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Do You See What I See? Exploring Vividness of Visual Mental Imagery in Product Design Ideation

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Abstract

This paper reports a preliminary study (N=16) exploring vividness of visual mental imagery in product design ideation. Vividness was observed to vary across designers in the study, from high (68.8% of participants) to moderate (18.8%) to low (12.5%). A significant, strong positive relationship was found between vividness and creativity. Most participants reported using imagery always or sometimes, except one who has difficulties forming mental images. The results have several implications, including the possibility of other 'ways of imagining' not captured by visual reasoning models of design.

Keywords: design cognition, design creativity, visualisation, mental imagery, idea generation

1. Introduction

Designers are believed to rely heavily on the mind's eye throughout the design process, to mentally visualise, transform, and simulate ideas and scenarios (Goldschmidt, 1991; Park and Kim, 2007). This cognitive function is broadly termed visual mental imagery (or 'visual imagery') (Hay *et al.*, 2017). Particularly in the early, conceptual phases, it is thought that designing involves a dynamic interplay between visual mental imagery and external representations such as sketches. Interpreting the visual elements of sketches stimulates evolution in the designer's mental images, which in turn drives changes to the external representation, which stimulates further mental imagery processing - and so proceeds the emergence and development of the design artefact over time (Goldschmidt, 1991). A series of studies on architects and product designers in the late 1990s and early 2000s even found that blindfolded designers - with no access to sketching or external representations - can successfully develop design concepts using mental imagery alone (e.g. Athavankar, 1997; Bilda *et al.*, 2006).

Much of our current thinking about product design education and practice is predicated on the idea that designers use visual mental imagery to design. 'Visual reasoning' is conceptualised as an essential component of conceptual design cognition. But few appear to have asked the counter-question: is it possible to design *without* using visual imagery? Do all product designers experience visual imagery in the same way? And if not, does this have an impact on their design performance and approach to conceptual design activities? To understand why these questions are worth exploring, we must consider a key dimension of visual imagery processing that has not received much attention in design research: the *vividness* with which mental images are subjectively experienced (Fulford *et al.*, 2018; Marks, 1973). Research in psychology and cognitive neuroscience has shown that not only are there considerable individual differences in vividness, there also exist extremes that are associated with distinct neural and behavioural correlates: (1) *hyperphantasia*, where imagery is "as vivid as real seeing;" and (2) *aphantasia*, where there is a complete absence of any sort of visual imagery (Zeman *et al.*, 2020, p.427). Work in this

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area is nascent; however, a study by Zeman *et al.* (2020) found that aphantasics wre more likely to work in scientific or mathematical domains, and hyperphantasics in creative professions.

So far, so good for visual reasoning models of design - based on these findings, it seems likely that product designers occupy the higher end of the vividness spectrum and are therefore particularly adept in the generation and manipulation of mental images. However, intriguing personal accounts from creative practitioners in other domains suggest that this may not necessarily always be the case. Renowned animator and illustrator Glen Keane reports an inability to mentally visualise, and claims to work solely with external representations in the creation and development of his characters. Ed Catmull, computer graphics expert and co-founder of Pixar animation studios, reports a complete absence of visual mental imagery, saying that he has a 'blind mind's eye'. A survey of his staff at Pixar also produced some surprising findings. For example, two acclaimed animation artists reported stark differences in visual imagery, with one able to mentally visualise and play a whole movie with ease, and the other unable to mentally visualise anything at all (Gallagher, 2019). Similarly, Adam Zeman and his colleagues have identified numerous hyperphantasic artists, but they have also been contacted by many who report experiencing little to no visual mental imagery - much to their surprise (Zeman, 2021).

These personal accounts are largely anecdotal, and animation and art are of course not equivalent to product design. However, given that all of these disciplines are presumed to heavily involve the visual domain, the accounts nonetheless raise fundamental questions about the role of visual mental imagery in the creation and development of product ideas. Although aphantasia is the extreme and therefore uncommon, imagery vividness in the general population still varies considerably (Milton *et al.*, 2021). It is therefore quite likely that product designers also vary in this dimension, at least to some extent. It is also conceivable, based on the personal accounts above, that there is a minority of product designers who experience no visual imagery at all. However, despite the perceived importance of visual imagery in design, there have thus far been no systematic investigations of imagery vividness in product designers and its role in conceptual design. As a first step towards increasing understanding in this area, this paper reports a preliminary study aiming to explore the vividness of visual imagery in product designers and its relationship with performance in a key conceptual design activity: ideation.

As discussed further in Section 5, individual differences in imagery vividness amongst product designers could have implications for scientific models of designing as well as pedagogical approaches in product design education. If there are designers with low vividness, who rely less (or not at all) on visual imagery in the development of ideas - does this mean there are alternative 'ways of imagining' that should be recognised by design researchers and educators? Could there be alternatives to visual reasoning models, or extended models that take into account a broader range of modalities, cognitive processes, and behaviours? When teaching conceptual product design, do we need to recognise and support a range of visual imagery abilities and different approaches to the generation and development of ideas? Or do we need to formally train students in how to vividly visualise, in the same way we train them how to sketch and externally represent ideas? We do not provide definitive answers to these questions here, but report an initial effort to quantify vividness in conceptual design as a foundation for further investigation.

2. Existing work on visual mental imagery in design

The concept of 'the mind's eye' has a long cultural, philosophical, and scientific history. In the 1800s, Sir Francis Galton was among the first to document individual differences in the ability to form visual mental images (Galton, 1880). Visual imagery has been the subject of much debate in psychology and neuroscience, with disagreement on how images are formed and used by the brain and the extent of cognitive/neural overlap with visual perception (Ganis, 2013). The work of a number of researchers, notably including Stephen Kosslyn (Kosslyn, 1995), has been influential in establishing knowledge about the cognitive processes involved in visual mental imagery. More recently, neuroimaging studies have begun to map the underpinning neural regions and networks (Fulford *et al.*, 2018).

As discussed in Section 1, visual mental imagery features prominently in visual reasoning models of design and is believed to play a key role in the generation and development of design concepts. This work is primarily based in the domains of product design, architecture, and engineering design. We searched major journals and conferences in these areas for papers on visual mental imagery, and found that there have been relatively few empirical studies on this topic in over six decades of design cognition

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research. Out of the 53 papers we found discussing visual imagery in some capacity, 31 reported empirical studies aiming to describe and/or quantify imagery processing in design (primarily protocol studies). Papers on visual imagery in design may be broadly split into four categories:

- Work conceptualising the dynamic interplay between visual mental imagery and sketching in conceptual design, notably including Fish and Scrivener's (1990) account of a hybrid percept-image theory of sketching and Goldschmidt's (1991, 1994) seminal work on dialectical modes of visual reasoning (seeing as and seeing that) driven by sketching, imagery, and interpretation. More recent work in this category includes the visual reasoning model proposed by Park and Kim (2007), which decomposes and links seeing, imagining, and drawing processes.
- Work importing and applying theories and models of visual mental imagery from psychology to design, including, for example: Purcell and Gero's (1998) account relating psychological theory to drawing in design; Kokotovich and Purcell's (2000) application of mental synthesis models and approaches in the study of creative synthesis and drawing in design; Kavakli and Gero's (2001, 2002) experiments on and accounts of sketching as mental imagery processing; and Oxman's (2002) exploration of visual emergence in design, drawing from psychological theory on visual perception and mental imagery.
- Studies on blindfolded designers, including Athavankar (1997), Bilda *et al.* (2006), and Athavankar *et al.* (2008), which demonstrated that designers can develop design concepts using mental imagery alone and with no access to external representations. More recently, Tedjosaputro *et al.* (2017) found that sketching and mental imagery (without sketching) both support ideation but in different ways.
- Work quantifying aspects of visual imagery ability in designers, such as Shah *et al.* (2013) who develop tests to measure different aspects of visual thinking in engineering design, including various dimensions of mental imagery ability (e.g. image rotation and transformation).

The work by Shah *et al.* (2013) above seeks to quantify individual differences in visual perception and imagery ability across designers. However, a key dimension of imagery processing that they do not directly measure is the vividness with which mental images are conjured and experienced. As discussed in Section 1, vividness varies widely across the general population, with aphantasia (complete absence of visual imagery) and hyperphantasia (imagery as vivid as real seeing) the extremes at either end of the spectrum (Milton *et al.*, 2021). Vividness is typically measured using the Vividness of Visual Imagery Questionnaire (VVIQ) developed by Marks (1973). In the VVIQ, respondents are asked to mentally visualise a range of scenarios and then rate the vividness of the image. The scores for each item are summed to give an overall score that indicates the respondent's self-reported imagery vividness.

Whilst the VVIQ has been demonstrated to be a reliable and valid instrument (Campos and Pérez-Fabello, 2009), it is inherently subjective - it is possible that different people have different understandings of what it means to 'form an image in the mind', and there is no common reference point for the vividness of such images. However, recent work comparing individuals reporting aphantasia, hyperphantasia, and midrange imagery vividness (Milton *et al.*, 2021) found significant differences in cognitive functions (autobiographical memory and imagination, face recognition) and personality traits (extraversion and openness) between the groups. Greater functional connectivity between the prefrontal cortex and visual brain networks was also observed in hyperphantasics compared to aphantasics. This suggests that aphantasia and hyperphantasia are distinct neuropsychological states, and provides stronger evidence for the existence of true individual differences in imagery vividness.

As conveyed above, the majority of the work on visual mental imagery in product, architectural, and engineering design to date has focused on describing the kinds of imagery processes involved in conceptual design activities, with a particular focus on the role of imagery in ideation and concept development (with and without sketching). Individual differences in how vividly designers conjure and experience imagery, and the relationship between vividness and design performance, have not been explored. In Section 3, we outline a preliminary study conducted as an initial step towards understanding these aspects in product design ideation, motivated by recent work on aphantasia/hyperphantasia and the varying personal accounts of vividness from creative practitioners discussed in Section 1.

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3. Methods

The reported study aimed to explore the vividness of visual imagery in product designers and its relationship with creative performance in ideation. 'Creative performance' was the focus because generating creative ideas is often framed as a key goal of ideation. There were three research questions:

1. To what extent does visual imagery vividness vary across product designers (RQ1)?
2. What is the nature of the relationship (if any) between visual imagery vividness and creative performance during product design ideation (RQ2)?
3. If there is variation in vividness, how do product designers with different vividness levels use imagery during ideation tasks (RQ3)?

The approach involved methods from psychology and design research, and is described in the following sub-sections. The study was conducted during a Covid-19 lockdown in October/November 2020, and as such there were several necessary limitations (discussed fully in Section 5). Nonetheless, the work provides preliminary insights into imagery vividness in conceptual product design.

3.1. Participants

A total of 16 individuals participated in the study. All were undergraduate product design students in the final year of a five year integrated Masters degree at the University of Strathclyde (UoS). The study was approved by the Department of Design, Manufacturing and Engineering Management Ethics Committee at UoS. Participants received no reimbursement for taking part in the study.

3.2. Tasks and procedure

Participants completed a design ideation task focusing on an open-ended product design problem and sketched their solutions. Afterwards, they completed two questionnaires on visual imagery: (1) the Vividness of Visual Imagery Questionnaire (VVIQ); and (2) a questionnaire on the use of visual mental imagery during design ideation. The whole experiment was conducted over Zoom due to the Covid-19 lockdown, and the questionnaires were hosted on the Qualtrics platform. Prior to starting the experiment, participants were provided with an overview of the study and informed consent was obtained.

3.2.1. Ideation task

The problem used in the ideation task was: *"Lighting towns and cities at night has negative environmental impacts e.g., fossil fuel depletion; light pollution; and disruption to wildlife. Generate concepts for products that may improve the environmental impacts of lighting urban areas."* This problem was developed in a prior fMRI study on design ideation, where it was piloted to ensure that the task was of moderate difficulty and participants could generate a range of different solutions (Hay *et al.*, 2019). During the experiment in the present study, the problem was presented to participants on screen over Zoom and they were given 10 minutes to generate up to five concepts (timings were determined through pilot studies with two design students). They were instructed to quickly sketch their concepts on paper, with just enough detail to be understood by the experimenter later. They were asked to clearly distinguish individual concepts and use annotations for further explanation where necessary. Participants scanned their sketch sheets and emailed them to the experimenter.

3.2.2. Vividness of Visual Imagery Questionnaire (VVIQ)

Once participants had completed the ideation task, they were given a link to complete the VVIQ. The VVIQ (Marks, 1973) consists of 16 items, which require participants to mentally visualise different scenarios and then rate the vividness of various aspects of the image along the following scale:

- 1 = Perfectly clear and as vivid as normal vision
- 2 = Clear and reasonably vivid
- 3 = Moderately clear and vivid
- 4 = Vague and dim
- 5 = No image at all, you only “know” that you are thinking of the object

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An example of a scenario is: *a country scene which involves trees, mountains and a lake*. Participants are then asked to rate the vividness of the following aspects: *the contours of the landscape*; *the colour and shape of the trees*; *the colour and shape of the lake*; and *a strong wind blows on the trees and the lake causing waves*. For each participant, the scores for the items were averaged to give an overall score that indicates self-reported imagery vividness.

Participants were instructed to complete the mental visualisation tasks in the VVIQ in whatever way felt most natural to them, e.g. with their eyes open or closed. No time limit was imposed on completion.

3.2.3. Use of imagery questionnaire

After completing the VVIQ, participants were lastly given a link to complete a questionnaire on the use of visual mental imagery in product design ideation. This consisted of four questions, and aimed to gain qualitative insights into how product designers with varying vividness levels use (or do not use) imagery to support their ideation process. The questions were:

1. Do you apply mental imagery in ideation tasks? (yes, always; sometimes; or no, never)
2. Please explain how you use imagery in ideation tasks.
3. If you do not use imagery in ideation tasks, please explain why.
4. Do you think mental imagery helps you produce creative outcomes in ideation tasks?

3.3. Creativity assessment

The creativity of generated concepts was subjectively rated. It was challenging to involve multiple expert raters in the study due to the Covid-19 lockdown. As such, creativity ratings were carried out by the experimenter alone (a limitation that is discussed further in Section 5). The experimenter was a product design student in the final year of a five year integrated Masters degree, and therefore considered to have sufficient domain knowledge to make judgments about the creativity of product concepts.

The rater evaluated creativity against their own implicit definition of the term. This approach to defining creativity draws from the Consensual Assessment Technique (CAT). In the CAT, rather than decomposing creativity into multiple criteria for rating (e.g. novelty, feasibility, fluency, etc.), domain experts are asked to rate the creativity of generated ideas according to their own personal definition of creativity. This is based on the principle that domain experts have sufficient knowledge to determine and agree on 'what is' and 'what is not' creative in their particular domain (Kaufman *et al.*, 2007).

The creativity of each concept generated in the study was rated on a scale from 1 (not at all creative) to 10 (exceptionally creative). An overall creativity score was then calculated for each participant by taking the mean of their concept creativity scores.

4. Analysis and results

(Table 1) below presents an overview of the VVIQ and creativity scores obtained for participants in the study. Sections 4.1 - 4.3 report the results of analyses conducted to answer each research question.

4.1. Variation in imagery vividness across product designers

To assess the extent to which imagery vividness varies across product designers (RQ1), the mean and standard deviation was computed for participants' VVIQ scores. The mean VVIQ score in the sample was 2.5 (range = 1.5 - 4.1) and the standard deviation was 0.8, i.e. the majority of the participants had VVIQ scores between 1.7 and 3.3. Thus, based on the VVIQ rating scale (Section 3.2.2), participants on average experienced perfectly clear and vivid to moderately clear and vivid imagery. A breakdown of the percentages of participants achieving each VVIQ score is presented in (Table 2).

Taken together, these results indicate that there is variation in the vividness of visual mental imagery across the sample. 68.8% of participants achieved the top two VVIQ scores, reflecting highly vivid imagery; furthermore, 31.3% obtained scores in the highest category (i.e. <2, perfectly clear and vivid), which may be indicative of hyperphantasia (Zeman *et al.*, 2020). However, it should also be highlighted that 12.5% of participants obtained scores of 4 or above. Whilst this does not indicate a complete absence of visual imagery (aphantasia), it does reflect low vividness (vague and dim) that is below average.

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Table 1. Overview of VVIQ and creativity scores for study participants

Participant number	VVIQ score[1]	Creativity score[1]
1	2.2	4.0
2	2.6	5.0
3	2.0	5.8
4	1.5	5.4
5	2.3	4.2
6	1.5	5.6
7	1.9	6.4
8	3.3	3.8
9	3.4	4.0
10	3.0	3.6
11	2.2	6.0
12	2.0	4.8
13	1.6	5.6
14	4.0	2.6
15	1.9	5.4
16	4.1	2.4

[1]*VVIQ score meaning: see (Table 2). Creativity scores: 1=not at all creative, 10=exceptionally creative).*

Table 2. Percentage of participants in each VVIQ score range

VVIQ score	Vividness level	% of participants in this range
1.0 - 1.9	Perfectly clear and as vivid as normal vision	31.3
2.0 - 2.9	Clear and reasonably vivid	37.5
3.0 - 3.9	Moderately clear and vivid	18.8
4.0 - 4.9	Vague and dim	12.5
5.0	No image at all, you only "know" that you are thinking of the object	0

4.2. The relationship between imagery vividness and creative performance

To assess the relationship between imagery vividness and creative performance in product designers (RQ2), a Pearson's correlation was run for VVIQ scores and creativity scores.

Preliminary analyses showed the relationship to be linear with both variables normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and there were no outliers.

There was a statistically significant, strong negative correlation between VVIQ and creativity scores ($r(15) = -.875$, $p < .001$). Importantly, note that whilst the sign of the correlation is negative, this indicates a **positive relationship** between vividness and creative performance due to the opposing direction of the scales used in the VVIQ (where 1 = highest score) and creativity assessment (where 1 = lowest score). That is, as imagery vividness increases (lower VVIQ score), creative performance also increases (higher creativity score). The relationship is visualised in a scatter plot in (Figure 1).

4.3. The use of visual imagery by designers with different levels of vividness

To understand how product designers with different vividness levels use imagery in ideation (RQ3), the qualitative responses provided to questions in the use of imagery questionnaire (Section 3.2.3) were interpreted for participants with different VVIQ scores.

The majority of participants indicated that they do use visual imagery in design ideation tasks (50% always and 44% sometimes). This included one participant with a VVIQ score of 4.1 (i.e. vague and dim imagery), who noted that they used imagery sometimes - suggesting that even designers with low

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vividness make use of visual mental imagery during ideation to some extent. The main explanations given for how imagery was used in ideation fell into four categories:

- imagining ideas for solutions that are then transferred to drawings (81% of participants);
- manipulating ideas to form new concepts (75%);
- imagining scenarios relating to the design problem, user, product, etc. (44%); and
- picturing design solutions in 3D space (38%).

One participant (with a VVIQ score of 3.4, i.e. moderate vividness) noted that they did not ever use imagery during design ideation, explaining that "I struggle to form mental images in my mind and prefer to ideate through sketching concepts down and developing them over a series of evolutions." Participants who stated that they do use imagery sometimes also outlined reasons for the instances where they do not, with the main explanations falling into three categories:

- a lack of knowledge/experience of the design problem, which made it difficult to form relevant mental images (44% of participants)
- a desire to avoid one image overwhelming the mind and potentially hindering creativity, e.g. one participant noted that "I find when I use mental imagery one image tends to dominate the picture, blocking creativity" (25%); and
- difficulties forming mental images quickly in rapid ideation activities e.g. brainstorming (19%).

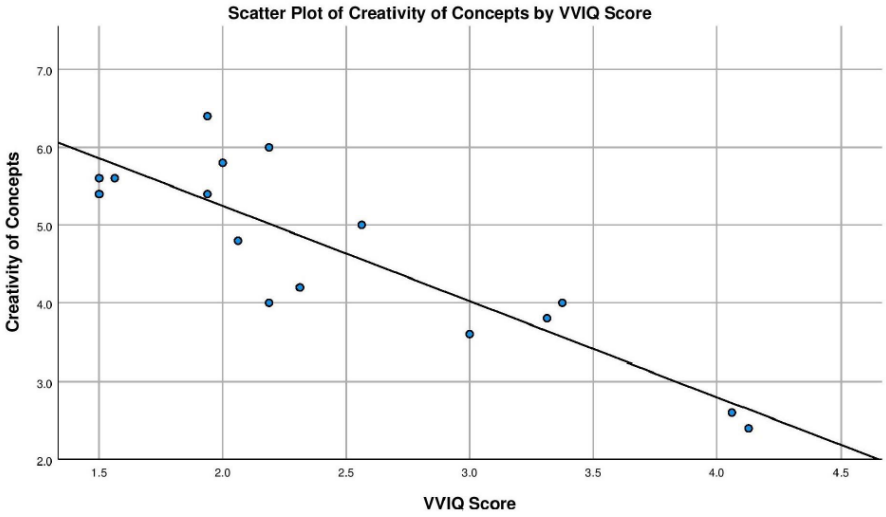

Figure 1. Scatter plot of participant VVIQ and creativity scores

5. Discussion

The potential implications of the results for product design research, education, and practice are discussed in Section 5.1, and study limitations in Section 5.2. Future work is highlighted throughout.

5.1. Implications

In some respects, the results provide support for the prevailing view that visual mental imagery is centrally involved in product design ideation. The majority of participants reported that they always or sometimes apply visual imagery during ideation, even those who scored moderate to low vividness in the VVIQ. The reported purposes of visual imagery are also well aligned with the existing design literature, suggesting that it is used alongside sketching to support the creation and transformation of ideas as well as simulating scenarios related to the design problem. The correlation analysis points to a statistically significant, strong positive relationship between imagery vividness and creative performance during product design ideation. This suggests that not only is visual imagery involved in ideation, but the vividness with which it is experienced may be a critical factor in meeting a key goal of this activity - i.e. the generation of creative solutions to a design problem.

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Nonetheless, some of the findings potentially have interesting implications. Analysis of the mean and standard deviation in participants' VVIQ scores revealed variation in imagery vividness across different designers. As shown in (Table 2), 68.8% of participants achieved the highest scores in the VVIQ (1 and 2), suggesting that the majority do experience highly vivid imagery (and those at the top of the scale may even be hyperphantasic (Zeman *et al.*, 2020)). However, 18.8% experienced only moderately vivid imagery, and a further 12.5% experienced vague and dim imagery. If these results are representative of the broader population of product designers, this suggests that over 30% may not be highly vivid visualisers. Given the strong positive relationship identified between vividness and creative performance - are these designers at a disadvantage when it comes to generating creative solutions? If yes, can anything be done to address this?

These are conjectures based on a preliminary study, and further work on a larger scale and addressing the limitations (Section 5.2) is needed to support conclusions and recommendations. However, one possibility is that product design education should include formal training in visual mental imagery, in the same way that we train designers in how to clearly visualise their ideas externally through sketching. There is evidence that some aspects of imagery ability can be improved through training (Jampole *et al.*, 1991; Rademaker and Pearson, 2012), and it may therefore be possible to develop pedagogical approaches (and perhaps even design methods) to improve imagery vividness in product designers. Another intriguing possibility is that there are alternative 'ways of imagining' in design, which are currently not clearly understood. For example, Zeman *et al.* (2020, p.430) uncovered a variety of alternative strategies employed by aphantasics when asked to count the number of windows in their home, including "the use of avisual spatial imagery, kinaesthetic imagery, and amodal 'knowledge'." An interesting avenue for future work could therefore be in depth investigation of the cognitive processes and strategies used by product designers low in imagery vividness, to determine whether there are differences from current visual reasoning models of concept creation and development. A subsequent question may then be: how can we support and foster diverse ways of imagining in product design education and practice? Is it possible that product design students who 'imagine differently' are currently not thriving in an educational system geared towards the visual domain?

The study reported here used an ideation task of relatively short duration (10 minutes to generate up to 5 concepts), which more closely resembles 'rapid fire' brainstorming in practice. It is possible that imagery processes may unfold differently in longer tasks focused on concept development and elaboration. It is also likely that the process of sketching undertaken by our participants has an impact on imagery, although its nature is not entirely clear from existing research (e.g. see Section 2). We used a single ideation performance measure (see also Section 5.2), and it is unclear how imagery vividness may relate to other measures such as the novelty, variety, and quality of ideas. It is also unclear how the vividness experienced by designers in our sample compares with the general population, e.g. whether they are above or below average. These may all provide fruitful avenues for future research on mental imagery in product design. The literature on imagery vividness, and imagery ability more generally, highlights several other potential areas for future work:

- Relationships have been identified between imagery vividness and a range of other aspects of cognition and behaviour, including autobiographical memory, face recognition, mood, and personality (Fulford *et al.*, 2018; Milton *et al.*, 2021). Future work could therefore explore relationships between imagery vividness and other aspects of design cognition, across a range of product design activities. Of note from the present study are several students who reported that a visual image can sometimes overwhelm the mind and block creativity. This suggests a potential relationship between design fixation and imagery vividness, which may be worth exploring further. Given the relationships between aphantasia and aspects such as mood, face recognition, and recall of past life scenarios, exploring the role of imagery vividness in user-centred design, empathy, and emotional design could also be fruitful.
- Zeman *et al.* (2020) found that aphantasics were more likely to work in scientific or mathematical domains, whilst hyperphantasics were more likely to work in creative professions. This raises the question of whether there are differences in imagery vividness across designers in different domains (e.g. engineering design versus industrial design), and whether designers with different

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vividness levels may be better suited to different 'types' of design work (e.g. the open-ended, 'blue skies' design work more typical of consultancies versus the constrained, routine work more typical of engineering firms). Systematically exploring such comparisons is another avenue for future research.

- There are other components of visual imagery ability in addition to vividness (Kosslyn, 1995). For example, several study participants reported using imagery to support 3D visualisation of objects, which involves spatial imagery processing. Future work should explore these other dimensions and their potential interactions to provide a more comprehensive picture on visual imagery ability in product design (with some existing work in this area by Shah *et al.* (2013)).

5.2. Limitations

The study was conducted during a Covid-19 lockdown in October/November 2020, which necessitated several limitations that should be addressed by future work. Firstly, the sample was small (N=16) and comprised product design students whose typically lower level of design experience may have impacted the results. Additionally, a single ideation task was used. To improve generalisability, future studies are needed using larger samples, practising designers as participants, and multiple tasks focusing on a variety of design problems. Secondly, the creativity ratings that formed the basis of the creative performance measure were carried out by one rater alone and may therefore lack reliability. This rater was also a design student, who may have lacked the necessary experience make appropriate judgments about creativity. There is also the potential for bias in their ratings given that they were assessing concepts produced by student peers. Future work should involve multiple independent expert raters to enable inter-rater reliability assessment, increase credibility, and reduce the possibility for bias. Finally, studies using in-person experimentation rather than Zoom are needed to ensure controlled conditions.

6. Conclusion

This paper has reported a preliminary study exploring the vividness of visual mental imagery in product designers and its relationship with creative performance in design ideation. The results suggest that imagery vividness may vary across product designers, with 68.8% of participants found to experience high vividness, 18.8% moderate vividness, and 12.5% low vividness. A statistically significant, strong positive relationship was found between imagery vividness and creative performance in ideation tasks. The majority of participants reported using imagery always or sometimes during ideation, with one reporting that they never used it due to difficulties with forming mental images.

Whilst the results provide support for the prevailing view that imagery is involved in conceptual product design, they also highlight the possibility that nearly a third of product designers may not be vivid visualisers. This reflects personal accounts from a small but increasingly vocal minority of artists, animators, and other creative professionals presumed to rely on the visual domain who experience low vividness or no imagery at all. The findings highlight several avenues for future work to develop a more comprehensive view on the relationship between imagery vividness and other aspects of product design cognition and the design process. However, perhaps the most intriguing possibility is this: there could be alternative 'ways of imagining' in product design, which are not captured by existing visual reasoning models. Understanding how to design with a blind mind's eye could provide new perspectives on design creativity, and a foundation for design pedagogy and methods that embrace diversity of imagination.

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