look on their own, but most of the mental images were of them being worn by me or seen on others out and about." (5e9…b36, male)*

Table 6-4: Mental Imagery Distribution

Product Type	Product-related	User-related	Scenario-related
Trainers	14.70 (10.05) 32.9%	17.77 (10.65) 39.8%	12.15 (11.34) 27.2%
Shirts	14.75 (10.98) 29.3%	20.10 (9.49) 40.0%	15.42 (11.19) 30.7%

Note. n = 200. *The figure represents the mean (SD) Percentage distribution.*

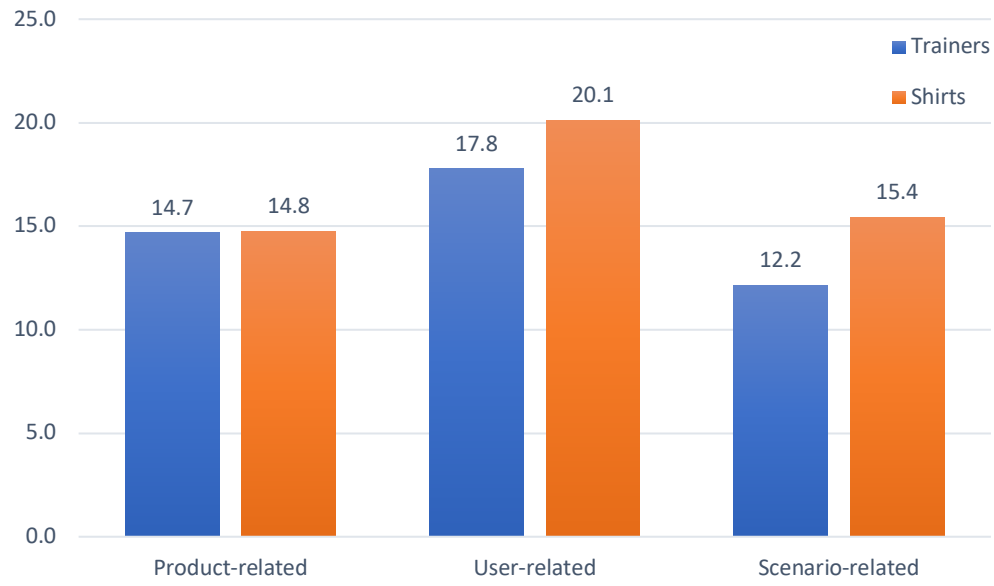


Figure 6-3: Participants' Mental Imagery Distribution in the Customisation Process, N=200.

Table 6-5: Descriptive Statistics – Visualisation Type

Configuration Approach	Product-related	User-related	Scenario-related
CvSS	14.42 (10.70)	18.45 (10.17)	12.88 (11.37)
Parameter-based	15.03 (10.34)	19.42 (10.12)	14.71 (11.31)
Trainers			
CvSS	14.07 (10.28)	16.62 (11.04)	11.20 (11.22)
Parameter-based	15.32 (9.84)	18.91 (10.17)	13.10 (11.43)
Shirts			
CvSS	14.77 (11.15)	20.28 (8.90)	14.55 (11.33)
Parameter-based	14.73 (10.86)	19.92 (10.09)	16.31 (11.02)

Note. The figure represents the mean (SD). The total number of participants n=400. The number of participants assigned to each product type n=200.

Many participants indicated that creating a mental image of the product in use wasn't challenging (79 instances). The study further found that the product simulation in the configurator could assist in forming these mental images (21 instances): *"The images on the website were vivid and clear, which helped me visualise the shoes once they had been designed." (600…852, female)*

However, several participants found it challenging to formulate mental images (42 instances); One of the reasons could be due to their inherent mental imagery capabilities: "*I am not great at using mental images. I relied mostly on the image on the screen and whether I liked it or not. I find it difficult to picture wearing anything I buy until I actually put it on." (63a***7d6, female)*

Notably, some participants mentioned they had challenges with one specific type of visualisation during their mental imagery strategy. From the feedback of participants, the study found that there was no mention of issues with product-related visualisation. However, some faced challenges when it came to user-related (13 instances) and scenario-related visualisation (8 instances). In the case of user-related visualisation: *"I never pictured myself actually wearing them until the review process, and I found that part somewhat more challenging for some reason!" (60e***aa8, female).* Meanwhile, others specified they had issues with generating scenario-related visualisation: *"I found it difficult to imagine how the shirt would fit me in different situations, such as socialising with friends and going out to restaurants." (599***5b8, male).*

Past empirical evidence suggests a high correlation between the ease of stimulating mental imagery and the number of images generated, leading researchers to typically consider these as one dimension (Fitzgerald Bone and Scholder Ellen, 1992; Babin and Burns, 1998). This study, however, discovered a strong correlation between vividness and quantity ($r=0.835$, $p<.001$) rather than between imagery ease and quantity ($r=0.344$, $p<.001$) *(Table 6-6)*.

	Ease	Vividness	Quantity
Imagery Ease	-	0.299***	0.344***
Imagery Vividness		-	0.835***
Imagery Quantity			-
Trainers			
Imagery Ease	-	0.358***	0.352***
Imagery Vividness		-	0.834***
Imagery Quantity			-
Shirts			
Imagery Ease	-	0.232**	0.320***
Imagery Vividness		-	0.833***
Imagery Quantity			-

*Note. The total number of participants n=400, each product type n=200. *p < .05; **p < .01; ***p < .001*

Table 6-6: Correlations Among Variables

In summary, the data from the study suggest that the CvSS configuration approach doesn't necessarily enhance users' mental engagement. Exploring the various types of visualisations, user-related visualisation emerges as the most prominent. However, all three visualisation types were employed by users in a relatively balanced manner, highlighting their collective significance. It's worth noting that this distribution can vary based on the product type. Furthermore, the data reveals that product simulations significantly aid users in forming mental images, especially when visualising the product. Nevertheless, some users encounter challenges in utilising these mental images. While individual abilities might explain some of these challenges, others find it difficult to utilise user-related and scenario-related visualisation without additional visual aids, suggesting potential avenues to craft practical methods for imagery support.

6.8.3 Correlation between Cognitive Effort Investment in Mental Imagery and Efficacy of the Process

The study hypothesised that users' cognitive effort invested in mental imagery is positively related to product satisfaction and decision satisfaction [H3]. In line with the initial projections, the quantitative data gathered from the study supports the hypotheses, indicating a linear positive relationship *(Figure 6-4)* between the efficacy of the process and cognitive effort investment in mental imagery (r=0.278, p<.001). This result remained consistent regardless of the configuration approach and product type *(Figure 6-5).*

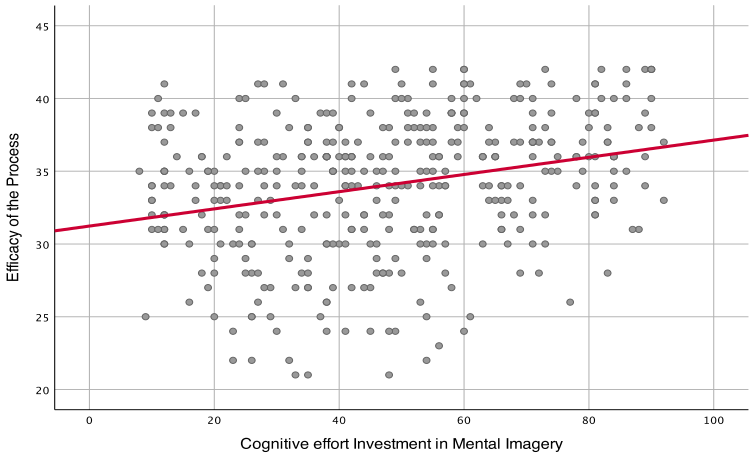
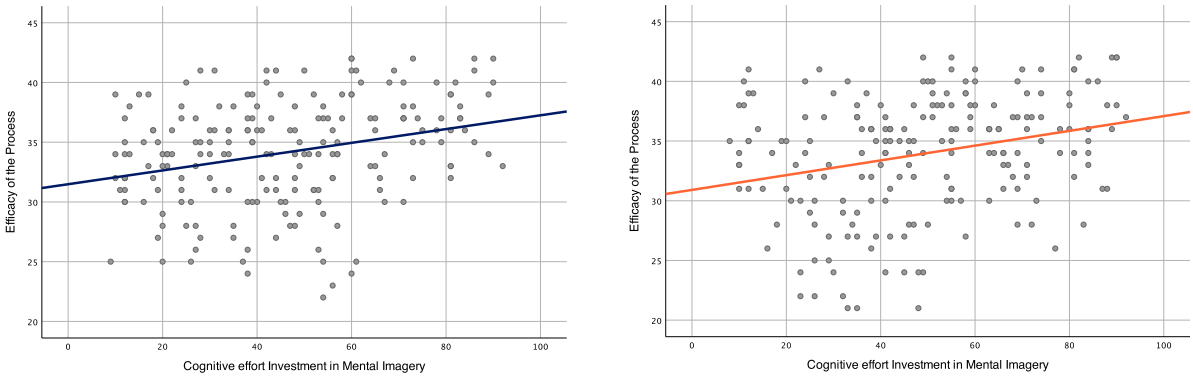


Figure 6-4: Scatter plot illustrating the relationship between cognitive effort invested in mental imagery and the efficacy of the configuration process, with an accompanying trend line



Left: Parameter-based (starting with a blank white design) Right: CvSS (starting with a pre-design inspiration)

Figure 6-5: Scatter plot illustrating the relationship between cognitive effort invested in mental imagery and the efficacy of the configuration process, with an accompanying trend line

Based on the responses collected from participants, the qualitative study further identified three subcodes to categorise how users believe the effort investment in mental imagery influenced their

satisfaction: positive influence (111 instances), no influence (52 instances), and negative influence (5 instances). The majority of participants expressed that investing effort in mental imagery positively influenced their satisfaction with the final design:

*"Investing more effort did increase my satisfaction as I could picture myself actually wearing these shoes if I got them. If I hadn't been able to visualise them in reality or on myself, I wouldn't have been as confident about the design." (607***96d, female)*

*"I believe that if I had dedicated more time to visualising how the shoes would appear, especially as part of different outfits, it would have streamlined the design process. I could have had more images in my mind and considered the product in various scenarios. I feel I focused too much on how the shoe appeared on screen rather than its potential appearance in real life and in different contexts. I wish I had prioritised the visualisation aspect more than what was immediately in front of me." (60f***810, female)*

Conversely, a substantial number of participants felt that mental imagery didn't influence their satisfaction with the final design, nor did they believe that investing more effort would have boosted their satisfaction. *"For me, the amount of effort I invest in creating a mental image isn't the crux – the ability to form an image at all is paramount. If I can't envision myself wearing the product, it suggests I can't see myself (quite literally) donning such an item, implying it's not suited to me." (5e2***fe6, female)*

Yet, only a handful of participants believed that investing more effort could have a negative outcome: *"On the contrary, if I had pondered more about actually wearing the item, considering when and where I'd use it, I might have grown more self-conscious about making unique choices. I might have gravitated towards more conventional designs, which would have left me less satisfied. While I feel the final design was distinctive and versatile, in reality, I might have ended up visualising no suitable occasion for it and reverted to a standard design." (5d4***26f, male)*

In summary, most participants believed that investing more effort in mental imagery enhanced both their design process and the end result. While a significant number did not see significant benefits from utilising mental imagery in their design process, they were not opposed to it. Only a very few participants believed it could negatively impact their design choices. Based on both qualitative and quantitative data, it's evident that promoting the use of mental imagery in the design process is likely to increase user satisfaction overall.

6.9 Discussions

6.9.1 The Relationship between Personal Preference and Configuration Approach

The study hypothesised that the CvSS configuration approach would receive higher satisfaction from users. However, the quantitative data told a different narrative: there's no significant difference between the two approaches. In some cases, the parameter-based approach even received slightly higher satisfaction. The qualitative data, on the other hand, reveals a more complex range of factors underlying user preferences for different configuration approaches.

For some users, the appeal of the CvSS configurator was clear. The pre-designed inspiration facilitated a more streamlined and decisive design process. It provided a template, reducing the complexity of choices stemming from an abundance of options. However, while the pre-designed inspirations served as guidance for some, others felt they could hinder creativity. Therefore, the choice between a CvSS configurator and a parameter-based approach may not hinge on one being universally better, but rather on aligning with a user's individual design approach and comfort level.

The significant preference for the blank white design of the parameter-based configurator revealed another dimension of the user experience. The autonomy it offers goes beyond just creating a product and seems to indicate the real enjoyment lies in the journey of creation itself. The satisfaction derived from this approach can be extrapolated from the user responses and found to be twofold: the joy of

designing something unique (decision satisfaction) and of creating a final product that truly represents personal choices (product satisfaction). This aligns with the study's definition of the efficacy of the process. For individuals who seek the freedom of navigation among options, starting from a blank white design encourages mental imagery utilization, which further leads to higher efficacy of the process. However, this freedom also poses a challenge. As some participants highlighted, with greater autonomy comes the potential for feeling overwhelmed. Therefore, striking a balance between autonomy and guidance can be crucial for the parameter-based configuration.

However, a third group offered a different perspective, suggesting that for some, configurator types and starting points might be irrelevant if they already have a clear design vision in mind. This suggests that while configurators serve as tools to aid the design process, they might not be the primary factor in decision-making for everyone. Given the diverse reactions to both configurator types, a one-size-fits-all approach seems insufficient. To enhance the efficacy of the configuration process, it may not be about choosing between a CvSS or parameter-based configurator but recognising the need for flexibility within these tools.

6.9.2 The Relationship between Cognitive Effort Investment and Mental Imagery

Mental imagery in the study was categorised into user-related, product-related, and scenario-related visualisations. By visualising how a product integrates with themselves, whether from a first-person perspective or third-person perspective, users make design choices that resonate more than just the product aesthetic. By visualising how a product aligns with their personal needs and preferences, users' design choices extend beyond mere aesthetics to reflect deeper values, self-expression, and identity.

Product-related and scenario-related visualisations also play distinct roles in the design process. Recognising these different layers of visualisation is critical for configuration processes aiming to engage users deeply, especially when certain products, like clothes, demand a more intimate visualisation due to their proximity to the body. This may account for the patterns seen in the quantitative data showing different preferences for different types of visualisations utilised between trainers and

shirts. While product-related visualisations allow users to engage with the inherent characteristics of a product, scenario-related visualisations enable users to foresee the design within different contexts and situations.

The data offers a more detailed perspective on cognitive effort and its distribution across the design process. Many users demonstrated a more substantial cognitive investment during the review phase, suggesting that the validation and reassurance process is vital. Users might initially be confident in their design choices, but the review phase offers them a final 'reality check', compelling them to reflect and ensure their choices align with their personal and contextual needs and preferences.

While supplementary tools like product simulations are valuable in guiding users towards product-related visualisations, they present certain challenges. Many users, despite the clarity of the product imagery, found difficulties in navigating user-related and scenario-related visualisations. This observation is crucial, especially considering the significant role every type of mental imagery plays in the configuration process.

6.9.3 The Relationship between Transpositional Effort Investment and Efficacy of the Configuration Process

The study introduces a new concept called Transpositional Effort, which refers to the cognitive effort users invest in mentally visualising and contextualising their digital design choices in real-world settings. This concept acknowledges the challenge of effectively translating decisions made in a digital environment into satisfactory outcomes in the physical world.

The research investigates the relationship between Transpositional Effort and the overall success of the product design process. Quantitative data analysis reveals a positive correlation between the level of Transpositional Effort invested by users and their reported satisfaction levels. Users who actively engage in mentally projecting their digital design selections onto real-world scenarios tend to express higher satisfaction with both the decision-making process itself and the final design outcome.

These findings highlight the importance of encouraging users to bridge the gap between the digital and physical realms during the product customisation journey. By promoting Transpositional Effort, designers can guide users to make choices that not only satisfy their aesthetic preferences but also align with their practical needs and intended use cases. Ultimately, investing Transpositional Effort enhances the user's confidence in their decisions and leads to a more successful and fulfilling product customisation experience.

However, the landscape of this relationship is multi-layered. As the qualitative data further reveal, while a solid majority believe that deeper engagement with mental imagery boosts their satisfaction, a significant number felt that simply being able to form mental images was enough. This proposes an intriguing idea that there might be a point beyond which added effort doesn’t increase satisfaction. Furthermore, a small number of participants introduce an intriguing perspective: is there a downside to over-relying on mental visualisation? Their insights point towards a delicate balance in the configuration process, where the goal is harnessing the full potential of mental imagery without it becoming overly effortful.

Despite subtle hints toward balancing effort in mental imagery, the current study doesn't often spotlight digital product configuration as overly demanding of mental imagery. Yet, immediate challenges arise. A number of users find it difficult to create user-related and scenario-related visualisations. This difficulty might be more about their inherent ability to visualise than the process itself. With strong evidence supporting the advantages of utilising mental imagery for a higher efficacy of the configuration process, our primary goal should be to encourage users to engage more with mental imagery, especially by visualising products grounded in different real-world contexts.

6.10 Conclusions

Product configurators serve as tools enabling users to customise products based on their preferences by making design choices on a digital platform. This study underscores users' deep engagement with

digital interfaces, especially when decisions impact tangible real-world products. Employing a mixed-methods approach has given comprehensive insight into the users' decision-making journey. Quantitative data objectively validated hypotheses, pinpointing patterns in user interactions with configurators. In tandem, qualitative data unveiled insights from users' subconscious, enriching our understanding of their decision-making process. Together, they present a harmonised perspective, allowing a more complete interpretation of the results.

In summarising this investigation, the results from this study provide a clearer understanding of the connection between cognitive effort, mental imagery, and the efficacy of product configurator processes. It was found that more effort spent engaging with mental imagery results in more successful outcomes. In addition, it can be seen that encouraging different types of mental visualisation can have a positive impact on experience throughout the customisation process and facilitate more successful designed outcomes.

This study goes beyond the typical user-interface interaction, revealing the cognitive processes users undergo while transposing digital decisions into real-world outcomes. The insights from this study lay a foundation for future configurator designs to consider individual cognitive journeys. As configurators continue to develop, embedding mental imagery as a key component is essential. Recognising the varied user experiences and their differing degrees of mental imagery utilisation, configurators can be tailored to better address individual needs. This approach, informed by the findings of this study, sets a promising direction for improving user satisfaction and bridging the digital and physical worlds. This not only facilitates product development aligned with user expectations but also ensures products are valued, utilised, and retained longer.

7. CONCLUDING DISCUSSION

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This chapter provides a summary of the research. The chapter starts by highlighting the research contributions. Following this, the discussion aligns with the original research objectives identified in the introductory chapter (*Chapter 1*) and highlights the key findings and knowledge gained from each study. The chapter then explores the implications and recommendations for digital product customisation. Furthermore, the limitations of the research are discussed, and potential future research areas are identified. Finally, the chapter concludes with reflections on the overall research.

7.1 Research Contribution

The research in this thesis employs a design research methodology framework to investigate the role of mental imagery and cognitive effort investment in digital product customisation from the end-user perspective. By identifying gaps in the existing literature and practice, and through empirical studies using a mixed-methods approach, this research draws evidence to support its conclusions and contributions. The key contributions of this research are as follows:

i. Identification of a lack of existing knowledge on the focus and emphasis of the end-user perspective in understanding product customisation.

ii. Investigation of the strengths, limitations, and gaps in established digital product configuration systems.

iii. Identification of mental imagery as a key contributor to cognitive effort investment during the digital product configuration process.

iv. Proposal of a new categorisation of users' mental imagery strategies, classified as user-related, product-related, and scenario-related visualisations.

v. Demonstration of a potential method to quantify cognitive effort investment in mental imagery, which supports the investigation and evaluation of the digital customisation process.

vi. Definition of a novel construct - Transpositional Effort, referring to the cognitive effort invested in mental imagery, which positively influences the efficacy of the digital customisation process.

7.2 Research Findings

The research focuses on investigating the digital product customisation process, aiming to propose a theoretical approach that enhances user satisfaction with both digital design outcomes and the decision-making process. The following section concludes the discussion by responding to the research contributions and the three objectives identified in the research.

7.2.1 Users' Decision Journey in Digital Product Customisation

Objective 1: *To understand users' decision journey and their expectations and concerns when conducting product customisation in the virtual environment.*

Digital product customisation presents an interplay of choices, preferences, and expectations. The mixed-method coding approach from study one has enabled the capture of both anticipated and emergent themes, revealing the details of the user experience. Therefore, through an in-depth analysis of participant responses, a comprehensive understanding of this digital journey emerges.

The customisation process presents an interesting tension between creative freedom and usability. While participants enjoyed the participatory co-design experience, data collected in this research show the paradox of choice was real, with many overwhelmed by excessive options. This highlights a critical need to rethink configurator interfaces for more seamless user journeys. However, there is a delicate balance to strike in how much guidance to provide, enough to enhance creative freedom but not so much that it diminishes user autonomy. These findings underscore the lack of existing knowledge on the end-user perspective in product customisation (Contribution i.), as they reveal the complex challenges and expectations users face in the digital customisation process, which are not adequately addressed in previous research or configurator designs. By providing a detailed, user-centric analysis of the customisation journey, our research contributes to a deeper understanding of users' needs, preferences, and challenges, which is essential for improving configurator design and user satisfaction.

Another interesting aspect of co-creation platforms is their broad appeal, attracting users ranging from those with little knowledge to those with more experience with the product. This diversity highlights the necessity to reconsider how user experiences are designed. Platforms must become more accessible to newcomers, ensuring simplicity in their interaction with design tools. Simultaneously, it's critical to preserve the benefits that come from users who bring a deeper understanding and creativity to the process. Balancing these needs is key to leveraging the collective creativity and expertise of all users in the customisation process. These findings highlight the limitations of current digital product configuration systems in accommodating diverse user needs and expertise levels (Contribution ii.), emphasising the need for more adaptable and user-centric platform designs.

Visualisation persists as a pain point, one of the most important findings from the study is that with even realistic 3D renderings proving insufficient for driving a sense of ownership. In the case of fashion industry, the ability to envision garments on one's unique body emerges as critical for user confidence and. This underscores the need for more intuitive methods, such as virtual try-on innovations, that can bring garment customisation to the forefront of the digital experience. However, concerns around the intangibility of current digital experiences also remain, highlighting the need to better simulate tactile and sensory aspects. As virtual try-on technologies become more accessible, they could also play a role in sustainability by reducing the need for physical samples—a beneficial side effect that requires further investigation.

In conclusion, the study highlights that customers value ease, flexibility in the customisation process, but struggle with decision-making due to option overload and the intangible nature of online platforms. There is a critical demand for platforms to enhance guidance, provide realistic visualisation, and integrate advanced technologies for better product prediction. Addressing these issues by improving the tangibility and accuracy of digital customisations could significantly improve customer confidence and satisfaction with the digital product outcome.

7.2.2 Users' Utilisation of Mental Imagery in Digital Product Configuration

Objective 2: *To analyse the distribution of users' cognitive effort in the digital product configuration process, specifically how they utilise mental imagery when evaluating the digitally configured product.*

The research presents a comprehensive view by integrating both qualitative and quantitative findings, offering insightful conclusions on the use of configurators in product customisation process. From the quantitative perspective, a significant insight is the relationship between mental imagery abilities, as measured by VVIQ and SUIS, and the effort invested in the configurator process. Interestingly, the study found no significant correlation between the vividness of mental imagery or the frequency of its use in daily life, and the effort participants put into customising their product. This finding is counterintuitive as one might expect a higher mental imagery ability to translate into a more involved or effective customisation process. It suggests that while mental imagery is a tool used in customisation, its effectiveness or impact is not necessarily proportional to the user's inherent ability to visualise.

On the other hand, the research also suggests that one's utilisation of mental imagery is a complex structure, where the quality, quantity, and ease of mental imagery all contribute to the proportion of effort invested. This implies that understanding the role of mental imagery in the customisation process requires a holistic approach. It highlights that not just the inherent mental imagery abilities, but also how individuals apply these abilities in specific contexts, impacts the customisation experience. The interplay between these factors suggests that effective utilisation of mental imagery in product customisation may depend on a combination of personal capabilities and situational factors, underscoring the need for a comprehensive understanding of how mental imagery contributes to user satisfaction in customisation processes. These findings directly support the contribution of identifying mental imagery as a key contributor to cognitive effort investment during the digital product configuration process (Contribution iii.). By recognising the complex and multifaceted nature of mental imagery in the customisation process, this research highlights the need for a more detailed understanding of how users engage with and invest cognitive effort in digital product configuration systems.

The qualitative analysis of configurator experiences in the study provides several key insights. A notable finding is the extensive and varied use of mental imagery by participants during the customisation process. This imagery ranged from holistic visualisations, where participants desired a comprehensive view of the product, to tactile visualisations, where they mentally simulated the texture and feel of the materials. Interestingly, these visualisations were not only product-centric but also incorporated self-visualisation, where participants imagined themselves interacting with the product, and environmental visualisation, placing the product within a specific context or setting. Another significant insight concerns the decision-making strategies employed by participants. The study revealed a combination of comparative evaluation, attribute filtering, and considerations of product form, fit, and function. This indicates a detailed and highly personalised approach to decision-making. Participants were not simply choosing based on immediate visual appeal, they were engaging in a deep analysis that involved comparing subtle differences, filtering attributes based on personal needs and preferences, and considering the practical aspects of the product in terms of its aesthetic appeal, fitting, and functional use.

One of the key results from the study two was categorised mental imagery into user-related, product-related, and scenario-related visualisations. Users' tendency to visualise themselves within the design outcome suggests that they naturally gravitate towards imagery they can directly relate to. It was found that user-related visualisation was the most frequently triggered, especially when considering the product’s form, fit, and function. However, for minor product details, product-related visualisation was preferred. Scenario-related visualisation, though less frequent, still played a significant role. The extensive and varied use of mental imagery by participants, as revealed in the research, underscores the importance of investigating the strengths and limitations of digital product configuration systems in supporting these cognitive processes (Contribution ii.). The findings suggest that current configurators may not adequately cater to the diverse types of mental imagery employed by users, indicating a gap that needs to be addressed to enhance the user experience and satisfaction. These findings also underscore the value of our proposed categorisation (Contribution iv.) in capturing the complex nature of users' mental imagery strategies, and in providing a framework for analysing their relative importance and impact on the customisation process.

In summary, by visualising how a product integrates with themselves, users make design choices that resonate more than just with the product's aesthetics. By visualising how a product aligns with their personal needs and preferences, users' design choices extend beyond mere aesthetics to reflect deeper values, self-expression, and identity. This underscores the central role of mental imagery in the digital product configuration process and the importance of understanding users' utilisation of mental imagery in the product customisation process. The new categorisation of mental imagery proposed in this research offers a fresh perspective on understanding and investigating this crucial process. It emphasises the varied dimensions through which mental imagery influences user engagement and satisfaction, suggesting that the decision-making strategies users employ with mental imagery can significantly impact the cognitive effort investment during the digital customisation experience.

7.2.3 Users' Cognitive Effort investment in Mental Imagery

Objective 3: *To propose a new construct to investigate and further understand users' cognitive effort in mental imagery during the digital product configuration process.*

Following the new categorisation of different types of mental imagery utilised by users, the research further introduces a potential computational method to quantify cognitive effort investment in mental imagery. Through further investigation, the study reveals a clear link between cognitive effort in mental imagery and the efficacy of the product design process. The quantitative data reveals users who invest more cognitive effort in mental imagery are generally more satisfied with both the decision-making process and the final design outcome. This implies that users who actively bridge their digital design outcome to real-world contexts not only enjoy the process but also tend to enhance satisfaction in their decision, ensuring these choices are not just visually appealing but also aligning with their needs and preferences. The demonstration of this potential method to quantify cognitive effort investment in mental imagery represents a key contribution of our research (Contribution v.), as it provides a novel approach to investigating and evaluating the digital customisation process. By enabling the quantification of cognitive effort investment in mental imagery, the research opens up new possibilities for analysing and

optimising the digital product configuration process, which can lead to improved user experiences and more satisfied digital customisation outcomes.

Reflecting on the nature of product configurators, they present a unique dynamic. The modular design requires users to engage in continuous, thoughtful decisions. Data from our discussions indicate that these decisions involve a blend of mental imagery – conjured by different users with varying levels of vividness, quantity and ease. Meanwhile, users often navigate differing spectrums of user-related, product-related, and scenario-related visualisations to help them imagine their products. This combination serves as the foundation that structures the cognitive effort investment in mental imagery, highlighting the need for configurators that align with these detailed mental processes. This also highlight the practical value of our demonstrated method for quantifying cognitive effort investment in mental imagery, as it enables researchers and designers to empirically investigate the factors that contribute to user satisfaction and success in the digital customisation process.

Acknowledging this challenge of transposing digital decisions into real-world outcomes, this study introduces the new construct of Transpositional Effort. The definition of Transpositional Effort as a novel construct represents a significant theoretical contribution of the research (Contribution vi.), as it provides a new lens through which to understand and analyse the cognitive processes involved in digital product customisation. The study aims to provide a novel concept for understanding the specific phenomenon of digital product configuration and offer a unique perspective to this emerging and important area. Grounded in the data and supported by user narratives, this concept outlines the cognitive effort invested in mental imagery as users interact with the digital system. Rather than seeing mental imagery as simply "used" or "not used", Transpositional Effort provides a way to quantify its depth and scope, and how this effort positively influences the efficacy and outcomes of digital product configuration. This not only advancing the theoretical understanding of mental imagery in digital customisation and in providing a foundation for future research and practical applications in this field, especially when examining the complex cognitive journey users undergo such as during product configuration.

7.2.4 Transpositional Effort Measure

Building on the initial proposal from Study Two and the evaluation and validation from Study Three, with consideration of the generalisability to a wider product range and configuration systems, this research presents the measure of Transpositional Effort as a design support tool for digital product configurators (Contribution v.). This measure quantifies the cognitive effort invested by users in mental imagery during the product configuration process, focusing on transposing digital choices to real-world contexts.

Transpositional Effort is conceptualised as a quantifiable measure, presented as an 18-item assessment tool. The measure can be adapted based on the specific product type and configuration stages being examined:

Please now consider the following two stages in your decision-making process:

- The ***design phase***, which took place before you completed your design.
- The ***review phase***, which will occur after you completed your design.

1. During the design process **/** *When reviewing your completed design*, did you have any mental images that only included the product itself?

   (Yes or No; if Yes, to Ease, Vividness and Quantity; if No, skip to q2)

2. During the design process **/** *When reviewing your completed design*, did you have any mental images of yourself using the product?

   (Yes or No; if Yes, to Ease, Vividness and Quantity; if No, skip to q3)

3. During the design process / *When reviewing your completed design*, did you have any mental images of yourself using your product in specific situations?

   (Yes or No; if Yes, to Ease, Vividness and Quantity; if No, finish the survey)

Ease: How easily were you able to create these mental images?

(1: imagining was difficult, 7: imagining was easy) (reverse item)

Vividness: How clear were these mental images that came to your mind?

(1: no image at all, 7: vivid and clear)

Quantity: How many mental images did you have?

(1: Few mental images, 7: Many Mental images)

Inputs and Development Process: The measure was refined using both quantitative and qualitative data from users' experiences with digital product configurators. The development process involved:

- Validating the three distinct types of mental imagery visualisations
- Confirming the significance of both the design and review phases
- Establishing the relationship between mental imagery effort and user satisfaction
- Creating a scoring system that accounts for imagery vividness, ease, and quantity

Application: This measure can be used by designers and researchers to:

- Evaluate the effectiveness of product configurators in engaging users' mental imagery
- Identify areas where users struggle to visualize the product in real-world contexts
- Guide the development of configurator features that support different types of mental imagery

Further details on the application of this measure are discussed in section *7.3.2 Implications for Industry Practice*.

7.2.5 Summary of Research Findings

In summary, this research has demonstrated a wide range of insights into the digital product customisation process, with a particular focus on understanding users' decision-making journeys, their utilisation of mental imagery, and the cognitive effort invested in this process. Through a combination of qualitative and quantitative analyses, the research has identified the key challenges and expectations users face in the customisation process, such as the paradox of choice, the need for adaptable and user-centric platform designs, and the importance of supporting diverse types of mental imagery (Contributions i. and ii.). Moreover, the research has shed light on the complex and multifaceted nature of mental imagery in the customisation process, identifying it as a key contributor to users' cognitive effort investment (Contribution iii.). By proposing a novel categorisation of users' mental imagery strategies into user-related, product-related, and scenario-related visualisations (Contribution iv.), the research has provided a more detailed and structured approach to investigating the role of mental imagery in digital customisation. Furthermore, this research demonstrates a potential method to quantify cognitive effort investment in mental imagery (Contribution v.), opening up new possibilities for analysing and optimising the digital product configuration process. Finally, the introduction of the novel construct, Transpositional Effort (Contribution vi.), offers a new theoretical lens through which to understand and analyse the specific cognitive effort invested in mental imagery during the customisation process, and how this effort positively influences the efficacy and outcomes of digital product configuration. Collectively, these findings and contributions advance the understanding of digital product customisation from the end-user perspective, providing valuable insights and frameworks for researchers and practitioners in this field. They also lay the foundation for future research and practical applications aimed at enhancing user experiences and outcomes in digital product customisation.

In discussing the generalisability of the findings from this study, it is crucial to consider the fit-form-function profile that frames the digital product customisation process (Schillaci, 2018b). The research demonstrates that mental imagery plays a significant role across various aspects of product

interaction—form, which pertains to the aesthetic and physical attributes; fit, which involves the product's appropriateness or suitability for the user; and function, concerning the practical utility or operation of the product. These findings, while robust within the context of digital customisation for fashion items like trainers and shirts, suggest broader applicability across different product categories.

However, the transferability of these insights to other domains requires careful consideration. Products with a heavy emphasis on technical specifications, such as electronics, or those that integrate complex functionalities, might interact differently with user's cognitive processes, especially in terms of how users employ mental imagery (Pearson, Clifford and Tong, 2008; Buchenberg, 2018). Therefore, while the findings offer valuable perspectives on user engagement and decision-making in customisation platforms, their application to other product types should not assume direct correlation without adjustments or further empirical validation.

This understanding encourages a novel approach to applying the study's insights beyond the fashion industry. Future research could expand upon this foundation by exploring how these dynamics function in other sectors, potentially adjusting the digital customisation tools and strategies to better align with the specific cognitive and perceptual demands of different product types. This exploration is essential for developing more universally applicable digital customisation frameworks that can adapt to the unique challenges presented by various products, enhancing user experience and satisfaction across a broader range of industries.

7.3 Research Implications

The implications of the research findings and contributions are applicable to both research and practice in the field of digital product customisation. By understanding the factors that influence users' experiences and cognitive processes, we can inform the design of more effective and user-centric configurators, enhance user satisfaction and engagement, and ultimately drive the success of customisation offerings in the marketplace. This section will explore the key implications of the research

for configurator design and industry practice, highlighting the potential impact and applications of the contributions in each of these areas.

7.3.1 Implications for Configurator Design

The findings and contributions of this research have significant implications for the design of digital product configurators. By understanding users' decision-making processes, mental imagery strategies, and cognitive effort investment, we can identify key areas for improvement and innovation in configurator design. One of the primary challenges highlighted in the research is the paradox of choice: digital product configurators must balance the enjoyment users find in the customisation process with the potential overwhelm caused by too many options. To combat this, a tiered customisation approach can be implemented, where users start with a simple set of options and gradually unlock more complex ones as they become more comfortable. This not only prevents initial overwhelm but also keeps users engaged as they explore deeper customisation possibilities. AI-driven recommendation systems can play a critical role in personalising the experience by analysing user data to suggest options that align with previous choices or preferences. A guided customisation mode enhances the user experience by providing step-by-step assistance, simplifying the process and making it more accessible. Additionally, offering pre-designed inspirations or popular designs can serve as an efficient starting point, helping users begin the customisation process with less effort and decision-making stress.

Moreover, the research highlights the need to enhance the user experience across varying levels of product knowledge. Configurators should cater to a diverse user base that ranges from novices to experts. Implementing an adaptive interface that adjusts the complexity based on detected user expertise can make the tool more user-friendly. For beginners, this might mean a simplified, more guided experience, while experts might see more advanced options and controls. A layered information architecture ensures that users can investigate more detailed product information as needed without overwhelming those who require less detail. For novices, interactive tutorials or tooltips can assist in understanding product features and customisation options, providing a learning curve that is both informative and engaging. For more knowledgeable users, an 'expert mode' could unlock additional

customisation layers, offering deeper technical specifications and complex options that cater to their advanced understanding.

Another key challenge is overcoming visualisation challenges in digital customisation. Visual representation is critical in digital customisation, as it directly affects the user's ability to relate to and feel ownership of the product. Besides realistic digital representation of the product, advanced AR/VR technologies can significantly enhance this by allowing users to visualise products in real-world settings or on themselves, thus bridging the gap between digital and physical. Providing detailed, high-resolution visuals from multiple angles, along with zoom capabilities, allows for a thorough inspection of materials and craftsmanship. Dynamic, real-time rendering that immediately reflects changes helps maintain user engagement and satisfaction by providing instant visual feedback. Comparative visualisation tools are particularly effective as they allow users to compare different customisation options side-by-side, facilitating more informed decision-making.

This research also highlights that utilising mental imagery is crucial in digital customisation, as it supports the cognitive process and enhances user satisfaction. The quality, quantity, and ease of mental imagery significantly influence the effort users invest in customisation. Offering diverse visual aids such as photos, videos, and 3D models caters to different preferences and enhances the ability to visualise. A visualisation assistance feature can provide crucial support for users who struggle with mental imagery, offering prompts and guidance to help them visualise the product more effectively. Imagination exercises can be made optional for those who wish to further develop their visualisation skills, and multi-sensory cues like descriptive text and ambient sounds can enhance the mental imagery, making the customisation process more immersive and enjoyable. Providing rich, contextual information about the materials, textures, and potential uses of the product helps stimulate the imagination, making the customisation experience more vivid and personal. Storytelling elements can further enrich this experience by framing the product within compelling narratives that resonate with users' lives. Using evocative language and imagery throughout the process not only engages the senses but also enhances the overall aesthetic and emotional appeal.

Meanwhile, configurators should be designed to support different types of mental imagery—user-related, product-related, and scenario-related. Each category can be addressed through specific features that enhance the visualisation process. For instance, modes like "See it on you" allow users to visualise the product on themselves, "Explore the product" can provide detailed explorations of product features, and "Imagine the scenarios" can help users visualise the product within various life contexts. Virtual avatars and mood boards or collages can be effective tools in these modes, enabling users to project the product into their personal and aspirational spaces, thus making the customisation experience more relatable and engaging. Designers could also explore the potential to introduce motion and dynamics into the digital experience by building on the already existing interactive simulations. While users currently explore static visualisations, motion-enabled simulations can further illustrate products in use, underlining functional aspects in real-life scenarios. This dynamic exploration can offer a more holistic understanding, allowing users to perceive form, fit and functionality in conjunction.

The table below (Table 7-1) presents the key findings from this research along with the actionable recommendations. This serves as a quick reference guide for the design and implementation of digital product configurators, ensuring they are user-friendly and effective in addressing diverse user needs.

Research Findings	**Actionable Recommendations**
Paradox of choice in customisation	• Implement tiered customisation • Utilise AI-driven recommendation systems • Provide guided customisation mode • Offer pre-designed templates
Diverse user expertise in configurator systems	• Adaptive interfaces • Layered information architecture • Interactive tutorials for novices • Expert mode for advanced users
Visualisation challenges in digital customisation	• Implement AR/VR technologies • Provide multi-angle, high-resolution visuals • Use dynamic, real-time rendering • Offer comparative visualisation tools

Importance of mental imagery in customisation	• Offer diverse visual aids • Provide rich contextual information • Use storytelling elements • Employ evocative language and imagery • Encourage visualisation at key points
Categories of mental imagery utilised by users	• Develop visualisation-specific modes • Create interactive scenarios • Implement virtual avatar systems • Provide tools for mood boards and collages • Implement motion-enabled simulations

Table 7-1. Research Findings and Actionable Recommendations

7.3.2 Implications for Industry Practice

One of the key implications of the research is the need for industry to adopt a user-centric and data-driven approach to configurator design and development. The findings highlight the importance of understanding and accommodating the diverse needs, preferences, and behaviours of users in the customisation process. To leverage this knowledge, industry should invest in robust user research, data analytics, and continuous testing and optimisation of their configurator platforms. This could involve conducting in-depth user interviews, surveys, and contextual inquiry to gain insights into users' decision-making processes, mental imagery strategies, and cognitive effort investment. By incorporating these insights into the design and development of configurators, the industry can create satisfying customisation experiences that drive customer interaction and engagement to create the product they enjoy and cherish.

The research introduces novel constructs and methods, such as the categorisation of mental imagery strategies and the quantification of cognitive effort investment, which offer valuable tools for configurator designers to assess and optimise the user experience. The construct of Transpositional Effort, which refers to the cognitive effort invested in mental imagery during the digital customisation process. This novel construct offers a novel and promising approach to understanding and evaluate users' cognitive

processes and their impact on user experience and satisfaction, further optimising user experience in digital product customisation. As a measure of the cognitive effort invested in mental imagery during the customisation process, Transpositional Effort provides a valuable lens through which industry can evaluate and improve their configurator platforms. However, the practical implementation and application of this construct require careful consideration and planning. Given that Transpositional Effort positively contributes to user satisfaction, the goal for businesses should not be to minimise it but rather to optimise it. In other words, configurators should be designed to facilitate and encourage users' investment of cognitive effort in mental imagery, as this engagement can lead to more satisfying and personally meaningful customisation experiences. However, it's important to strike a balance, as too much overall cognitive effort may lead to fatigue or frustration, while too little may result in a lack of engagement or perceived value.

One way in which measuring Transpositional Effort can assist in providing information on the configurator itself is by identifying areas where the current design may be facilitating or hindering users' mental imagery processes. For example, if users consistently report low levels of Transpositional Effort for a particular customisation feature or step, it may indicate that the configurator is not effectively supporting users' ability to visualise and evaluate the potential outcomes of their choices. This insight could prompt feedback to investigate whether the current visual representations, interaction mechanisms, or decision support tools are adequate and explore opportunities for improvement. Conversely, if users exhibit high levels of Transpositional Effort for certain configurator elements, it may suggest that these components are particularly effective in engaging users' mental imagery and developing a sense of creative investment, which can then prioritise and build upon these successful design features to enhance the overall customisation experience and drive user satisfaction.

In practice, the industry can utilise Transpositional Effort measurement as part of a comprehensive configurator evaluation and optimisation framework. This could involve integrating Transpositional Effort assessment into existing user research and testing methodologies, such as usability studies, customer feedback surveys, or A/B testing. By systematically collecting and analysing data on users' Transpositional Effort across different configurator variations, businesses can identify patterns,

benchmarks, and best practices for configurator design. For example, In the initial design phase, the manufacturer could conduct usability studies with representative users, tracking their Transpositional Effort as they interact with different configurator features and customisation options. Based on this feedback, the manufacturer could refine the configurator design to optimise the level and distribution of cognitive effort investment in mental imagery across the customisation journey. As the configurator is launched and deployed to a wider user base, the manufacturer could continue to measure Transpositional Effort through ongoing customer feedback surveys and behavioural analytics. By analysing how Transpositional Effort correlates with other key performance metrics, such as conversion rates, order value, or customer satisfaction scores, the manufacturer can identify opportunities for further optimisation and personalisation. For example, if customers with high Transpositional Effort tend to configure more complex options, the manufacturer may want to explore ways to encourage and support greater mental imagery investment.

In summary, the measurement of Transpositional Effort provides a powerful tool that industry can evaluate and optimise their configurator platforms. By quantifying and analysing users' cognitive effort investment in mental imagery, businesses can gain actionable insights into the effectiveness of different configurator design features and user preferences. The integration of Transpositional Effort measurement into configurator development and management processes can enable a data-driven, user-centric approach to continuous improvement and strategic decision-making, ultimately leading to more engaging, interactive and satisfying digital customisation experiences.

7.3 Research Limitations and Future Research

This study is subject to several limitations. While the research introduced the concept of emotional attachment with the customised product in study one, customers' emotional responses in the research context are limited to the purchase situation. The research acknowledges that emotional bonding with a product can also be established through long-term ownership, however, due to the scope of the study focussing only on the journey to designed digital outcome, this can be neither considered nor verified

in this research. Therefore, this research focused on evaluating engagement at the point of design and purchase as an initial step towards facilitating longer-term ownership. The financial investment in obtaining the product is another variable that can contribute to customer engagement. However, as the research focuses on a technical method to facilitate efficient customer-centred customisation, the financial impact was not considered in the research design; this was made clear to the recruited participants during all evaluation processes.

The second limitation is its focus on a single industry product type. The effort invested by users in customisation may significantly vary across different product types and the attributes that can be configured. The choice of products - trainers and shirts from fashion industry - was deliberate, as resulted from these common consumer goods offer a high degree of generalisability. However, the apparel domain predominantly focuses on aspects like form and fit. Therefore, results might be different when users engage with products from other domains. For example, in electronics or interior design, functionality could play a critical role in user decisions. Thus, the use of mental imagery could unfold differently in domains where functionality or technical specifications are paramount. This limitation suggests that future research should compare customisation efforts across a diverse range of products to gain a more comprehensive understanding of user behaviour in different contexts.

Moreover, the results collected in this research are predominantly based on self-reported data. Even though questionnaires were presented directly after task completion across all studies, they inherently required participants to recall and reflect on their mental processes, which might introduce elements of bias. Additionally, the study did not capture some of the more subtle aspects of user interaction with the product. More holistic methods of understanding the configuration experience, such as cursor tracking and eye tracking, could reveal deeper insights into how users engage with and navigate the configurator interface (Zagermann, Pfeil and Reiterer, 2016). To better understand the effort invested on mental imagery, another avenue worth exploring would be the use of real-time tools, for instance, electroencephalograms (EEG), which might shed more direct light on the connection between cognitive processes and decision-making behaviours (Westbrook and Braver, 2015). Implementing these

methods could provide a more detailed view of the user experience, particularly in terms of how users' attention and focus are directed during the customisation process.

Another notable limitation of this study centres around the inherent differences between the imagined products during the customisation process and the actual products received by users. While digital customisation systems enable users to visualise and modify products according to their preferences, there remains a gap between the digital representations and the physical reality (Mugge, Schoormans and Schiffersteinb, 2009). This discrepancy can lead to variations in user satisfaction, as the tactile and material quality of a real product may not fully align with what was envisioned. Such differences are particularly significant in industries like fashion, where texture, fit, and comfort play critical roles and are difficult to accurately simulate digitally.

Furthermore, this study does not extensively cover the long-term satisfaction of ownership, which can significantly change from the initial satisfaction post-purchase. Ownership satisfaction over time is influenced by factors such as durability, performance, and continued relevance of the product to the user's needs, which can’t be fully anticipated during the customisation process (Mugge, Schoormans and Schiffersteinb, 2009). The initial excitement of customisation and personalisation may decrease as the practical aspects of the product come into play in everyday use.

To address these issues, future research could explore and gather long-term user feedback post-purchase to assess satisfaction over time. This would not only help in narrowing the gap between user expectations and reality but also in understanding how personalised products can retain their value and relevance for users, enhancing the overall experience of digital customisation.

Finally, the study offers a notable contribution to the limited explorations of cognitive effort investment in mental imagery, however, the introduction of “Transpositional Effort” as a new construct brings a challenge. This concept, though filling a significant gap in the literature and offering a unique perspective, comes with its limitations such as its broad applicability and validation across wider settings and diverse

scenarios remain untested. Thus, it is important for its findings and implications to be interpreted with careful consideration.

Looking ahead, while the focus has been on visual mental imagery, there are other sensory dimensions in product configuration that deserve attention. The tactile sensation, especially regarding texture, can play a critical role in some products (Wilfling *et al.*, 2023). Similarly, the influence of olfactory and auditory elements, such as smell and sound, could be significant for particular products (Jackie Andrade *et al.*, 2014).

The advancement of new technologies such as Generative AI and Extended Reality (XR), including Virtual Reality (VR) and Augmented Reality (AR) and Mixed Reality (MR), holds transformative potential for the future of product configurators (Kuksa, Fisher and Kent, 2023). These technologies are poised to significantly enhance the interactivity and realism of the customisation experience, providing users with more intuitive and immersive ways to design and visualise products before purchase.

The integration of Generative AI into product configurators promises not only to streamline and personalise the design process but also to revolutionise how users begin their customisation journey. Generative AI has the potential to act as a sophisticated recommendation engine, providing users with initial design suggestions based on their preferences and historical data (Tankelevitch *et al.*, 2024). By analysing user behaviour, past interactions, and even trends within broader user segments, Generative AI can intelligently suggest product configurations that align with individual tastes or popular styles (Kuksa, Skinner, Fisher, *et al.*, 2023). This proactive approach reduces the initial complexity and decision fatigue that users might experience when faced with blank-slate customisation options. Moreover, these AI-driven recommendations can adapt dynamically as users interact with the configurator, refining the suggested options in real-time based on user feedback and choices during the customisation session. This adaptive recommendation system not only enhances user engagement but also improves the likelihood of user satisfaction by continuously aligning with the evolving preferences of the user during the customisation process.

The role of Generative AI in product configurators extends beyond mere automation of design tasks; it fundamentally transforms the user experience by making the entry into product customisation more accessible and less overwhelming. As this technology matures, it will likely become a central feature in next-generation digital customisation platforms, offering users a blend of creativity, personalisation and efficiency.

Another innovative application of AI in product configurators is the use of Large Language Model (LLM) powered chatbots that assist users during the customisation process. These chatbots can act as virtual assistants, offering guidance, answering questions, and providing recommendations in real-time(Roumeliotis, Tselikas and Nasiopoulos, 2024). This interaction mimics a personal shopping assistant, enhancing the user experience by making it more interactive and supportive. AI chatbots can intelligently interpret user inputs and queries, offering solutions and suggestions that align with the user's intentions and preferences (Szilágyi and Tóth, 2024). For example, if a user is unsure about which colour or material to choose for a custom furniture piece, the chatbot can suggest options based on current trends, the user's past choices, or even colour theory, thus simplifying decisions and enhancing satisfaction. The real-time assistance provided by chatbots is crucial, especially in complex customisation environments where users might feel overwhelmed by the available options (Sánchez Cuadrado *et al.*, 2024). By engaging with the user throughout the customisation process, the chatbot helps maintain a flow and this continuous interaction ensures that users feel supported at every step, making the customisation experience more enjoyable.

On the other hand, XR technologies can bridge the gap between digital customisation and physical reality by allowing users to see and interact with a virtual prototype of their customised product in real-time (Luong *et al.*, 2019; Koulouris *et al.*, 2020). For example, MR tools, enable interactive virtual prototyping, empowering users to manipulate product features within a realistic 3D environment. These tools combine VR environments and Tangible User Interfaces (TUIs), allowing users to actively participate in the design process with a high level of both immersion and control (Arrighi and Mougenot, 2019). This integration enables users to interact with and modify digital prototypes naturally and intuitively, improving user satisfaction and ensuring the final design aligns closely with user

requirements (Arrighi and Mougenot, 2019). This capability not only enriches the user experience but also provides a more concrete sense of the product's physical attributes, such as size, fit, and aesthetics, which are often difficult to explore through traditional digital interfaces (Lau and Lee, 2019). The integration of XR into product configurators can also facilitate a more detailed and user-friendly customisation process by visualising complex product options and configurations in an accessible and engaging way. Users can experiment with different configurations in a virtual space, seeing the impacts of their choices in real-time, which can help in making more informed decisions.

As these technologies continue to advance, the future of product configurators will likely see a shift towards more dynamic, interactive systems that can offer a nearly tactile shopping experience from the comfort of one's home or office. The convergence of Generative AI with XR could create a highly sophisticated platform where the boundaries between digital and physical product experiences begin to blur, providing a seamless and highly engaging user experience.

7.4 Concluding Reflections

The inspiration for this research came from my own experience in garment production within both traditional hand craftsmanship and modern technological settings. The refinement and dedication involved in creating a bespoke product made me appreciate how much freedom and possibility can be achieved through customisation. In the modern age, where everything is mass-produced to standard specifications, custom-made products have become synonymous with exclusivity. This raised a question in my mind: Why has individualisation become a luxury? The concept of mass customisation - "producing goods and services to meet individual customers' needs with near mass production efficiency" - led me to envision a potential future of production and consumption, a time when people could purchase customised products with ease and accessibility. In this future, everyday ordinary products that people own would have their own unique identity and sense of belonging, and people would cherish and take pride in every item they own because these items truly belong to them.

However, achieving mass customisation is no easy task, and despite the concept originating in the late 20th century, it still finds limited implementation across industries. The technical challenges posed by manufacturing and logistics make it difficult to compare to the efficiency of mass production. In many industries, such as fashion, existing technologies have been shown to be not yet sufficient for mass customisation purposes, and the process still heavily relies on manual production methods with limited automation strategies incorporated. Many emerging technological advancements in manufacturing shed light on how to achieve mass customisation. However, at the beginning of this research, when I laid out the production journey of customisation, I realised that it not only ends with the customer but also starts with the customer. One of the fundamental differences between customisation and mass production is that the product won't be finalised until the end-user's wants are known.

My narrative quickly pinpointed the enabler of mass customisation today, which is the product configurator. As the starting point for digital customisation, configurators are in a critical position to effectively extract the end-users' preferences and needs. Determining the success of a product's customisation largely depends on whether the end-user receives the product they expected. How can configurators be designed to engage users effectively and ensure they are satisfied with the final product? This becomes the key question that runs through the entire exploration and investigation of my research.

One of the biggest challenges for this research is its highly cross-disciplinary nature, which is reflected in several aspects. Firstly, the terminology used to define concepts can vary across different fields. For example, the term "mental imagery" is commonly used in consumer research, while "visual working memory" is more prevalent in psychology. This can lead to potential confusion or misinterpretation when integrating knowledge from various disciplines. Secondly, the perception of certain constructs may differ depending on the field of study. For instance, in Human-Computer Interaction, cognitive effort is often viewed as a construct that should be minimised to improve user experience and usability. However, in decision-making research, cognitive effort is considered a crucial factor that justifies and strengthens the decision-making process. Reconciling these contradictory views requires a deep understanding of the context and the specific goals of the research. Lastly, the methodology of experiment design and

participant recruitment can also pose challenges in cross-disciplinary research. Each discipline has its own established practices, standards, and guidelines for conducting experiments and recruiting participants. Ensuring the justification and validity of the experimental approach requires careful consideration of which discipline's methodological framework to follow, or how to effectively integrate methodologies from different fields.

The time span of this research witnessed changes in the industry landscape. Covid-19 disrupted many research activities, but it also brought new opportunities to this research. The pandemic accelerated the adoption of digital technologies across industries, it became more important than ever to develop effective digital systems due to geographical limitations. With physical stores closed and supply chains disrupted, businesses were forced to rapidly shift their operations online, placing a greater emphasis on the role of digital product configurators in engaging customers and facilitating personalised purchases. This heightened the relevance and urgency of the research question, as understanding how to design configurators that effectively capture end-users' preferences and ensure satisfaction with the final product became critical for businesses to survive and thrive in the new reality. Moreover, there were changes in consumer behaviour, such as the increased reliance on e-commerce and the desire for personalised, meaningful experiences, further underscored the importance of this research. The insights and recommendations generated from this study could help businesses adapt to the evolving needs and expectations of customers in the post-pandemic world, where digital customisation is likely to play an even greater role in shaping the future of production and consumption.

Towards the end of the research, the world witnessed the booming of AI development. The successful demonstration of the capabilities of generative AI has the potential to revolutionise many industries. Similarly, for digital product customisation, we could foresee a number of potential advancement directions. Generative AI algorithms could be leveraged to create more intelligent and adaptive product configurators. These AI-powered systems could analyse user preferences, behaviour patterns, and contextual data to generate personalised product recommendations and design suggestions in real-time, enhancing the user experience and streamlining the customisation process. Moreover, generative AI could enable the creation of photorealistic product visualisations and immersive virtual try-on

experiences, allowing users to see and interact with their customised products in a more engaging and convincing manner. This could help bridge the gap between the digital and physical world, reducing uncertainty and increasing user confidence in their customisation decisions. Additionally, AI-driven chatbots and virtual assistants could be integrated into product configurators to provide users with personalised guidance, support, and inspiration throughout the customisation journey, further enhancing user satisfaction and engagement. As AI technologies continue to advance and mature, there is a vast potential for their application in digital product customisation, opening up new avenues for research and innovation in this field.

This thesis marks the end of a research study, but academia and industry never stop moving forward. My passion for customisation and personalisation allows me to continue looking ahead, as both a scholar and a practitioner in creating a more intelligent, user-centric, and sustainable future. Curiosity continues to drive me to discover how a product or service can be developed, why it should be offered, and what makes it extraordinary.

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APPENDIX

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Appendix I – A: Study One – Participant Information Sheet

Imperial College London

Participant Information Sheet

Research Project Title

Evaluation of Customer Engagement and Interaction in the Online Customisation Process

Principal Investigator: Dr Leila Sheldrick

Co-investigators: Bowen Zhan

Invitation

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Part 1 tells you the purpose of this study and what will happen to you if you take part.
Part 2 gives you more detailed information about the conduct of the study

Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

This research is based on the garment industry's rapid trends of providing customisation services. Digital technologies are offering new ways for retailers to work with customers to create customised items. A successful garment customisation process should understand personal preferences, engage with the customer through an enjoyable and interactive process. The study aims to understand how the current digital garment customisation process engages with the customer. The study will evaluate customer engagement and interaction in a digital environment using an online garment configuration tool.

This study is being conducted for a PhD research project at Imperial College London.

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Why have I been invited?

Your participation is important for us to understand the customer decision journey during the garment customisation process. Your interaction with the online configurator and completing the survey will further provide us with insight into the emotional bonding with the customised product.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What do I have to do?

The study will ask you to use an online configurator to design your own shirt then complete a short survey. At the end of the survey, you will be asked if you are willing to be contacted for an in-depth interview.

The session will be conducted through a remote-control session. Please use the following link to download TeamViewer:
https://www.teamviewer.com/en/teamviewer-automatic-download/

What are the possible disadvantages and risks of taking part?

Participating in the research is not anticipated to cause you any disadvantages or discomfort. The potential physical and/or psychological harm or distress will be the same as any experienced in everyday life.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator (Insert name and contact details). If you are still not satisfied with the response, you may contact the Imperial College Joint Research Compliance Office.

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What will happen to the results of the research study?

All the information that we collect about you during the course of the research will be kept strictly confidential. You will be assigned to a unique ID number and you will be identified by the ID number on all record documents and any electronic database. Your personal information (name, email) will only be used at initial contact or re-contact if you agreed to participate in the interview.

Configurator simulation part of the study will conduct under a remote-control session. The online activities during the stimulation (Cursor Movement) will be recorded. The record data will store securely and use for internal data analysis purpose only. Access to the original data will be limited to the research staff and authorised personnel.

- Who has reviewed the study?

This study was given ethical approval by Head of Department and Joint Research Compliance Office (JRCO).

Contact for Further Information

Dr Leila Sheldrick
l.sheldrick@imperial.ac.uk

Bowen Zhan
b.zhan19@imperial.ac.uk

Thank you for taking part in this study!

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Appendix I – B: Study One – Survey Questionnaires

Survey Questionnaires

Evaluation of Customer Engagement and Interaction in Online Garment Customisation

Qualtrics:
V 2.0

Welcome! Thank you for taking the time to complete your shirt design.

Your feedback is important for us to understand your customisation journey and your emotional responses towards a digitally customised product.

Q0 What is your Participant ID?

_____

Q1 What is your gender?

- ○ Male (1)
- ○ Female (2)

Q2 What is your age?

- ○ 18 - 25 (1)
- ○ 25 - 30 (2)
- ○ 30 - 35 (3)
- ○ 35 - 40 (4)

Version 2.0
Date 16/05/2020

Q3 How many shirts (formal & casual) do you currently own?

- ○ 0 (1)
- ○ 1 - 3 (2)
- ○ 4 - 6 (3)
- ○ 7 - 9 (4)
- ○ More than 10 (5)

Q4 How often do you wear shirts?

- ○ Never (1)
- ○ Rarely (2)
- ○ Occasionally (3)
- ○ Often (4)
- ○ Always (5)

Q5 Have you ever had a garment customised for you before?

- ○ Yes (1)
- ○ No (2)

Version 2.0
Date 16/05/2020

Q6 Have you ever used an online garment configurator before?

- ○ Yes (1)
- ○ No (2)

Q7 It is easy to navigate within all the available options to get the shirt design I want?

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q8 All the available options are *equally important* to create my shirt.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Version 2.0
Date 16/05/2020

Q9 The digital simulation of the shirt is in **high quality** and **realistic**.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q10 I feel confident the physical product will look the same.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q11 I am able to visualise myself wearing the shirt.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Version 2.0
Date 16/05/2020

Q12 I am satisfied this shirt will look good on me.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q13 I am confident my design of this shirt fits my image.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q14 I am able to complete all the steps **independently** without any assistance.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Version 2.0
Date 16/05/2020

Q15 I have given a lot of thought when I'm creating this shirt.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q16 Please describe your overall decision-making process using the configurator by selecting on the following scale.

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	
Difficult	○	○	○	○	○	Easy
Boring	○	○	○	○	○	Fun
Unappealing	○	○	○	○	○	Appealing
Confusing	○	○	○	○	○	Clear
Restrained	○	○	○	○	○	Free

Version 2.0
Date 16/05/2020

Q17 I feel like I already own this shirt now I have spent time customising it.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q18 I believe I will be more emotionally attached to this shirt than if I had bought one without customising it.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q19 Please describe your feelings about the shirt you have customised by selecting on the following scale:

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	
Indifferent	○	○	○	○	○	Excited
Ordinary	○	○	○	○	○	Special
Unsatisfy	○	○	○	○	○	Pleased

Version 2.0
Date 16/05/2020

Q20 I will be more likely to purchase after customising the shirt myself.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Q21 The inability to physical try-on during the customisation process constitutes a problem for my purchase decision.

- ○ Strongly disagree (1)
- ○ Somewhat disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat agree (4)
- ○ Strongly agree (5)

Thank you for completing the survey!

For us to understand your customisation journey better, would you like to be contacted for an ***interview***?

- ○ Yes (1)
- ○ No (2)

Version 2.0
Date 16/05/2020

Appendix I – C: Study One – Interview Schedule

Interview Schedule

Evaluation of Customer Engagement and Interaction in Online Garment Customisation

In-Depth Interview:
V 2.0

Introductions:

Thank you so much for participating in this study. We have reviewed your shirt customisation session and survey questionnaire. This research aims to understand how the customer evaluates the garment appearance and fit in the digital customisation process, and it will be very helpful for us to understand your decision journey in-details.

I would like to ask about 30 mins of your time, and would it be okay if I audio recorded our conversation? All the information will be for internal purposes only.

Design Session:

Have you considered what occasion you will be wearing this shirt when designing it? Or what does this shirt for? (Work or Casual)

What options did you feel missing from your shirt design process?

If you can recall, any particular option you found was difficult to make a decision, and why? (e. g. back details, back yoke)

Fitting Issues: *Taking shirt as the examples:*

What are the fitting issues you have experienced when purchasing standard sizing garments?

Which parts on the garment (e.g. collar, sleeve, shoulder, waist) do you take particular attention when evaluating the fit?

Do you make any particular movement when evaluating the garment fit? (e.g. raising arms, walk, sit)

Customisation Experience:

When was your most recent garment customisation experience?

Version 2.0
Date 01/08/2020

Which type of garment did you have it made? Are you still wearing this customised item? What are the options you have to choose from?

How did that experience consider your preferences on fitting?

Comparing in-store experience, are you feeling more restrained/free when customising a garment online?

Open Discussion:

Do you think adding your body-figure in the digital simulation will help you make better decisions on the design and fit?

Do you consider yourself as a co-creator when customising a garment?

What is your overall attitude towards digital customisation? What will you expect from the customisation experience?

Appendix: Codebook

Evaluation of Customer Engagement and Interaction in Online Garment Customisation

Codes highlighted in red are based on theories and constructs identified and adopted in the study during the deductive coding cycle.

Codes highlighted in yellow represent new themes that emerged, along with recurring patterns from the data, during the inductive coding cycle.

Deductive Codes:

1. Co-Creation **(28 instances)**

Description: References to collaborating with the system, feeling like a co-designer

2. Customisation Process **(54 instances)**

Description: Discussion of the ease, flexibility, accuracy of the customisation process.

3. Virtual Simulation **(19 instances)**

Description: Comments about digital visualisation and simulation of garments.

4. Body Visualisation **(43 instances)**

Description: Feedback on seeing garments on virtual body models.

5. Fit Evaluation **(61 instances)**

Description: Remarks related to assessing fit and sizing through the virtual experience.

6. Decision Journey **(31 instances)**

Description: Description of the thought process and decision-making during customisation.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

Version 2.0
Date 23/08/2023

Inductive Codes:

Theme: **Customisation Process**

1. Excitement about customisation capabilities (**3 instances**)
2. Interest in exploring digital customisation (**2 instances**)
3. Preference for recommended designs (**5 instances**)
4. Desire for flexibility and range of choice (**5 instances**)

Theme: **Challenges with Fit Visualisation**

1. Difficulty envisioning final product (**5 instances**)
2. Challenge assessing fit on physical body (**6 instances**)
3. Fear of dissatisfaction with end product (**2 instances**)

Themes: **Need for Fit Optimisation**

1. Focus on accurate chest/waist fit (**7 instances**)
2. Importance of proper sleeve length (**4 instances**)
3. Shoulder width challenges (**3 instances**)
4. Need for perfect fit (**6 instances**)
5. Need for fit for intended activities (**2 instances**)
6. Priority on comfort and movement (**5 instances**)

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

Version 2.0
Date 23/08/2023

Theme: **Design Decision Challenges**

1. Overwhelmed by options (**6 instances**)
2. Confusion over construction details (**4 instances**)
3. Lack of fashion design expertise (**9 instances**)
4. Hesitance to choose unconventional options (**1 instance**)

Theme: **Tangibility of Materials**

1. Need for physical product interaction (**8 instances**)
2. Concerns over quality (**2 instances**)

Themes: **Positive Emotions**

1. Positive feelings of control and self-expression (**4 instances**)

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

Version 2.0
Date 23/08/2023

Appendix II – A: Study Two – Participant Information Sheet

Imperial College London

Participant Information Sheet

Research Project Title

Cognitive Effort Investment on Mental Imagery in Digital Product Customisation

Principal Investigator: Dr Leila Sheldrick

Co-investigators: Bowen Zhan

Invitation

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

This research is based on the industry's rapid trends of providing product customisation services. Digital technologies are offering new ways for retailers to work with end-users to create customised items. The study aims to understand how users evaluate a digital product, and the effort spent when visualising the product in mind. The study will investigate user interactions in a digital environment using an online configuration tool.

This study is being conducted for a PhD research project at Imperial College London.

Why have I been invited?

Your participation is important for us to understand how you evaluate digital objects before purchase and the effort invested in your decision making.

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All participants (Millennials and Gen Z Consumers) will be recruited through a social media advert (i.e. Facebook, Instagram) and snowballing method. After completing the survey questionnaire, you will be directed to a page to choose a date and time slot for participating in the task assignment and interview. Thirty participants (N=30) will be recruited for participating in both activities in the study. The survey will require 15 minutes to answer, the task and interview session will take around 1 hour to complete.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and given the link to participate the survey. Implied consent will be granted on completion of the online survey. At the end of the survey, you will have the option to select a date and a 1-hour timeslot to participate in the Zoom session for the task and interview. Once your time slot is confirmed, you will receive a confirmation email and asked to digitally sign and give consent on the consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

When withdrawing from the study, you should let us know that you wish to withdraw. You may provide the research team with the reason(s) for leaving the study. However, you will not be required to provide any reason. You should let the research team know if you will allow the use of your information by the researchers' subject to the following:

1. Continued use of collected data up to the withdrawal moment.
2. Anonymisation of your data.
3. Full withdrawal and deletion of your data.

What do I have to do?

The study will ask you to complete a 15-mintue survey first. At the end of the survey, you will be direct to another page to select a date and a 1-hour timeslot for a Zoom session. During the session, you will use an online configurator to design your own shirt. At the end of the session, based on your interaction with the configurator, a member of the research team will ask you several questions regarding how you made the decisions. The session, including the task and interview, will take around 1 hour to complete. Your design session on the screen and the interview will be recorded with Zoom's recording feature. The session is voice only, and there is no requirement for webcams. The interview will be transcribed by the research team for later data analysis.

What are the possible disadvantages and risks of taking part?

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Participating in the research is not anticipated to cause you any disadvantages or discomfort. All data will be collected adhering to the Data Protection Act 2018 and in line with the Imperial College London's general data protection regulation.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator Bowen Zhan (b.zhan19@imperial.ac.uk). If you are still not satisfied with the response, you may contact the Imperial College Research Governance and Integrity Office (RGIT).

What will happen to the results of the research study?

Results of the research will be published around July 2021. You will not be identified in any report or publication with reference to the interviews. If you wish to be given a copy of any reports resulting from the research, please ask us to put you on our circulation list.

- **Who is organising and funding the research?**

Imperial College London is the study sponsor. This study is unfunded.

- **Who has reviewed the study?**

This study was given ethical approval by Weston Baxter, Head of Department and Research Governance and Integrity Office (RGIT).

Contact for Further Information

Dr Leila Sheldrick
l.sheldrick@imperial.ac.uk

Bowen Zhan
b.zhan19@imperial.ac.uk

Thank you for taking part in this study!

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Survey Questionnaire

Start of Block: Default Question Block

Welcome! Thank you for participating in this study! Your participation is important for us to understand how you evaluate digital objects before purchase and the effort invested in your decision making. The study will ask you to complete a 10-minute survey first. At the end of the survey, you will be direct to another page to select a date and a 1-hour timeslot for a Zoom session. During the session, you will use an online configurator to design your own shirt. At the end of the session, based on your interaction with the configurator, a member of the research team will ask you several questions regarding how you made the decisions. The session, including the task and interview, will take around 30 minutes to complete.

Page Break

What is your first name?

_____

What is your email address?

_____

What is your gender?

- ○ Male
- ○ Female

What is your age?

- ○ 18 - 24
- ○ 25 - 30
- ○ 31 - 35
- ○ 36 - 40

Page Break

How many shirts (formal & casual) do you currently own?

- ○ 0
- ○ 1 - 3
- ○ 4 - 6
- ○ 7 - 9
- ○ More than 10

How often do you wear shirts?

- Always
- Often
- Occasionally
- Rarely
- Never

How often do you buy clothes online?

- Always
- Often
- About half of the time
- Rarely
- I never buy clothes online

Page Break

Part 1: Questionnaire Upon Mental Imagery.

This questionnaire measures the clarity and vividness of your ability of mental imagery. You will be asked to generate an image of specific items in your mind, and to rate how clear and vivid you "see" these items in your mind.

For example: Think of a red traffic light. Use the following scale to describe how clear and vivid you "see" the red traffic light.

- Vivid and Clear as in reality
- Clear and reasonably vivid
- Moderately clear and vivid
- Vague and unclear
- No image at all

Page Break

Think of some relative or friend whom you frequently see (but who is not with you at present) and consider carefully the picture that comes before your mind's eye.

1. The exact contour of face, head, shoulders and body.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

2. Characteristic poses of head, attitudes of body, etc.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

3. The precise carriage, length of step, etc., in walking.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

4. The different colours worn in some familiar clothes.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

Page Break

Visualize a rising sun. Consider carefully the picture that comes before your mind's eye.

5. The sun is rising above the horizon into a hazy sky.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

6. The sky clears and surrounds the sun with blueness.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

7. Clouds. A storm blows up, with flashes of lightning.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

8. A rainbow appears.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

Page Break

Think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

9. The overall appearance of the shop from the opposite side of the road.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

10. A window display including colours, shapes and details of individual items for sale.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

11. You are near the entrance. The colour, shape and details of the door.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

Page Break

Finally, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

13. The contours of the landscape.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

14. The colour and shape of the trees.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

15. The colour and shape of the lake.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

16. A strong wind blows on the trees and on the lake causing waves.

- ○ Vivid and Clear as in reality
- ○ Clear and reasonably vivid
- ○ Moderately clear and vivid
- ○ Vague and unclear
- ○ No image at all

Page Break

Part 2: Spontaneous Use of Imagery Scale

This questionnaire is designed to measure spontaneous use of imagery during daily life. You will use a 5-point scale to rate the degree to which each item is appropriate for you. Do not spend a lot of time thinking about each one, but respond based on your thoughts about how you do or do not perform each activity.

Page Break

1. When going to a new place, I prefer directions that include detailed descriptions of landmarks (such as the size, shape and colour of a gas station) in addition to their names.

- ○ Completely appropriate
- ○ Somewhat appropriate
- ○ Appropriate about half of the time
- ○ Slightly appropriate
- ○ Never appropriate

2. If I catch a glance of a car that is partially hidden behind bushes, I automatically “complete it,” seeing the entire car in my mind’s eye.

- ○ Completely appropriate
- ○ Somewhat appropriate
- ○ Appropriate about half of the time
- ○ Slightly appropriate
- ○ Never appropriate

3. If I am looking for new furniture in a store, I always visualise what the furniture would look like in particular places in my home.

- ○ Completely appropriate
- ○ Somewhat appropriate
- ○ Appropriate about half of the time
- ○ Slightly appropriate
- ○ Never appropriate

Page Break

4. I prefer to read novels that lead me easily to visualise where the characters are and what they are doing instead of novels that are difficult to visualise.

- ○ Completely appropriate
- ○ Somewhat appropriate
- ○ Appropriate about half of the time
- ○ Slightly appropriate
- ○ Never appropriate

5. When I think about visiting a relative, I almost always have a clear mental picture of him or her.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

6. When relatively easy technical material is described clearly in a text, I find illustrations distracting because they interfere with my ability to visualise the material.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

Page Break

7. If someone were to tell me two-digit numbers to add (e.g., 24 and 31), I would visualise them in order to add them.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

8. Before I get dressed to go out, I first visualise what I will look like if I wear different combinations of clothes.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

9. When I think about a series of errands I must do, I visualise the stores I will visit.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

Page Break

10. When I first hear a friend's voice, a visual image of him or her almost always springs to mind.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

11. When I hear a radio announcer or DJ I've never actually seen, I usually find myself picturing what they might look like.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

12. If I saw a car accident, I would visualise what had happened when later trying to recall the details.

- Completely appropriate
- Somewhat appropriate
- Appropriate about half of the time
- Slightly appropriate
- Never appropriate

Page Break

Thank you for completing the survey.
You will be directed to a new page to select a convenient time for participating in the shirt design session and interview.

End of Block: Default Question Block

Appendix II – C: Study Two – Interview Schedule

Interview Schedule

Understanding Cognitive Effort Investment
in Mental Imagery during Digital Product Customisation

Observation Inquiry - Interview:
V 2.0

Pre-session Introductions:

I will now direct you to the page for the shirt design. Please take your time navigating to complete your shirt design. The financial impact is not being considered in this study, so please feel free to explore all the available options. You can decide what the shirt will look like and whether it is formal or casual. The only thing to remember is that the shirt is for yourself!

If you're not pleased with the design and want to start over at any time during the session, please click the reset button located in the top right corner. There's no time limit for the session, so relax and try different options until you get the shirt design you like!

Once your shirt design is complete, leave it on the page, I'll then contact you for the interview.

Interview Introductions:

Thank you for completing the shirt design. I have some questions based on your interactions.

The study aims to understand how users evaluate a digital product, and the effort spent when visualising the product in mind. So, it will be very helpful for us to understand your decision journey in-details.

I would like to ask about 30 mins of your time, and would it be okay if I audio recorded our conversation? All the information will be for internal purposes only.

Version 2.0
Date 22/03/2021

Observation: Key Moments

1. Long Pause
2. Comparing between alternatives
3. Skipping steps
4. Reverse action
5. Zoom in and out

Observation: Questions check list

- How did you decide between fabrics with same colour but different texture?
- Did you imagine how does the fabric feels like in real life?
- Can you describe the image you visualised in your mind?
- Did you imagine when are you going to wear it? In what scenario?

- I noticed that you skipped many options, why?
- You had a long pause, what were you thinking about?
- Do you still need to visualise the product itself after seeing the simulation?
- Did you imagine yourself wearing it for every option?

- Did the self-related visualisation helped you making the final decision?
- When the option doesn't reflect any changes in the simulation, how did you decide?

- For a concealed or less obvious detail (collar stand or back), how did you decide?

- Can you describe the image you visualised during your final review?

- Are you satisfied with your design? Scale 1 - 5
- Are you confident this shirt will look good on you? Scale 1 - 5

Version 2.0
Date 22/03/2021

Appendix B: Codebook

Understanding Cognitive Effort Investment in Mental Imagery during Digital Product Customisation: A Case Study of Tailored Shirts

Codes highlighted in red are based on theories and constructs identified and adopted in the study during the deductive coding cycle.

Codes highlighted in yellow represent new themes that emerged, along with recurring patterns from the data, during the inductive coding cycle.

Deductive Codes:

1. Pre-Task Imagery **(14 instances)**

Description: References to mental images and design ideas before starting the customisation task

2. Post-Task Imagery **(13 instances)**

Description: References to mental images after completing the customisation task

3. Product Fit **(24 instances)**

Description: Remarks related to the product fit and sizing

4. Product Form **(37 instances)**

Description: Comments about product aesthetic details like colours, patterns, shapes

5. Product Function **(19 instances)**

Description: Discussion of product functional utility consideration

6. Design Satisfaction **(19 instances)**

Description: Feedback on satisfaction with the final customised product design

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

Version 3.0
Date 15/11/2023

7. Process Satisfaction (**11 instances**)

Description: Comments about satisfaction with the customisation process

8. Product-related visualisation (**46 instances**)

Description: Mental images focused on details of the product itself

9. User-related visualisation (**57 instances**)

Description: Mental images of user interacting with the product

10. Scenario-related visualisation (**18 instances**)

Description: Mental images situating the product in specific contexts or environments

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Inductive Codes:

Theme: **Visualisation Process**

1. Holistic Visualisation (14 **instances**)
2. Tactile Visualisation (6 **instances**)
3. Self-Visualisation (15 **instances**)
4. Mirrored Visualisation (4 **instances**)
5. Third-person Visualisation (3 **instances**)
6. Environmental Visualisation (6 **instances**)
7. Memory-based Visualisation (7 **instances**)

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

Version 3.0
Date 15/11/2023

Theme: **Decision-Making Strategy**

1. Comparative Approach (13 **instances**)
2. Filtering Approach (8 **instances**)

Themes: **Design Process**

1. Change in Direction (16 **instances**)
2. Revisiting Selections (9 **instances**)

Theme: **Problem & Challenges**

1. Choice Overload (9 **instances**)
2. Knowledge Gaps (8 **instances**)
3. System Constraints (14 **instances**)

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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Date 15/11/2023

Appendix III – A: Study Three – Participant Information Sheet

Imperial College London

Participant Information Sheet

Research Project Title

Choice Overload in Digital Product Customisation: A Transpositional Effort Scale (TES) to Understand Cognitive Effort Investment in Mental Imagery

Principal Investigator: Dr Leila Sheldrick

Co-investigators: Bowen Zhan

Invitation

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

This research is based on the industry's rapid trends of providing product customisation services. Digital technologies are offering new ways for retailers to work with end-users to create customised items. The study aims to understand how users evaluate a digital product, and the effort spent when visualising the product in mind. The study will investigate user interactions in a digital environment using an online configuration tool.

This study is being conducted for a PhD research project at Imperial College London.

Why have I been invited?

Your participation is important for us to understand how you evaluate digital objects before purchase and the effort invested in your decision making.

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All participants will be recruited using Prolific (Prolific.com). A total of 400 participants will be recruited for the study, which will take around 1 hour to complete.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep. Implied consent will be granted on the completion of the online survey. If you decide to take part you are still free to withdraw at any time and without giving a reason. You can withdraw from the survey and task assignment by exiting the survey session. All the non-completed survey responses will be deleted after one week.

However, if you intend to withdraw after the data is submitted, due to all the data being collected fully anonymised, we will be unable to locate your specific survey response. Therefore, your response cannot be deleted after you complete your survey.

What do I have to do?

The study will ask you to complete a survey questionnaire. In the middle of the survey, you will be direct to another page to use an online configurator to design your shoes. Your age group and gender will be collected during the survey questionnaire. All the collected data will be fully anonymised. There is no recording of any on-screen activities during the task of using the online configurator. There is no identifiable data collected during the task session. At the end of the session, several questions will be asked regarding how you made the decision based on your interaction with the configurator. You will need to upload the screenshot of your completed design during the survey to validate your participation.

All the data collected in the study are in digital format and will store in a password protected college computer for data analysis. The recorded data will store securely and used for internal data analysis purposes only. Access to the original data will be limited to the research staff and authorised personnel.

What are the possible disadvantages and risks of taking part?

Participating in the research is not anticipated to cause you any disadvantages or discomfort. There will be no sensitive questions asked in this study.

What will happen to the results of the research study?

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Results of the research will be published around July 2023. You will not be identified in any report or publication with reference to the interviews. If you wish to be given a copy of any reports resulting from the research, please ask us to put you on our circulation list.

- Who has reviewed the study?

This study was given approval by Weston Baxter, Head of Department of the School of Design Engineering and Research Governance and Integrity Team (RGIT).

Who is organising and funding the research?

Imperial College London is the study sponsor. The study is funded by the personal annual research allowance.

Contact for Further Information

Dr Leila Sheldrick
l.sheldrick@imperial.ac.uk

Bowen Zhan
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Thank you for taking part in this study!

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Appendix 1: Questionnaire

Cognitive Effort Investment in Mental Imagery: Understanding Transpositional Effort in Digital Product Configuration

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Transpositional Effort

$\alpha_{group1} = .847$, $\alpha_{group2} = .841$, $\alpha_{group3} = .829$, $\alpha_{group4} = .852$

Please now consider the following two stages in your decision-making process:

- The **design phase**, which took place **before** you completed your design.
- The ***review phase***, which will occur **after** you completed your design.

1. During the design process/***When reviewing your completed design***, did you have any mental images that only included the product itself?
   *(Yes or No; if **Yes**, to Ease, Vividness and Quantity; if **No**, skip to q2)*

2. During the design process/***When reviewing your completed design***, did you have any mental images of yourself using the product?
   *(Yes or No; if **Yes**, to Ease, Vividness and Quantity; if **No**, skip to q3)*

3. During the design process/***When reviewing your completed design***, did you have any mental images of yourself using your product in specific situations?
   *(Yes or No; if **Yes**, to Ease, Vividness and Quantity; if **No**, skip to Perceived Complexity)*

Ease: How easily were you able to create these mental images?
(1: imagining was difficult, 7: imagining was easy) (reverse item)

Vividness: How clear were these mental images that came to your mind?
(1: no image at all, 7: vivid and clear)

Quantity: How many mental images did you have?
(1: Few mental images, 7: Many Mental images)

Product Satisfaction

7-point scales (1: strongly disagree, 7: strongly agree)

$\alpha_{group1} = .748$, $\alpha_{group2} = .788$, $\alpha_{group3} = .759$, $\alpha_{group4} = .763$

1. The design result turned out better than I had expected.

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Date 22/07/2023

2. I was very satisfied with my design.

3. Given the identical set of design options to choose from, I would make the same choice again.

Decision Satisfaction

7-point scales (1: strongly disagree, 7: strongly agree)

$\alpha_{group1} = .720$, $\alpha_{group2} = .725$, $\alpha_{group3} = .721$, $\alpha_{group4} = .806$

1. I found there were many good options were available for me to choose from.

2. I was very satisfied with my experience of deciding which option to choose.

3. I found the process of deciding which option to choose was interesting.

Efficacy of the Process

= Product Satisfaction + Decision Satisfaction

$\alpha_{group1} = .777$, $\alpha_{group2} = .815$, $\alpha_{group3} = .785$, $\alpha_{group4} = .832$

Qualitative Questions

1. Did you explore various options before you settled on your final design? How much effort did this consideration take, and how did it affect your satisfaction with your final design?

2. Was there a point during the process where you felt overwhelmed by the options or started to find it difficult to make meaningful decisions? If so, can you describe that point and how it affected your overall experience?

3. Could you describe the effort you invested into creating mental images of your product? Where there specific moments that required more visualisation or were particularly challenging?

4. How do you believe the effort invested into creating mental images of your product influenced your satisfaction with the final design? Do you think that investing more effort into visualisation would have increased your satisfaction with the final product?

5. How did starting with a white design/a pre-designed inspiration influence your decision-making process? Do you think your experience would have been different if you had started from a pre-designed/a white design inspiration? If so, how and why?

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Appendix 2: Codebook

Cognitive Effort Investment in Mental Imagery: Understanding Transpositional Effort in Digital Product Configuration

Codes highlighted in red are based on theories and constructs identified and adopted in the study during the deductive coding cycle.

Codes highlighted in yellow represent new themes that emerged, along with recurring patterns from the data, during the inductive coding cycle.

Question 1: Design Exploration

"Did you explore various options before you settled on your final design? How much effort did this consideration take, and how did it affect your satisfaction with your final design?"

1. Code: **Effort Investment (61 instances)**

Description: Participants spent effort exploring design options.

2. Code: **Product Satisfaction (114 Instances)**

Description: Participants expressed higher or lower satisfaction with the final design.

3. Code: **Perceived Enjoyment (65 instances)**

Description: Participants expressed enjoyment in exploring design options.

4. Code: **Extent of Exploration (178 instances)**

Description: Participants described varying degrees of exploration.

5. Code: **Lack of Options (35 instances)**

Description: Participants expressed that there weren't enough configurable options.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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Question 2: Feeling Overwhelmed

"Was there a point during the process where you felt overwhelmed by the options or started to find it difficult to make meaningful decisions? If so, can you describe that point and how it affected your overall experience?"

1. Code: **Overwhelmed (69 Instances)**

Description: Participants felt overwhelmed

1.1 Parameter-based configurator **(43 instances)**
1.2 CvSS configurator **(26 instances)**
1.3 Code: Number of Options **(40 instances)**
1.4 Code: Number of Attributes **(21 instances)**

2. Code: **Not Overwhelmed (138 Instances)**

Description: Participants did not feel overwhelmed.

3. Code: **Appreciation for Variety (33 Instances)**

Description: Participants expressed appreciation for the variety of options.

4. Code: **Difficulty Making Decisions (23 Instances)**

Description: Participants had difficulty or described specific challenges in making decisions.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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Date 03/08/2023

Question 3: Mental Imagery Effort

"Could you describe the effort you invested into creating mental images of your product? Where there specific moments that required more visualization or were particularly challenging?"

1. Code: **Visualization Effort (161 instances)**

Description: Participants described varying levels of effort in visualization.

2. Code: **Ease in Imagining (79 instances)**

Description: Participants found it easy to create mental images.

2.1 Code: Product Simulation **(21 instances)**

3. Code: **Challenging Moments (42 instances)**

Description: Participants faced challenging moments in visualization.

3.1 Parameter-based configurator **(22 instances)**
3.2 CvSS configurator **(20 instances)**
3.3 Code: User-related Visualisation **(13 instances)**
3.4 Code: Scenarios-related Visualisation **(8 instances)**

4. Code: **Personal Connection (5 instances)**

Description: Participants expressed a personal connection to the design.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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Date 03/08/2023

Question 4: Influence of Mental Images

"How do you believe the effort invested into creating mental images of your product influenced your satisfaction with the final design? Do you think that investing more effort into visualisation would have increased your satisfaction with the final product?"

1. Code: **Effort Influence (Positive) (111 instances)**

Description: How effort in mental images influenced satisfaction.

2. Code: **Effort Influence (No Influence) (52 instances)**

Description: How effort in mental images influenced satisfaction.

3. Code: **Effort Influence (Negative) (5 instances)**

Description: How effort in mental images influenced satisfaction.

4. Code: **Potential change in Satisfaction (32 instances)**

Description: More effort in visualization could have increased satisfaction

5. Code: **Perceived Enjoyment (12 instances)**

Description: Participants emphasized enjoyment in the process.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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Date 03/08/2023

Question 5: Configurator Type Influence

"How did starting with a white design/inspiration influence your decision-making process? Do you think your experience would have been different if you had started from a pre-designed inspiration/ a white design? If so, how and why?"

1. Code: **Preference for Pre-designed Inspiration (73 instances)**

Description: Participants expressed they prefer starting from a pre-designed inspiration.

2. Code: **Preference for Blank White Design (99 instances)**

Description: Participants expressed they prefer starting from a blank white design.

3. Code: **No Preference (36 instances)**

Description: Participants expressed no preferences with the starting point.

4. Code: **Positive Influence (69 instances)**

Description: Starting with a white design/inspiration was helpful or inspiring.

4.1 Code: Quick and Easy process **(9 instances)**
4.2 Code: Encourage Creativity **(8 instances)**
4.3 Code: User Autonomy **(6 instances)**
4.4 Code: Perceived Ownership **(4 instances)**

5. Code: **No or Negative Influence (28 instances)**

Description: Starting with a white design/inspiration had no or negative influence.

5.1 Code: Challenging **(8 instances)**
5.2 Code: Overwhelming **(10 instances)**

6. Code: **Different Experience (85 instances)**

Description: Pre-designed inspiration/white design would have led to a different experience.

Code: Deductive Coding Cycle
Code: Inductive Coding Cycle

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