A FRAMEWORK FOR UNDERSTANDING MENTAL IMAGERY IN DESIGN COGNITION RESEARCH

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ABSTRACT

Mental imagery is the experience of perceiving an object within one's own mind and is a subjective experience, leading to difficulties in the research and understanding of the phenomenon. This paper documents the development and verification of a framework for researching the elements of mental imagery. The framework was developed following a review of both psychology and design literature which signified three fundamental conceptual viewpoints of mental imagery: imagery modalities, dimensions of imagery ability, and imagery processes. The aim of this framework is to allow for structured research on mental imagery in any given research field. This is verified through discussion for the product design engineering discipline and provides a base for future work on this topic. The conclusions made in this paper reveal that mental imagery, and particularly visual mental imagery, is largely considered to be integral in design overlooking the different realities of designers and confirming a greater need to understand mental imagery experiences in product design engineering.

Keywords: Mental imagery, Design cognition, Creativity, Design process

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1 INTRODUCTION

Mental imagery is the experience of visually, or with another sense, perceiving an image within one's own mind (Pearson, 2007; Nanay, 2018; Maciel et al., 2021). Whilst there is an abundance of research into the workings of mental imagery, the cognitive function is still not fully understood, due largely to the personal and subjective nature of mental imagery experiences (Richardson, 1991). Whilst research on the phenomenon of mental imagery is largely psychology-based and on psychological conditions (for example post-traumatic stress disorder) (Holmes & Mathews, 2010), it is widely acknowledged that it has significant importance across many other scientific and creative fields (Kozhevnikov et al., 2013) and an almost casual use in day-to-day life for many people (Pearson, 2007; Casakin & Kreitler, 2011).

The design industry spans a large variety of different professions and roles, including that of product design engineering. It is widely assumed that designers rely heavily on mental imagery, in particular on visual mental imagery, and that visual mental imagery is an essential part of design cognition (Hart & Hay, 2022). However, research shows that there are considerable variations in the experience of mental imagery, from different sense imagery (Floridou, Peerdeman & Schaefer, 2022) to differing levels of clarity between individuals (Gallagher, 2019; Zeman, 2021). There are even reports of distinguished animation artists (Gallagher, 2019) and visual artists (Zeman, 2021) reporting that they experience no visual imagery, and while product design engineering is a very different type of design to art and animation, there are similarities in the assumptions made regarding creative professions and visual mental imagery (Hart & Hay, 2022). Despite the evidence, there is a distinct lack of research into how designers use and experience mental imagery in product design engineering, particularly outside of the visual domain.

This paper provides an overview of the development of a framework for researching mental imagery, as well as current literature found to support its use in a product design engineering context. The framework will support structured research on mental imagery which, given the different and interconnecting elements, can be a relatively unstructured topic. Within product design engineering, the framework will allow for necessary discussion and help to find important areas for further research. This will create a basis for future work that considers all elements and viewpoints of a designer's experience of mental imagery within the design process.

2 DEFINING MENTAL IMAGERY IN DESIGN COGNITION RESEARCH

The field of mental imagery research is expansive and ranges from psychological uses for mental imagery (Holmes & Mathews, 2010) to benefits of imagery utilisation in the design industry (Dahl et al., 2001; Goldschmidt, 2007). This paper was developed from a literature review covering mental imagery research in design, with the scope of the literature ranging from psychology to design in order to gain an in-depth understanding of the experience and map out the research available. The literature was sourced using a range of trusted databases and journals covering both the design and psychology domains, and keywords and phrases that related to both psychology and design research. During this literature review it was realised that research on the topic of mental imagery is complex and interconnecting, with wide differences occurring between individual experiences. In order to provide more structure to the review, a framework was developed for researching mental imagery and applied within a design cognition context. Relevant papers were gathered and grouped together by themes and results that they had in common before the final viewpoints were specified. The final collection of papers that have been used were selected and justified based on their importance to the understanding of mental imagery experiences within design. This section provides a brief overview of the neurobiology and psychology of mental imagery to allow for context before detailing the development of the framework.

2.1 An overview of the neurobiology and psychology of mental imagery

It is widely acknowledged that mental imagery involves a complex brain network (Pearson, 2019), with evidence that activated brain regions are dependent on the form of imagery being engaged (Richardson, 1991). For example, neuroimaging revealed that visual mental imagery activates regions in the occipitotemporal cortex and the ventral visual stream within the brain, while the parietal cortex is active during spatial imagery (Dijkstra et al., 2019). Mental imagery is often described as a "perceptual experience" (Maciel et al., 2021) in which the mind behaves as if it is experiencing a physical sense.

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Evidence does suggest that the mental imagery activity can result in small physical reactions within the body, such as the pupils dilating or constricting in response to imagining light or dark scenarios and objects, in the same way as looking at a bright light (Laeng & Sulutredt, 2014; Zeman, 2021).
It has been determined that other cognitive functions are needed for mental imagery processing due to the complexity of the task, as is discussed further in this paper. The cognitive functions used within mental imagery may differ slightly depending on the task being undertaken, from daydreaming to visual imagination imagery, or even dreaming (Palmiero et al., 2016). For example, Zeman (2021) found that an individual asked to visualise a flower would need to use functions associated with being awake and attentive, whilst daydreaming often does not require someone to be fully attentive. Although mental imagery seems to play an important role in the day-to-day lives of many people (Kozhevnikov et al., 2013), there is still considerable scientific disagreement on what is involved and a number of competing hypotheses and models. This disagreement leads to added complexity in researching the function within design cognition and creates a solid basis for the development of a supportive framework.

2.2 Developing a framework for mental imagery research

Researching a topic as complex and subjective as mental imagery is a difficult task. Each person can have an entirely different experience of imagery, given that it exists entirely within one's own mind (Maciel et al., 2021). Within the development of the framework there are three fundamental conceptual viewpoints of mental imagery are identified. Considering literature from both psychology and design it was determined that these viewpoints consist of **imagery modalities**, the **dimensions of imagery ability**, and **imagery processes**. Imagery modalities consists of the different senses in imagery, as well as the connection and impact of emotion; dimensions of imagery ability are topics such as imagery vividness, spatial ability, and measurements of imagery; and imagery processes involves tasks such as image generation and retention, or the use of memory images. Whilst these can be standalone topics, it is necessary to keep in mind how closely they all interact with each other. For example, dimensions closely interact with modalities in that individuals can have differing levels of vividness across different modalities (Maciel et al., 2021), and memory imagery (process) can impact on emotion and modalities (Taruffi & Küssner, 2019). Figure 1 provides a graphic interpretation of the framework, and depicts the three viewpoints surrounding the main topic, with all viewpoints interconnecting, and then converging back into the centre. This framework has been developed with the expectation that it can be employed to research mental imagery within different fields. Exactly that has been done here for product design engineering, and the remainder of this paper is a discussion of the literature findings as verification of the framework.

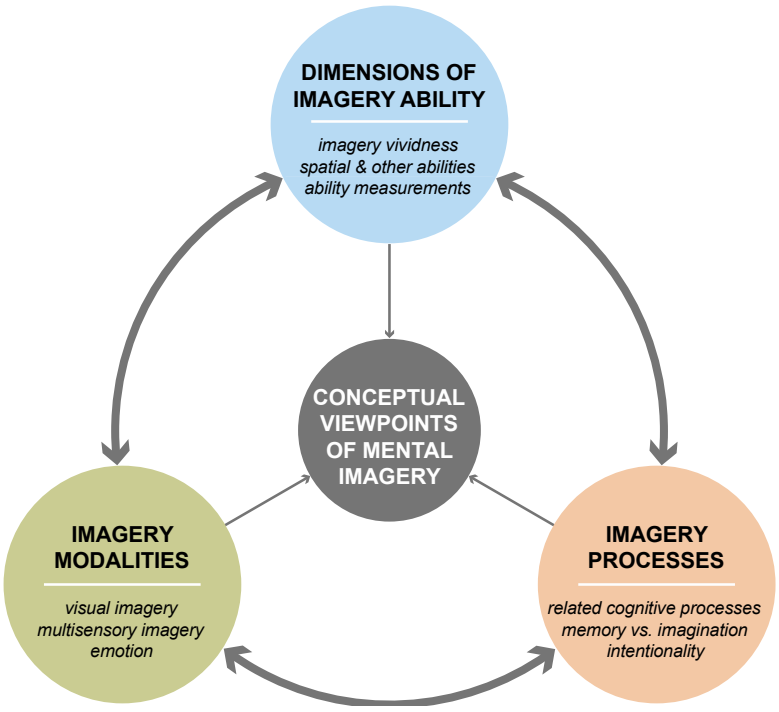

Figure 1: Framework for understanding the multiple viewpoints of mental imagery

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3 MENTAL IMAGERY IN PRODUCT DESIGN ENGINEERING

As mentioned, it is regularly assumed that design and mental imagery are consistently closely intertwined (Goldschmidt, 1991; Hart & Hay, 2022). This assumption, however, overlooks that the mental imagery experience can vary greatly between designers, design processes, and design tasks. It has been shown throughout research that designers are capable of creating entirely within the "mind's eye" (Athavankar, 1997) or despite having no experience of mental imagery at all (Gallagher, 2019; Zeman, 2021). Through the framework developed and detailed above, it is possible to analyse the relevant design research, as well as any psychological research that may contain important insights for design.

3.1 Mental imagery modalities

Commonly, mental imagery is believed to be an entirely visual experience, but in reality, it is a multisensory experience activated through the senses and can include auditory, olfactory, tactile and motor function imagery (Goldschmidt, 1994; Maciel et al., 2021). The majority of mental imagery research, particularly within design, focuses on visual imagery, largely disregarding other modalities. One potential reason for this is that it is commonly believed (potentially erroneously) that visual imagery is the most dominant modality that designers use (Bensafi et al., 2012). Whilst visual imagery in particular is useful for problem-solving as it encourages creative thinking and allows for easier simulation both internally and externally (Athvankar, 1997; Bilda et al., 2006; Bilda & Gero, 2008), it would be naive to assume that other modalities do not have use in design.

3.1.1 Visual imagery

Visual mental imagery, often referred to as “visual thinking”, “visual perception” or “visualisation” (Goldschmidt, 1994; Dahl et al., 2001; Kavakli & Gero, 2001; Zeman, 2021) refers to the act of “seeing” within the so-called “mind’s eye”. It refers to a task that is similar to visual perception (Cui et al., 2007), and is often triggered by information obtained from a stimulus other than a visual representation itself (Kosslyn, Behrmann & Jeannerod, 1995), for example music can trigger visual memories (Taruffi & Küssner, 2019). Often, visual mental imagery consists of a remembered image, either in its initial form or as a modification of remembered information (Taruffi & Küssner, 2019).

In neurobiological terms, there is evidence to suggest that mental imagery and visual perception rely on similar neural mechanisms within the brain (Dijkstra et al., 2017; Dijkstra et al., 2019) and that impacts on visual perception can also impact on mental imagery (Pearson et al. 2011). An example may be found in the binocular rivalry paradigm (Dijkstra et al., 2019). Binocular rivalry describes the visual fight for perceptual dominance that occurs when a person is shown two differing images at one time. In terms of mental imagery, there is evidence that if an observer mentally visualises one of the images first, it produces a bias whereby this is the image they will likely perceive (described by Dijkstra et al. (2019) as having “a priming effect”).

Whilst mental imagery has been shown to improve both experience and outcome in design, several designers claim to refuse to use it or cannot use it due to reduced vividness (Dahl et al., 1999; Dahl et al., 2001). Gallagher (2019) provided evidence that creative individuals and designers can successfully design despite having low or no visual imagery, and so it can be deduced that the assumption that mental imagery is key to design (Bilda & Gero, 2008) is not necessarily correct.

3.1.2 Multisensory imagery

As noted earlier, mental imagery can occur in each of the senses and measuring such will be discussed further in this report. Whilst an individual can experience all forms of imagery, it is also possible for them to experience differing variations, for example one may experience high levels of imagery in every modality except visual (Maciel et al., 2021). Multisensory imagery has a vast range of applications, including psychological treatments, such as auditory imagery in cognitive behavioural therapy (CBT) (Nanay, 2018). There is also evidence that physical sensory practice has immense effects on imaging ability: musicians tend to outperform non-musicians in auditory vividness questionnaires, and perfumers have stronger reported olfactory imagery than the general public (Bensafi et al., 2012). Whilst research into the impact of multisensory imagery in design is extremely limited, it is interesting to consider whether there is a significance to some of these findings within a design setting, such as theorising if designers have stronger visual imagery because they are trained in a largely visual setting.

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3.1.3 Emotion and mental imagery

Research provides strong links between emotion and mental imagery, and suggests that trait empathy differences are linked to higher levels of imagery (Taruffi & Küssner, 2019). Mental imagery often has a greater emotional impact than verbal interpretations of potential future situations as it allows for "pre-experiencing" of said situations (Ji et al., 2022) and there is evidence that mental imagery plays a key role in emotional and psychiatric disorders and treatments (Holmes & Mathews, 2010). Additionally, there is physical evidence that fear imaging produces a stronger response than neutral situational imaging in that, for example, fearful mental imagery has been shown to cause an increased heart rate (Holmes & Mathews, 2010). As discussed, multi-sensory mental imagery appears to mimic multi-sensory perception in those that are capable of the experience and evidence suggests that emotional imagery works in the same way. For example, if an individual has a phobia of snakes, using mental imagery to visualise a snake approaching would cause a similar emotional response as physically watching a snake approach (Holmes & Mathews, 2010). Additionally, the nature of an image, as well as the emotional capabilities of the individual, will play a role in the impact an image has; there is evidence that the more vivid visual imagery a person experiences, the more intense and emotional any imagined future events are (D'Argembeau & Van der Linden, 2006, Holmes & Mathews, 2010). Within a design context, evidence shows that if a designer visualises the customer use of a product, it can increase the level of empathy featured in the design process and lead to a greater understanding of the customer's perspective (Dahl et al., 2001).

3.2 Dimensions of imagery ability

The mental imagery experience is different for each individual and is not one-size-fits-all, with individuals experiencing mental imagery at varying ability and clarity (Kavakli & Gero, 2001). Mental imagery is a largely personal experience and therefore subjective (Richardson, 1991) and while differences can occur across different modalities, the research on dimensional abilities largely refers to visual imagery.

3.2.1 Mental imagery vividness

The spectrum of mental imagery clarity is normally referred to as the "vividness" of mental imagery. Individuals report anywhere from a complete lack of mental imagery to extremely vivid mental imagery (Cui et al., 2007; Kozhevnikov et al., 2013; Pearson, 2019; Bainbridge et al., 2021; Zeman, 2021), though the research primarily covers clarity or vividness differences in the visual modality. Whilst differences in visual imagery vividness have been discussed for decades, it was only in 2015 that the extremes of aphantasia and hyperphantasia were named by Professor Adam Zeman (Bainbridge et al., 2021; Zeman, Dewar & Della Sala, 2015). Aphantasia is the complete lack of visual mental imagery (Gallagher, 2019; Zeman, Dewar & Della Sala, 2015), while hyperphantasia describes imagery so vivid it can be similar to a physical sensation (Bainbridge et al., 2021). Aphantasia affects roughly 1-3% of people, although most adults knowingly living with aphantasia do not realise it exists until they are into adulthood (Rhodes, 1981), whilst hyperphantasia affects around 3-7% (Zeman, 2021). Milton et al.'s (2021) studies suggest people with hyperphantasia perform better in memory tests, whilst people with aphantasia tend to be less extraverted and open than those with hyperphantasia. Despite the lack of visual mental imagery, aphantasia does not usually have a negative impact on life experience (Bainbridge et al., 2021) nor does it necessarily impact on creative abilities (Gallagher, 2019; Zeman, 2021).

3.2.2 Spatial and other abilities

According to Allan (2010), the components of imagery spatial ability include mentally seeing in 2-dimensions (2D) within a 3-dimensional (3D) environment, mentally rotating objects, and mentally seeing objects in scale within mental imagery. There is evidence that while those with diagnosed or self-diagnosed aphantasia consistently score as such on visual imagery tests, they tend to still score highly on mental rotation and spatial ability tests (Keogh & Pearson, 2018). This implies potentially separate functions for different abilities, but there is a lack of further research into this occurrence.

Mental scanning is a task where an individual perceives, within imagery, moving from one point to another, usually engaging visual imagery (Gallace, 2012). Another example of a difference in dimensional ability is the timing for mental rotation (Pearson et al. 2011) and the speed at which individuals manipulate or process images within their mind: there is evidence that the more mental

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rotation that a task requires, the longer said task will take (Kosslyn, Behrmann & Jeannerod, 1995). Researchers in mental rotation differences tend to rely heavily on theories of embodied cognition and suggest that this plays a role in differences (Voyer et al., 2020). Whilst standard definitions perceive cognition as a computational activity with the brain performing the operation alone, embodied cognition provides a more complex and inclusive view (Tedjosaputro & Shih, 2019). Embodied cognition views thinking as an active relationship between the body, the mind and the surrounding environment, where cognition is the body's interaction with the world (Tedjosaputro & Shih, 2019).

3.2.3 Measurement systems

Measurement systems have been developed across the field of mental imagery psychology research as a way of quantifying the different imagery experiences. The most common method of measurement within psychology are written or verbal self-report questionnaires. One example of these questionnaires are spatial or mental rotation ability tests which use pictorial questions to ask the responder to match up rotated images (Peters et al., 1995). Whilst the exact nature, appearance and content of visual mental imagery is difficult to measure, the Vividness of Visual Imagery Questionnaire (VVIQ), first developed by psychologist David Marks in 1973 (Bainbridge et al., 2021), is a written questionnaire designed to provide a way to measure vividness of mental imagery through scenario-style questions (Kozhevnikov et al., 2013; Zeman, 2021). Further questionnaires have been created in an attempt to quantify multisensory imagery vividness, such as the Plymouth Sensory Imagery Questionnaire (PSI-Q), which was developed to measure appearance, sound, smell, taste, bodily sensation, feeling and touch imagery (Andrade et al., 2014). In psychology, so-called "social desirability measurements" have been suggested to minimise the subjective nature of mental imagery questionnaires. Social desirability scales are a psychological measure that were designed to test whether individuals answer self-response tests in what is seen as a culturally approved way by presenting questions and scenarios that intend to describe improbable or negative behaviours (Holtrop et al., 2021). It is believed that if a person responds to many of these claims in a way that depicts them as an overly virtuous person, they are more than likely lying or answering in what they deem to be a socially desirable way (Holtrop et al., 2021).

Whilst still lacking in evidence, other measures of imagery vividness have been suggested which could provide a more objective form of measurement (Bainbridge et al., 2021). According to Cui et al. (2007), it is possible that the vividness individuals experience is directly linked to the activity of their visual cortex, and it has been suggested that there could be a way to develop a method using modern technology, for example fMRI, which tracks and measures the visual cortex. There is further evidence in Pearson, Rademaker and Tong (2011) which shows that subjective vividness ratings can predict level changes in the visual cortex during mental imagery. More recently, there has been evidence that pupil response may be an appropriate measure of aphantasia. Hawley's (2022) work has shown that when asked to mentally visualise a light versus a dark image, the pupils of people living without aphantasia respond as they would to visually seeing a light versus a dark object, whereas in people living with aphantasia, there is no pupil response when asked the same.

Measurement systems for mental imagery within design itself are lacking, but one method for understanding experiences during design tasks is protocol analysis. Protocol analysis is a psychological method that comes under the banner of self-reporting and allows for the analysis of mental processes through verbal reports (Hay et al., 2017; Lawrie, Hay & Wodehouse, in press). In design research, protocol analysis is undertaken through visual and audio recordings of a designer either during or after a design task, following which the recordings are coded and analysed according to a coding scheme (Gero & McNeill, 1998; Hay et al., 2017; Lawrie, Hay & Wodehouse, in press). The recordings can include verbal responses, sketches, and actions (Hay et al., 2017). Although the high level of data gathered in protocol studies makes it a very time-consuming analysis method, the detailed insight into the internal process of a designer, which is a subjective experience, makes is a popular method in design research (Hay et al., 2017).

3.3 Mental imagery processes

Mental imagery processes, meaning the imagery actions and tasks undertaken by an individual, can take many different forms and styles, from the generation, transformation and inspection of imagery (Rademaker & Pearson, 2012) to perceptual or active imagery (Kavakli & Gero, 2001). Kosslyn, Behrmann and Jeannerod (1995) suggest that mental imagery involves a number of working processes that include forming, scanning, interpreting, maintaining and transforming images. In the same

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literature, mental imagery processes are grouped into four categories: learning and memory, perception and action, information processing, and reasoning using imagery (Kosslyn, Behrmann & Jeannerod, 1995). The term "interactive imagery" has been used to describe the task of refining and transforming images within the mind due to the ease at which individuals can interact with and manipulate the shapes (Goldschmidt, 1991). The experience of mental imagery itself allows individuals to access thoughts, senses, and emotions entirely within their mind and provides a strong base for creating new ideas (Palmiero et al., 2016).

One often discussed difference in mental imagery processes are the clear distinctions between memory imagery and imagination imagery (Rhodes, 1981; Dahl et al., 1999; Dahl et al., 2001; Pearson, 2007; Pearson, 2019). Whilst mental imagery can include the creation of new, "imagined" ideas and images, it can also be as simple as remembering an image or idea that has already been defined within memory (Dahl et al., 1999; Dahl et al., 2001; Kavakli & Gero, 2001). Different imagery processes can impact on problem-solving in design: memory imagery allows the designer to draw from their own experiences and knowledge to design a product, whilst imagination imagery can allow them to create more novel ideas (Dahl et al., 1999; Dahl et al., 2001). Evidence suggests most designers will automatically begin by focusing on memory imagery before moving to imagination imagery, if they are capable, likely due to it being simpler to start from something they know and have experienced (Dahl et al., 2001). For this reason, it is somewhat unsurprising that Gero and Milovanovic (2020) found that designers who are experienced in their fields tend to think and work faster and more intuitively than novice designers. Whilst both memory and imagination imagery are described as useful for the design process, imagination imagery has been suggested as more efficient for product ideation as it appears to allow for a more novel product (Dahl et al., 1999; Herd & Mehta, 2019).

One way in which we can discuss imagery use is through intentionality and whether mental imagery is experienced voluntarily, meaning an individual can willingly call up images within their mind, or involuntarily, such as whilst experiencing intrusive thoughts (Floridou, Peerdeman & Schaefer, 2022). There is a simplicity that comes with using mental imagery in design (Goldschmidt, 2007) due to the potential reduction in tools needed and the ease with which new ideas can be generated. Furthermore, as design is heavily dependent on context (Goldschmidt, 2007), evidence suggests that a designer's experience of visual imagery during the design process can have a big impact on both the novelty and usefulness of the final design (Dahl et al., 2001). Additionally, the transformation from mental imagery to physical visualisation creates a form of balance between fantasy and reality that allows for more creative and novel designs (Allen, 2010). However, evidence suggests that experienced designers are still reluctant to take full advantage of the experience of mental imagery to assist them in design, or so they claim (Dahl et al., 2001). It is possible that this could be explained by intentionality: if a designer assumes that their mental imagery is an involuntary or expected part of the design process, we can theorise that they may be overlooking the potential power of voluntarily creating new ideas within their so-called mind's eye.

There are different steps within mental imagery according to Casakin and Kreitler (2011), and designers alternate between "framing", "making moves" and "evaluating moves" during the design process to navigate their way through problem-solving. An important point raised by Bilda and Gero (2008), is that whilst design obviously occurs during the design process itself, it can also occur out with the physical design environment, and a designer could find themselves struck with inspiration at another time, for example while travelling from work. Through the phenomenon, a designer can have an idea or a design breakthrough at any time, with inspiration coming from even the smallest places (Bilda & Gero, 2008).

Mental imagery does come with its own set of issues, such as problems stemming from short term memory – if a designer was to create entirely within their own mind, they would be at risk of forgetting and excluding parts of the final design (Athavankar, 1997). One method around this issue is to use mental imagery in conjunction with tools and design methods, such as mind mapping, which in itself is a method that relies heavily on imagery and the fast processing of ideas within the mind (Athavankar, 1997; Bilda & Gero, 2008). Techniques such as this encourage the designer to look for creative solutions within their own skill base and knowledge (Allen, 2010). As mentioned throughout this paper, the use of mental imagery is an entirely internal process, meaning that designers live within their own catalogue of images and design can rely on the interaction between this internal process and external processes, such as sketching (Athavankar, 1997; Bilda & Gero, 2008; Tedjosaputro et al., 2014). Most designers would argue that sketching is an essential step in the design process

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(Athavankar, 1997) and it is a simple yet reliable method of communication and reasoning which encourages the development of ideas (Goldschmidt, 1991; Bilda & Gero, 2008; Tedjosaputro et al., 2014). Sketching is particularly useful within design teams as it increases communication by allowing ideas and images to be shared more easily (Goldschmidt, 2007).

4 CONCLUSIONS

The literature review conducted for this paper provided insight into how mental imagery can be successfully researched within the context of product design engineering. It allowed the development of a framework breaking down the elements involved in mental imagery research. It was found that mental imagery can be split into three conceptual viewpoints that can be viewed interconnectedly with each other: imagery modalities, dimensions of imagery ability, and imagery processes. Whilst this research is limited by the amount of literature on the topic in product design engineering specifically, it was found that psychology research and design research in other domains, such as architecture, could have relevance to the field of product design engineering.

Mental imagery itself is a personal experience with designers able to manipulate the ideas within their minds (Athavankar, 1997; Oxman, 2002). The subjective nature of the experience leads to different definitions and understandings. This is a particular issue in a field such as design, where individuals are strongly believed to need mental imagery to thrive (Hart & Hay, 2022). In this paper, the framework presented in Figure 1 was used to structure the literature on mental imagery from across the design and psychology fields. This has allowed a greater insight into the aspects of the mental imagery experience that should be considered when researching the topic in the product design engineering context, as well as providing evidence of the different experiences of mental imagery (Gallagher, 2019; Zeman, 2021). The use of the framework in respect to product design engineering alongside further work on this topic should allow for a definition of mental imagery within the field to emerge.

An important detail of the framework that should be considered during mental imagery research is that each of the viewpoints interact with each other. It is difficult to consider one element of mental imagery without keeping the others in mind, particularly when considering how it is experienced within product design engineering. An example of this is that Maciel et al. (2021) found that it is possible that individuals can experience differing levels of mental imagery vividness for different modalities. Given the varying experiences of visual mental imagery in design (Gallagher, 2019), it is feasible that different designers use different sensory perception at different levels. Additionally, Dahl, Chattopadhyay and Gorn (1999; 2001) found that intentionally utilising mental imagery within the design process by way of visualising the end user of a product provides a designer with a greater sense of empathy, leading to more useful final products. Given that there is an intricate connection between emotion or empathy and imagery (Taruffi & Küssner, 2019), it is feasible that there is a link between intentionality of mental imagery (process) and emotion or empathic ability in design (modality).

This review has uncovered important literature on the experience of mental imagery in product design engineering. However, there is a significant lack of research on the topic within the relevant field, leading to questions about how mental imagery is experienced and if it can be better utilised to create stronger solutions. Given that there is still a strong assumption that design and mental imagery are inherently connected but that there is evidence suggesting this is not the case (Gallagher, 2019; Zeman, 2021), it is worth considering that important aspects are being overlooked. For example, can a designer choose which imagery modality to use during design, or are they able to train their intentionality? For this reason, it is evident that this framework can be used further in potential studies as a way of considering the aspects that may impact a designer's experience, use or understanding of their own mental imagery during the design process.

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