A Multifactorial Model of Visual Imagery and its Relationship to Creativity and the Vividness of Visual Imagery Questionnaire

Abstract

Visual imagery vividness (VIV) quantifies how clearly people can 'conjure up' mental images. A higher VIV reflects a stronger image, which might be considered an important source of inspiration in creative production. However, despite numerous anecdotes documenting such a connection, a clear empirical relationship has remained elusive. We argue that (a) a misunderstanding of visual imagery as unidimensional and (b) an overreliance on Marks' Vividness of Visual Imagery Questionnaire (VVIQ), are responsible.

Based on both the proximal/distal imagination framework and the distinction between the ventral/dorsal visual pathways, we propose a new Multifactorial Model of Visual Imagery (MMVI). This argues that visual imagery is multidimensional and that only certain dimensions are related to creativity: inventive combinatorial ability, story-boarding, and conceptual expansion (all distal); together with the quasi-eidetic recall of detailed images (proximal).

Turning to the VVIQ, a factor analysis of 280 responses in Study 1 yielded a three-factor solution (all proximal): episodic/autobiographical imagery; schematic recall; and controlled animation. None of these factors overlap with the creative dimensions of the MMVI. In Study 2, 133 participants had to remember non-verbalizable detail of unfamiliar pictures for later recall: performance on this quasi-eidetic task again did not correlate with any VVIQ factors.

We have thus demonstrated that the VVIQ is not unidimensional and that none of its factors appear suitable for probing imagery-creativity connections. The MMVI model is currently theoretical, and future research should confirm its validity, permitting a new, better targeted measure of VIV to be established which fully reflects its multidimensionality.

Keywords: Visual Imagery Vividness; VVIQ; Distal and Proximal imagery; Object/ventral and spatial/dorsal visual pathways; Creativity.

Visual imagery is the creation of a perceptual experience within the mind, enabling individuals to relive the past and simulate future events in the absence of external visual input (Moulton & Kosslyn, 2009). Representations of objects or events are generated from previously stored memory traces, typically resulting in a 'weak perception' - an internal image of the scene sharing some characteristics of true visual perception (Pearson et al., 2015). Despite the familiarity of the experience for most people, the elusive nature of visual imagery makes it a challenge to define, although the phraseology “seeing with a mind's eye” (Kosslyn et al., 2001, p.635) is commonly understood.

Visual Imagery Vividness (VIV) is the dimension of visual imagery which relates to individual differences in the ability to conjure up mental pictures, and the level of clarity, detail and liveliness achieved. The higher the 'vividness' of these quasi-perceptual experiences, the closer the experience is to the actual perception of the object or event in question (Marks, 1973; McKelvie, 1995).

This ability to evoke particularly vivid and lively images might naturally be viewed as a potentially important source of inspiration in creative production and insight. Indeed, 'creativity' and 'imagination' are themselves inextricably intertwined in common parlance (Abraham, 2016; Daniels-McGhee & Davis, 1994). Furthermore, if creativity is the ability to produce work which is novel/original and appropriate/adaptive (Feist, 1998; Runco & Jaeger, 2012; Sternberg & O'Hara, 2000), with its roots in divergent thinking (LeBoutillier & Marks, 2003; Runco & Acar, 2012), then possessing the ability to vividly imagine a range of possibilities from a qualitatively different perspective to others could be seen as a clear advantage.

Nevertheless, previous research in the area of creativity and visual imagery has failed to demonstrate a clear relationship between visual imagery and creativity (Kozhevnikov et al., 2013; LeBoutillier & Marks, 2003), flying in the face of both anecdotal case studies and intuitive sense (LeBoutillier & Marks, 2003). In this article, we argue that these perplexing results may have arisen from a number of key research confounds: the presumption of unidimensionality in the construct of visual imagery; the failure to distinguish certain aspects of visual imagery which may be more strongly allied to creativity from those which are not; and the over-reliance on one particular instrument - the 'Vividness of Visual Imagery Questionnaire' (Marks, 1973) - which we argue is inappropriate to the study of creative imagining.

Visual Imagery and its Multidimensional Nature

1.1 Visual Imagery and Individual Differences in Visual Imagery Vividness

Historically, much research into visual imagery has attempted to account for the mechanisms whereby these images are generated, with a vigorous debate focusing on the issue of whether the mental representations are truly depictive (e.g. Kosslyn et al., 2001) or merely mental descriptions, resembling the underpinnings of language and reasoning (e.g. Pylyshyn, 2002). In recent years, the debate has to all intents and purposes been settled in Kosslyn's favour by the advent of neuroimaging studies (Pearson et al., 2015). These have demonstrated that visual imagery shares many of its mechanisms in common with visual perception (Kosslyn et al., 2001; Pearson et al., 2015), albeit leading to a weaker, fleeting and more fragile percept, resembling "photographs from which the sharpness of the edges and borders had been removed" (Eysenck & Keane, 2015, p.114).

There is a spectrum of abilities in VIV ('trait vividness' - D'Angiulli et al., 2013), ranging from the profoundly aphantasic, with no visual imagery whatsoever (Keogh & Pearson, 2018; Zeman et al., 2016) to 'hyperphantasic' individuals (Luft et al., 2019; Zeman et al., 2018), including visual imagery savants such as Stephen Wiltshire (Hermelin et al., 1999; Pring et al., 1997) and Temple Grandin (Grandin, 2009). Indeed it has been suggested that those cognitive scientists (such as Watson, Pylyshyn, and Galton's scientific colleagues) who remained fiercely sceptical about the existence of depictive mental images, may in fact have been influenced by their own subjective experience of reduced VIV (Keogh & Pearson, 2018; Reisberg et al., 2003).

1.2 General Uses of Visual Imagery in Everyday Life

Visual imagery is important for a wide range of everyday tasks involving the veridical recall of previous experiences, such as the interpretation of language (Bergen et al., 2007), the mental simulation of routes in navigation (Ghaem et al., 1997), the recollection of faces (Ishai et al., 2002; O'Craven &

Kanwisher, 2000) and the reliving of past events (Libby et al., 2007; Moulton & Kosslyn, 2009). Whilst it is generally adaptive to recall the specifics of past events, problematic vivid visual recall (Schacter's 'sin of persistence', 2013) has also been reported in psychological disorders such as Obsessive Compulsive Disorder (OCD), Post-Traumatic Stress Disorder (PTSD), depression and eating disorders (Holmes et al., 2007; Holmes et al., 2016), as well as in their treatment through imaginal exposure and imaginal rescripting in Cognitive Behavioural Therapy (CBT: Arntz et al., 2007; Holmes et al., 2007; Pearson et al., 2015).

This use of visual imagery in CBT also evidences our ability to use mental imagery to shape, reinterpret and rewrite past events, to engage in mental mind-travel to the future (Madore et al., 2015; Tulving, 2002) and to explore objects or events which do not exist, or have never been personally perceived or experienced (Pearson, 2007). These imaginative mental representations allow us, for example, to try out 'what-if' scenarios in our heads (Dietrich & Haider, 2015; Moulton & Kosslyn, 2009), to plan and problem-solve (Isaac & Marks, 1994; Pearson & Kosslyn, 2013) and to engage in prospective mental rehearsal, such as in sport and dance (Cross et al., 2017; Cumming & Ramsey, 2008; Cumming & Williams, 2012; Macintyre et al., 2013) or in music (Fine et al., 2015; Highben & Palmer, 2004; Keller, 2012; Pascual-Leone, 2003; Zatorre & Halpern, 2005).

1.3 Visual Imagery as a Component of Creative Ability

This ability to simulate and elaborate upon remote imaginary situations could be viewed as a potentially important source of inspiration in creative production and insight. From this, studies arguing that VIV might play a causal role in creativity abound (e.g. Finke, 1996; Kozhevnikov et al., 2013; LeBoutillier & Marks, 2003; Morrison & Wallace, 2001; Palmiero et al., 2011; Palmiero et al., 2015; Pearson, 2007), although the precise explanatory mechanism for the purported connection differs from study to study (Palmiero et al., 2011; Pearson, 2007) and the results of creativity/VIV studies in the past have been inconsistent and contradictory (Kozhevnikov et al., 2013; LeBoutillier & Marks, 2003).

Despite this failure to demonstrate an empirical link between VIV and creativity, a connection is plausible on *a priori* grounds. Studies frequently cite a number of anecdotal cases of renowned scientists, artists, actors, directors and writers (e.g. Kekulé, Poincaré, Einstein, Hitchcock, Coleridge and Keats) whose creative output was allegedly influenced by imagining states such as lucid dreams, psychedelic hallucinations, day-dreams, thought-experiments and meditation (Daniels-McGhee & Davis, 1994; Irving, 2014; Kozhevnikov et al., 2013; LeBoutillier, 1999; LeBoutillier & Marks, 2003; Miller, 1992a, 1992b; Pearson, 2007). Recent neuroimaging studies of eminent scientists and artists (Chavez, 2016; Luft et al., 2019) have begun to explore the neural correlates of this association; and spontaneous mind-wandering has also been studied in its own right as a potential source of creative inspiration (Abraham, 2016; Gable et al., 2019; Zedelius & Schooler, 2016). Indeed, when people are engaged in active problem-solving or creative imagination they often close their eyes, or shift their gaze to an empty part of their environment, in order to disengage the external world and wander round their own internal cognitive landscape (Salvi & Bowden, 2016, p.1, citing Paul Gauguin "I shut my eyes in order to see").

1.4 Proximal/Distal Simulation and Creative Production

Importantly, Meyer and colleagues (2019) have recently drawn a distinction between veridical types of imagery (such as recalling the appearance of a friend, or the reliving of well-known routines such as going shopping, rehearsing the fixed steps of a dance, or making a cup of coffee) and the more fanciful creations of the human mind (such as imagining what it might be like to live in the next century, or at the bottom of the ocean). Indeed, Meyer et al.’s work is close to the seminal study of 'structured imagination' by Ward (1994) in which participants were asked to imagine animals that might live on a planet somewhere else in the galaxy. Similarly, Zabelina and Condon have also recently drawn attention to the many mundane ~~and uncreative~~ imaginings which are commonplace in normal human life (such as imagining forthcoming conversations, or work-based aspirations), in their development of the Four Factor Imagination Scale (FFIS, Zabelina & Condon, 2020, measuring the frequency, complexity, emotional valence and directedness of imagination). Terming the more veridical images '*proximal* *simulations*' and their more fanciful cousins '*distal simulations*', Meyer et al. argue that distal simulation is more likely to lead to creativity. Indeed, it is the transcending of the here and now, in terms of the generation of alternative temporal, spatial, social and hypothetical simulations, which is argued to mark out the creative 'expert' from the less creative (Meyer et al., 2019).

A similar contrast has been made in the creativity literature (Hass & Beaty, 2018). Here the comparison has been made between the Alternative Uses Task (Guilford, 1967), where less creative responses to prompts such as "think of creative uses for a brick" are often heavily dependent upon proximal prototypic or episodic uses which the participant has already encountered (Gilhooly et al., 2015), versus the more cognitively probing distal demands of the Consequences Task (Torrance, 1974; Wilson et al., 1954) which contains items such as "imagine that humans no longer needed to sleep". The underlying nature of distal imagination thus appears to be that it breaks free from the constraints of existing categories and knowledge structures, in order to explore novel and untrodden territories (Ward, 1994) - a process termed 'Conceptual Expansion' by Abraham (2014; 2012).

1.5 A New Model of Visual Imagery: Proximal/Distal; Ventral/Dorsal

However, although the distinction between proximal and distal imagining is itself a useful explanatory concept adopted in this paper, the bigger picture may not be as straightforward as Meyer suggests. As discussed in detail below (sections 1.6-1.7), at least one other approach (Kozhevnikov et al., 2010; Kozhevnikov et al., 2013) has been proposed to explain the apparent lack of connection between creativity and visual imagery. According to this model, visual imagery employs the same neural pathways (dorsal/ventral) as actual vision (e.g. Milner & Goodale, 2006), with the dorsal pathway specialising in the spatial/rotational aspects of vision and the ventral pathway enabling the capture of the colour, texture and shape of objects. This is argued (Kozhevnikov et al., 2013) to lead to different dimensions of creativity among scientists (typically using the dorsal-spatial pathway) and artists (using the ventral-object pathway). The weak correlations between creativity and imagery are thus argued to arise from the fact that both constructs are typically viewed as unitary, disregarding the differences which exist between both the creative outputs and the imaginal processes of artists and scientists.

Consideration of these two approaches has led the authors of the current study to propose a new blended model of visual imagery which is presented in Figure 1, and summarised in the key to Figure 1 and sections 1.6-1.8. This model suggests that the construct of 'visual imagery' is multidimensional, in terms not only of the proximal and distal nature of the imaging process (Meyer et al., 2019), but also of the neural pathways involved (ventral/dorsal, Kozhevnikov et al., 2010). A detailed discussion of each of these areas follows, beginning with the ventral pathway.

<INSERT FIGURE 1 SOMEWHERE AROUND HERE>

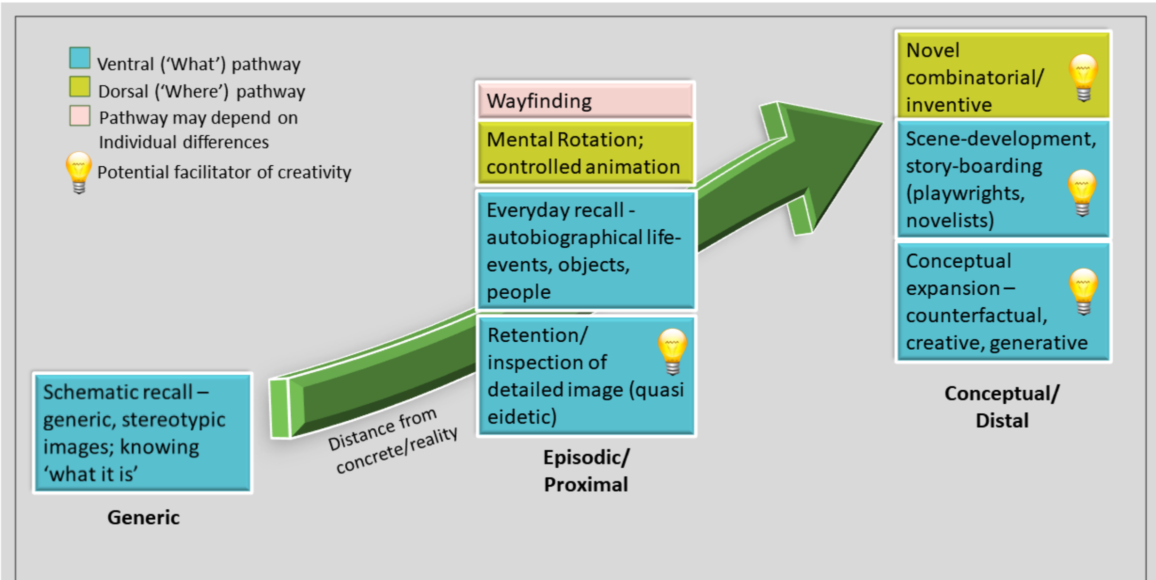

Figure 1: A suggested Multimodal Model of Visual Imagery (MMVI), showing neural pathways and applications

Key to Figure 1:

This paper argues that the ventral ('What') pathway (see section 1.6, and the items shaded turquoise (dark grey)) facilitates a number of visual imagery applications, three of which (Retention/inspection of detailed image; Scene development/storyboarding; conceptual expansion) could potentially be thought to have links with creativity (indicated by a light bulb symbol). The remaining two ventral applications (Schematic recall; Everyday recall) are argued below to be too proximal in nature to lead to creative output. Wayfinding, too (item shaded pink (white)), is often achieved through ventral pathway visualisation, although this varies according to individual differences; and this, too, is proximal, not distal. By contrast, the dorsal ('Where') pathway (see section 1.7, and items shaded green (medium grey)) is argued to relate to both controlled mental rotation/animation of a non-creative, proximal nature, but also to the distal visualisation of novel, combinatorial and inventive products which could be considered creative.

1.6 The Ventral ('What') Imagery Pathway and its Relationship to Creativity

Investigation of the relationship between the ventral and dorsal neural pathways and visual imagery resulted in the development of the Object-Spatial Imagery and Verbal Questionnaire (OSIVQ) (Blazhenkova & Kozhevnikov, 2009). Using this instrument, research by the same team has found that artists are primarily 'object visualisers', using the ventral pathway for visual imagery, whereas scientists are more commonly 'spatial visualisers' employing the dorsal pathway (Blazhenkova & Kozhevnikov, 2009). Furthermore, there appears to be a trade-off (rather than independence) between the two styles of visualization, with specialisation potentially arising from the conflicting attentional demands of the two systems (Kozhevnikov et al., 2010). According to this approach, ventral imagery is therefore conceived as primarily supporting artistic creation, and this is captured in Figure 1 by three items: Retention/inspection of detailed image; Scene development/storyboarding; and Conceptual Expansion. These are all discussed in the sections which follow.

1.6.1 *Artistic Creativity: the Ventral Pathway, and Clarity of Object Recall*

One hypothesized mechanism for the influence of VIV on artistic creativity (Figure 1, Episodic/Proximal: **Retention/inspection of detailed image)** lies in the creative individual's ability to visualize the shape, colour and texture of recalled objects with extreme clarity (Kozhevnikov et al., 2013), suggestive of an expertise in proximal simulation which goes beyond that of the typical recall of everyday events. These abilities appear to align with the view that artists also perceive the world differently to non-artists, and that various aspects of their visual processing are central to their advantages in drawing (for a comprehensive review, see Chamberlain et al., 2019). For example, in one study, artistically gifted children were found to have a better recall of line quality, composition, colour, form and content of presented artwork than their non-gifted peers (Rosenblatt & Winner, 1988), mirroring real-life advantages in actual visual perception enjoyed by art students in a study at Carnegie Mellon University (Glazek, 2012; Kozbelt, 2001; see also Kozbelt & Seeley, 2007). Again, a small-scale study of artists

(Piechowski & Cunningham, 1985) exploring Dabrowski's 'over-excitabilities' in this population (Dabrowski, 1967; Dabrowski & Piechowski, 1977), identified high levels of vivid imagination, with an intense degree of clarity in the resulting mental scenes, viewed “as if in living detail” (p.162). Furthermore, a study of art students who were technically stronger at drawing than their peers found that they showed better visual memory ability on the Rey-Osterrieth immediate recall task (McManus et al., 2010).

In his notebooks, Leonardo da Vinci also referred to the necessity of mentally retaining the form of natural objects:

> The mind of a painter should be like a mirror, which always takes the colour of the object it reflects and is filled by the images of as many objects as are in front of it. Therefore you must know that you cannot be a good painter unless you are universal master [*sic*] to represent by your art every kind of form produced by nature. And this you will not know how to do unless you see them and retain them in your mind. (Horváth, 2018; Wells, 2008, p.206)

At the furthest extreme, the savant artist Stephen Wiltshire possesses exceptionally accurate and detailed snapshot recall of cityscapes, providing material for his idiographic artwork. For example (of one television documentary about Wiltshire), Treffert reports that "after a 12-minute helicopter ride over London, he completes, in 3 hours, an impeccably accurate sketch that encompasses 4 square miles, 12 major landmarks and 200 other buildings all drawn to scale and perspective" (Treffert, 2009, p.1356).

From all these examples, we might argue that an enhanced ability to recall fine detail 'on demand', and to mentally inspect a complex image in a quasi-eidetic manner, may be a relevant factor in art expertise, enabling the faithful recollection of material and potentially providing rich inspirational material to foster creativity. Kozhevnikov and colleagues classify those displaying particularly sensitive recall of form, shape and colour 'object visualizers', claiming that they “consistently prefer to construct pictorial, colourful, high-resolution images of individual objects and scenes” (Kozhevnikov et al., 2013, p.198). This strength is hypothesized to arise from the efficient use of visual recall using the ventral pathway (Blajenkova et al., 2006).

We might also draw parallels with Kosslyn's original conception of the four cognitive stages of visual imagery (Kosslyn et al., 2006; Pearson et al., 2013). These comprise *image generation* (the ability to form an image, whether voluntary or involuntary); *maintenance* (the ability to hold in mind the fragile and rapidly decaying image); *inspection* (the scanning and cognitive appreciation of the image); and *transformation/manipulation* (the ability to transform or rotate the image). It could be argued that clarity of object recall relates to all of the first three stages, but to inspection in particular, as the viewer is thereby able to engage in aesthetic terms with the image they are beholding.

1.6.2 ***Artistic Creativity: Scene Development /Storyboarding and Conceptual Expansion***

Unusually rich proximal recall of detail and colour may therefore be a factor in artistic creativity. Nevertheless, there is evidence of distal simulation, too, amongst artistically creative populations; and indeed as Meyer et al. point out, one might hypothesise on *a priori* grounds that novelists, actors and theatre/film directors might all be heavily reliant upon the need to use distal visualization for elements such as character development, perspective taking and mental storyboarding. See Figure 1: Conceptual/Distal '**Scene development; story boarding**'. Piechowski also found evidence of this tendency in his study of artists (Piechowski & Cunningham, 1985), reporting high levels of 'imaginational over-excitability':

> For another subject, thinking "almost isn't thinking but a silent movie inside my head most of the time; sometimes I feel my brain is like a movie camera." […] They can fantasize themselves into different periods at will like being an American Indian 200 years ago or a Victorian aristocrat sitting in a Victorian parlor sipping tea and discussing latest Victorian literary events. There is a facility for moving between fantasy and reality. (p.162)

Similarly, in a qualitative study of artists by Aldworth (2018), one participant noted:

> It feels like I zoom into my head and explore all my thoughts visually, this could be scenarios with conversations or ideas for pieces of work, it manifests by a sort of film screen coming down in front of my eyes or a bubble in my head of ideas. (Participant MF, p.177)

Other studies of Dabrowski's over-excitabilities have also found high levels of imaginational intensity in artists compared to intellectually gifted individuals and college students (Piechowski et al., 1985), and in Venezuelan artists (Falk et al., 1997). Furthermore, explorations among those who read poetry (Belfi et al., 2018) found that, across participants, the vividness of imagery evoked while reading the poem was the strongest contributor to aesthetic pleasure, indicating that 'story-boarding' may also be an important component of poetry appreciation.

Using neuroimaging techniques, Meyer and colleagues (2019) found that creative experts appear to support their ability to create distal simulations (involving the generation of alternative temporal, spatial, social and hypothetical imaginations) by recruiting different neural mechanisms to their less creative peers, primarily utilising the dorsomedial subsystem of the default network. However, Meyer et al. do not distinguish between two potentially distinct categories, termed in this paper '**Scene development; story-boarding**' (which may involve the reinterpretation of existing material such as a film-script, aesthetic engagement with a poem, or the development of a novel, within the traditional framework of literary composition), and '**Conceptual Expansion'** which may feature more strongly unbounded creative fantasies and the deliberate breaking of pre-existing knowledge structures (Abraham, 2014; Abraham et al., 2012). For the purposes of this discussion, Figure 1 includes both aspects as separate entities, while recognising that they may exist on a continuum.

1.6.3 *Non-creative 'What' Pathway Recall: Faces, Routines, Language and Wayfinding*

At the other extreme, it is also plausible that individuals might utilise 'What' pathway imagery on a more prosaic, proximal level without invoking their creative 'imagination': and indeed, although etymologically connected, imagery/imagination should not be considered synonymous (Aldworth, 2018; Irving, 2014). In these situations, imagery is used in support of goal-directed everyday cognitive activities serving a more basic purpose or outcome (termed 'directedness' in the FFIS: Zabelina & Condon, 2020).

Meyer et al. (2019) and Zabelina and Condon (2020) both point out that we all indulge in mundane and uncreative 'proximal' imaginings about the small details of our lives, permitting us - for example - to recall faces, conversations and typical routines: see Figure 1 Episodic/Proximal **'Everyday recall - autobiographical life-events, objects, people'**.

'What' pathway imagery is also used in the interpretation of language: see Figure 1: '**Schematic recall - generic, stereotypic, knowing 'what it is**''. For example, following the dual-coding theory (Paivio, 1978, 2014), a word with high imageability may incidentally evoke a spontaneous associated image during use, promoting recall and linguistic interpretation (Bergen et al., 2007; Paivio & Begg, 1981). However, this representation is necessarily fleeting, and need not result in either veridical or intensely experienced high-definition images; nor indeed would it be efficient to do so, given the resulting impact on cognitive load (Kozhevnikov et al., 2010). Rather, in the course of transitory visual recall, most individuals appear routinely to generate a prototypic image of an object based on its global features (for example 'an apple' or 'a house') rather than drawing on a detailed episodic memory for a high-fidelity image (for example of one particular apple or one's own home). In this more abstract and schematic form of recall, the viewer is blind to the fine details of the object, recalling only the most salient attributes of the object relative to the task in hand (for example that a prototypic tiger has stripes) but remaining indeterminate on specifics (for example the number of stripes on this imagined tiger's back: Chambers & Reisberg, 1985). Cornoldi and colleagues describe this type of simulation as a 'generated image', with the subsequent representation being highly dependent upon selected perceptual-conceptual object properties held in long term memory (Cornoldi et al., 1998).

Visual imagery employed in this way tends to reflect the demands of the task. For example, it is more likely to be invoked in more demanding relative size comparisons than in situations where the information is more accessible through semantic memory (hence, comparing the size of a fly with an elephant is less likely to need a mental image than comparing a leopard and a tiger: Pearson et al., 2013). It has been argued that this 'schematic recall' is a style particularly employed by spatial visualisers (e.g. Blazhenkova & Kozhevnikov, 2009); however it is equally possible that this style could routinely be used in everyday situations by both object and spatial visualizers, depending on cognitive load and the fleetingness and importance of the task demand.

Other imaginal non-creative tasks with a practical application would include route-planning and wayfinding (see Figure 1: Episodic/Proximal: **'Wayfinding'**). Here again pragmatic sufficiency is the key mode of operation, with the route being recalled either by mentally tracing a sequence of landmarks (object visualization) or by using a spatial map of an environment using the dorsal pathway (see below, section 1.7), according to individual visualization preferences (Kozhevnikov et al., 2010).

1.7 The Dorsal ('Where') Imagery Pathway and its Relationship to Creativity

Creativity is not, however, solely the preserve of the artistic domain, and as noted above, spatial visualisers have been found to be particularly prevalent amongst the scientific creative community (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2010). This strength is hypothesized to arise from the efficient use of spatial reasoning using the dorsal pathway (Blajenkova et al., 2006), and bears a close relationship to Kosslyn's 'image transformation and rotation' stage (Kosslyn et al., 2006; Pearson et al., 2013). Even here, however, spatial imagery abilities might usefully be divided into those which rely upon the more pragmatic rotation and controlled movement of a given object (Figure 1 Episodic/Proximal: '**Mental Rotation, controlled animation**'*)* and those which require the recombination, synthesis and transformation of spatially presented information into a new object (Figure 1 Conceptual/Distal: *'***Novel combinatorial/inventive***'*).

1.7.1 *Proximal Simulation: Rotation and Controlled Animation*

In the case of mental rotation and controlled animation, the output simulation is proximal and (at least in laboratory tests) generated 'on demand' following a set of specific instructions. Tests are based on the mental inspection, controlled movement and/or rotation of stereotypic items such as a 3D geometric net (the Mental Rotation Task (MRT), Shepard & Metzler, 1971), a folded piece of paper (Paper Folding Test (PFT), Ekstrom et al., 1976), or an imagined car in various defined states of motion (the Test of Visual Imagery Control (TVIC), Gordon, 1949). Importantly, in all these lab-based tasks, the participant is asked to maintain and control a mental image according to the experimental instructions. Interestingly, Bainbridge and colleagues (2021) found that aphantasics showed high accuracy on spatial imagery recall tasks, equivalent to controls, whilst showing impaired performance on object recall. This dissociation provides additional supporting evidence for separate memory systems supporting object versus spatial information.

Similar real-life tasks might include the mental shifting of furniture to decide how it will fit in a different arrangement within a room (Kosslyn et al., 1984); jigsaw puzzling (Fissler et al., 2018); and the savant-like skills of Temple Grandin, involving her ability to mentally 'test-run' her 2D design of a cattle-handling plant as if in 3D, to explore it from different perspectives, and to travel through the passages and tunnels while inspecting engineering details (Grandin, 2009, 2010). Indeed, Grandin's ability is argued to be based upon an enhanced ability in mental rotation tasks often seen among autistic populations (Soulieres et al., 2011). Perhaps unsurprisingly, attempts to correlate performance on these proximal tasks with creative ability or artistic output have generally met with disappointing results (Allen, 2010; Calabrese & Marucci, 2006; Kozbelt, 2001; Kozhevnikov et al., 2013; Pelowski et al., 2019). For a detailed review, see Palmiero and Srinivasan (2015).

1.7.2 *Distal Simulation: Novel Combinatorial*

Conversely, following the 'Geneplore Model', Finke and Slayton developed the 'Creative Mental Synthesis Task' (CMST, Finke, 1996; Finke & Slayton, 1988; Finke et al., 1992) to explore imaginal spatial construction ('mental discovery', Logie & Helstrup, 1999) - see Figure 1, Conceptual/Distal: **'Novel Combinatorial/inventive'**. The CMST is a distal task, which employs visualization to execute the mental manipulation and synthesis of imagined forms and objects (e.g. primitive 'geon'-like, pre-inventive 3D forms; or 2D forms such as a circle, triangle; the letters X, J; or the figure 8), with the aim of generating novel creations and exploratory insights. Unlike the tests of 'rotation and controlled animation' therefore, the participant is not a mere agent of the test's instructions, but is free to exploit their powers of mental manipulation for spontaneous creative invention.

Indeed, research has found that results on the CMST are not associated with scores of proximal visual imagery control (e.g. the controlled movement of the car in the TVIC - Antonietti et al., 1997) and thus seem to be measuring a distinct factor; furthermore, fMRI studies have found that mental rotation and CMST tasks share some neuronal activities involved in the visual-spatial rotation of objects (e.g. in the posterior parietal cortex), but that the CMST also activated robust parallel activities largely in the left hemisphere, including the dorsolateral prefrontal cortex (Aziz-Zadeh et al., 2012). Aziz-Zadeh et al. further note that these areas have been implicated in other studies of creativity and spontaneous counterfactual creativity, implying that the CMST is utilising a pattern of activation which goes beyond mere spatial rotation. The CMST has been used with some success in studies of the relationship between creativity and VIV, with some studies finding a correlation between VIV and specific dimensions of the CMST (e.g. Morrison & Wallace, 2001; Palmiero et al., 2011; Palmiero et al., 2015), whereas other studies have failed to do so (Anderson & Helstrup, 1993; Palmiero et al., 2010).

1.8 The Multidimensional Nature of Visual Imagery Vividness: Implications for Research

From the above review, it follows that VIV is not an unidimensional construct at which one is simply 'good or bad' (Kosslyn et al., 1984), but that there will be a complex variety of individual differences in the strengths and weaknesses shown across the different facets. Whereas previous research has explored visual imagery, and in particular the relationship between VIV and creativity, in terms of simple dichotomies such as visual vs. spatial visualization (Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2010) or proximal/distal imagery (Meyer et al., 2019), the reality may be somewhat more nuanced, as Figure 1 indicates.

It is also plausible that only some of these modes of visualization will be relevant to creative production, highlighting the need to select the type of visualization task carefully in order to explore the relationship with precision (Kozhevnikov et al., 2013; Pidgeon et al., 2016). Here we must resist the temptation to slip into faulty syllogisms: for example, simply because scientists in general indisputably tend to have enhanced spatial imagery abilities ('*All scientists have enhanced spatial abilities*') and creative scientists form a subset of that population, sharing the same attributes ('*All creative scientists have enhanced* *spatial abilities*'), it does not follow that '*All scientific creativity arises from enhanced spatial abilities*'. In other words, there is no demonstrable evidence that spatial abilities such as **object rotation and controlled animation** are causally involved in the underlying processes leading to enhanced scientific creativity, rather than that they are simply part-and-parcel of a basic toolkit which mechanistically enables any scientist (creative or otherwise) to fully engage with scientific concepts and techniques.

A similar argument might be applied to artists: enhanced abilities to recall real-world detail and to construct high-resolution images of objects ('**Retention/inspection of detailed image**') may certainly enhance technical draughtsmanship and professional expertise; but do they also lead to an enriched inner perception of the world, leading to creativity? Aldworth explicitly denies that this would be the case, describing the process of creative artistic production as being dependent upon something much more akin to a distal story-boarding or conceptual expansion instead:

> First-hand accounts of what a visual imagination means to individual artists are a rich source of information. From these accounts it seems that for some artists a visual imagination is "very different from simply visualising something that exists in the world - which seems to be the most common target for scientific studies of 'visualisation'." Some talk about "seeing new work in the mind's eye". This is a place in consciousness which does not feel the same as memory: it is fed by images of the world but does not simply reproduce them. The images tumble around with thoughts, ideas and feelings. (Aldworth, 2018 p.173)

Future research will therefore be needed to establish these relationships on a systematic basis. However, on *a priori* grounds one might suspect that those forms of visualization which support more prosaic, everyday activities (such as wayfinding, semantic interpretation, object rotation and the recall of commonplace activities, objects and people) will not show a strong connection with creative production. Conversely those which support conceptual, generative activities (marked with a lightbulb icon in Figure 1) such as novel combinatorial invention, storyboarding, and hypothetical distal imaginings, or those which invoke the intense reliving of a particular stimulus, perhaps using quasi eidetic recall, may potentially show a closer relationship. This may go some way towards explaining the inconsistent results of many creativity/VIV studies in the past.

Measuring VIV by Self-report Questionnaires: the VVIQ

2.1 Background and Critiques of the VVIQ (Marks, 1973)

One of the limitations in exploring individual differences in VIV, and the potential connection with creativity, is that it has been heavily reliant upon self-report as a metric (LeBoutillier & Marks, 2003). Although a range of self-report measures have been developed over the years (Blazhenkova, 2016), VIV is most commonly measured by the Vividness of Visual Imagery Questionnaire (VVIQ - Marks, 1973), a 16-question instrument involving 4 scenarios (for the content of the questionnaire, see Figure 2).

<INSERT FIGURE 2 SOMEWHERE AROUND HERE>

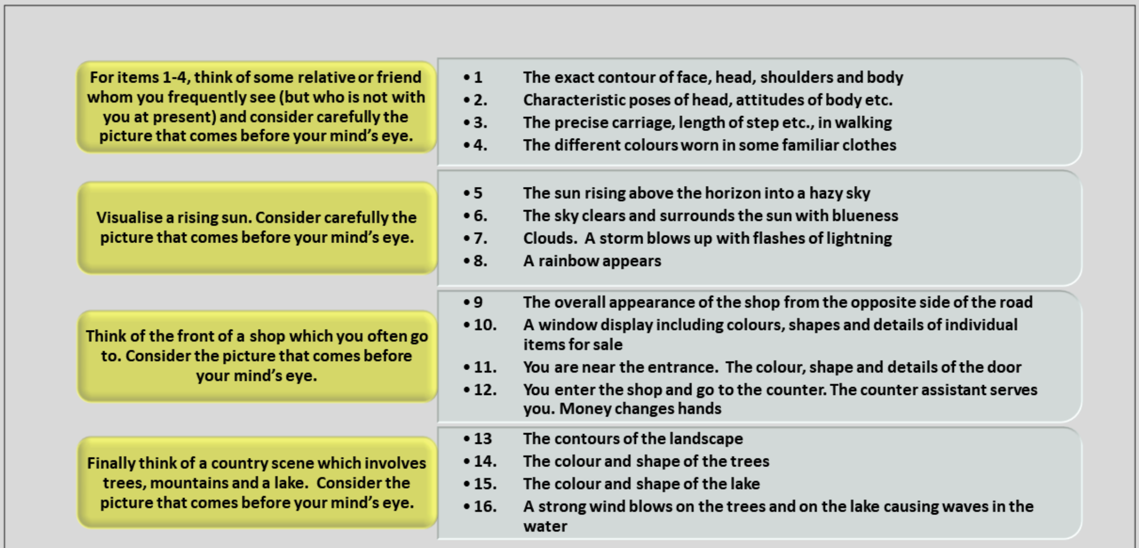

Figure 2: 16 questions/4 scenarios forming the VVIQ (Marks, 1973)

In common with many other self-report instruments measuring imagery vividness, the VVIQ requires participants to imagine a number of specified items determined by the test protocol, and to rate their subjective impression of vividness on a Likert scale (Blazhenkova, 2016). While the subjective scores on the VVIQ do show a significant relationship with fMRI activity in key areas of the visual cortex (Amedi et al., 2005; Cui et al., 2007), the test has generally shown inconsistent relationships with a wide range of quantitative visual imagery performance tasks (Blajenkova et al., 2006; Blazhenkova, 2016; Dean & Morris, 2003; McAvinue & Robertson, 2007; McKelvie, 1995).

2.2 Use of the VVIQ in Creativity Studies

Results are equally mixed when the VVIQ is used to explore the purported relationship between creativity and VIV. For example, a meta-analysis of nine studies (six involving the VVIQ) revealed a consistent, but weak, association between self-reported VIV and scores on a divergent thinking task - typically the Torrance Tests of Creative Thinking (TTCT Torrance, 1974) - with VIV accounting for only 3% of the variance in divergent thinking scores (LeBoutillier & Marks, 2003).

A series of experiments by Palmiero and colleagues (2011; 2010; 2015) again recorded inconsistent results. For example, in a study investigating the relationship between the originality and practicality subscales of the CMST, the graphic ability, aesthetic and creativity subscales of Clark's Drawing Ability Test (Clark, 1989), and scores on the VVIQ, the VVIQ only correlated (negatively) with the practicality subscales of the CMST (Palmiero et al., 2015). By contrast, an earlier comparison of scores on the VVIQ with the CMST by the same team had found a positive correlation between VVIQ and the practicality (but once more, not the originality) scores of the CMST (Palmiero et al., 2011). Similarly, in a study of factors involved in the acquisition of high-level representational drawing abilities, Chamberlain et al. (2015) found that scores on the VVIQ were uncorrelated with actual drawing ability although they were predictive of self-rated drawing ability. Again, in a study comparing scores on the Alternative Uses Task (AUT, Guilford, 1967), the figural scale of the TTCT, and the CMST, together with a large battery of other visual imagery tasks, the VVIQ correlated with three sub-scores of the AUT (originality, flexibility, fluency), an orally conducted ideational task, but failed to show a relationship with any of the visual creativity scores (Palmiero et al., 2010).

Finally, an investigation of the relationship between VVIQ scores and the Object-Spatial Imagery and Verbal Questionnaire (OSIVQ) found that OSIVQ-object scores, relating to ventral pathway imagery, were positively correlated with the VVIQ in a population of students (Blazhenkova & Kozhevnikov, 2009); however, the study did not include a specific measure of creativity. Later studies by this team (Kozhevnikov et al., 2013) therefore combined the scores on the VVIQ and the OSIVQ-object scales to form a 'Composite Object Visualisation' score, which correlated significantly with a second composite score of 'artistic creativity', based on the TTCT (figural scale) and the Creative Behaviour Inventory-art (Hocevar, 1979). Nevertheless, it should be noted that this study did not consider the pure VVIQ scores in an uncombined state.

Many have argued that this apparent lack of criterion validity may be attributed to the difficulties of using self-report scales, and the VVIQ in particular (Blazhenkova, 2016; McKelvie, 1995). One key issue lies in the fact that scores from the VVIQ are typically heavily negatively skewed (McKelvie, 1995), with participants generally reporting that they perceive a clear visual image, and even lower-scoring participants typically scoring around the scale's midpoint (Kihlstrom et al., 1991), suggesting that either the task is too easy, or that scoring is contaminated by a lenient response bias. Certainly, without a clear anchor point for the rating scale (such as by the use of indicative photographs showing a gradation in sharpness and exposure pegged to the response options), there is a danger that participants may respond overconfidently to the VVIQ, perhaps as a result of the 'better than average' bias (Chara Jr & Verplanck, 1986). As McKelvie (1995) notes, these points present a threat to criterion validity, in that nonsignificant relationships with other variables (such as creativity) are more likely to occur, on account of range compression and reduced scoring discrimination.

2.3 VVIQ: A Unidimensional Questionnaire?

A second issue may arise from the assumption of unidimensionality in the VVIQ, and indeed McAvinue (2007) cautions that much of the work on VIV has been vested in the use of a limited number of questionnaires (primarily the VVIQ) without adequate grounding in the theoretical basis of imagery and its likely subcomponents. The above review of VIV has suggested that it is a multidimensional construct, serving a number of different purposes, both distal and proximal, and that it utilises at least two distinct neural pathways. The question thus remains as to whether the VVIQ is itself unidimensional, or whether the global score is actually an amalgamation of multiple VIV factors. Previous split-half reliability analyses undertaken in six studies (as reported by McKelvie, 1995, esp. pp.27-29) showed acceptable internal consistency of the full VVIQ scale, with confidence intervals for Cronbach's alpha lying between .870-.906, centred on .890. Two of these studies (as reported by McKelvie, 1995) also demonstrated a single factor solution for VVIQ items.

Nevertheless, disquiet about the internal consistency of the VVIQ remains. A randomised version of the VVIQ (not delivered in the traditional four blocks) reduced the split-half estimate of the scale to .692, which fails to meet the commonly accepted standard of .75 (McKelvie, 1986); and two studies (Dean & Morris, 1991; Kihlstrom et al., 1991) found four underlying factors, which appeared to relate to the four groups of questions presented. LeBoutillier's factor analysis (LeBoutillier, 1999) revealed a similar three-factor solution which could be interpreted in terms of item block content: 'Nature' (sun rising; lake scenarios), 'Person' (recall a person scenario) and 'Shop' (shop scenario).

Close inspection of the questionnaire, however, also reveals that it taps into objects or events which undergo a wide variety of transformations 'on demand', including the manipulation of previously recalled items, and to require a climactic build-up of vivid recollection within each question block (Kihlstrom et al., 1991). Indeed, Kihlstrom remarks that in many of the VVIQ items, the participant is required to manipulate the image in a very similar manner to the imagined car in the TVIC (Kihlstrom et al., 1991), a measure of imagery control (similarly, McAvinue & Robertson, 2007). Furthermore, the VVIQ loaded unexpectedly to a number of factors within a model of imagery ability devised by Kosslyn and Shwartz (as reported in Kosslyn et al., 1984): it proved impossible to characterise the VVIQ sufficiently in advance, and the scale did not appear ~~to the authors~~ to be a simple measure of 'imagery vividness', leading Kosslyn et al. (1984, p.240) to remark that, “The VVIQ is clearly a more complex measure than is usually realized”. Finally, LeBoutillier (1999) also comments that, given the nature of the VVIQ, it would not be unreasonable to assume that it involves a wide range of visual imagery processes which render the usual technique of summation into one global score inappropriate. LeBoutillier also comments on the singular lack of interest in the scale's unity, given the widespread use of the measure in imagery research.

The Current Study

Study 1: Factor Analysis of the VVIQ

3.1 Research Questions and Hypotheses

The primary focus of our first study was therefore to explore the construct validity of the VVIQ, and in particular its factor structure. Contrary to the commonly held view that the scale measures a single unitary factor ('vividness of visual imagery') representing a single vividness dimension, we hypothesised that the VVIQ would prove to be multi-dimensional.

We based this hypothesis upon the observations that:

a. the scale leads participants to construct an increasingly complex image by gradually introducing extra elements to be included in each scenario;
b. in a number of cases these images need to be controlled and animated 'on demand'; and
c. the level of detail invoked by the 16 items varies considerably, which might in itself lead to changes in visualization approach.

We thus started from the premise that the VVIQ would draw upon a variety of abilities - potentially:

i. the recall of initially schematic components;
ii. the overlaying of these schematic elements with additional detail typically drawn from episodic memory and real-life experience, to construct a scenario 'to order';
iii. the control and animation of these elements, in response to instructions.

3.2 Materials and Procedure

VVIQ data were collected over several years as part of a number of studies exploring the VVIQ and its relationship to other visual imagery and creativity tests.

3.2.1 *Participants*

The populations under study are as follows:

i. 133 participants (82 students at the University of XXXX; 51 members of the general public; 95F/38M) took part in trials during 2017/18. Mean age = 27.8, SD = 13.97. All participants completed a demographic sheet and the VVIQ (Marks, 1973) before studying two colourful and detailed pictures shown for 90 seconds each (see Study 2).

ii. A further 47 participants (all Psychology students enrolled at the University of XXXX, 37F/10M), took part in a study in February 2019. Mean age = 21.9, SD = 4.29. All participants completed a demographic sheet and the VVIQ, followed by the OSIVQ (Blazhenkova & Kozhevnikov, 2009) (results to be reported elsewhere).

iii. Finally, 100 members of the general public took part in an on-line survey, during Autumn 2019; 59F/39M/2O (Other); Mean age = 33.25, SD = 15.59. All participants completed a demographic sheet and the VVIQ, followed by the OSIVQ (Blazhenkova & Kozhevnikov, 2009) (results to be reported elsewhere).

The full body of participants taking the VVIQ therefore totalled 280 (191F/87M/2O; Mean age = 28.75, SD = 14.05).

3.2.2 *Administration of the VVIQ*

Marks' original 16-question VVIQ (1973) was administered using standard wording, with participants recording responses in a booklet or on-line questionnaire; but in keeping with modern treatment, the rating scores were reversed from the original paper, such that a low score (1) now indicated 'No image at all, you only "know" that you are thinking of the object'; and 5 indicated 'Perfectly clear and vivid as real seeing' (on this issue, see discussion in Marks, 1995; McKelvie, 1995).

Full ethical permission had been obtained from the School of XXXX Ethics Committee at the University of XXXX for all stages of the research (i-iii above). All procedures performed were in accordance with the British Psychological Society's code of ethics (2014) which was current at the time of data collection. Informed consent was obtained from all participants in the study.

3.3 Study 1 Results

3.3.1 *Overall Distribution of Mean VVIQ Scores*

Scores on the VVIQ were summed, and means calculated for individual participants. Distributions of mean VVIQ scores in total and by gender are shown in Table 1. As is typical for this measure (McKelvie, 1995), VVIQ mean scores showed moderate negative skew (-.66 total sample; F = -.74; M= -.46; O = n/a). Overall and female mean scores were not normally distributed, as assessed by Shapiro-Wilk's test ($p < .001$). All statistics presented below have therefore been bootstrapped [BCa CI 95%]; gender comparisons for 'O' participants are not calculated due to sample size.

The overall mean VVIQ score (M = 3.43) was significantly higher than the scale midpoint of 3 (*M*diff = .43, 95% CI [0.34, 0.53], $t(279) = 8.89$, $p < .001$, $d = 0.53$) indicating that participants generally felt that they had good visualizing abilities. An independent-samples t-test indicated no significant F-M gender difference (F = 3.47; M = 3.35) in mean VVIQ scores: *M*diff = 0.12, 95% CI [-0.11, 0.38], $t(276) = 1.16$, $p = .29$, $d = 0.14$. This is in line with previous findings (e.g. LeBoutillier, 1999), although others, including Galton in his original study (1883) have found gender differences in self-reported visual imagery - see LeBoutillier's discussion (1999, p.6) and e.g. Isaac and Marks, 1994.

Table 1

Mean VVIQ Scores by Gender and in Total

	N	Min	Max	M	Std. Dev	95% CI (M)
Female	191	1	5	3.47	0.77	3.36-3.58
Male	87	1	4.94	3.35	0.93	3.15-3.55
Other	2	3.44	3.69	3.57	0.18	1.98-5.00
Total cohort	280	1	5	3.43	0.82	3.34-3.53

Note: Upper bound CI for Other capped at 5.00, the theoretical maximum. The CI is very broad due to a sample size of only 2.

3.3.2 *Distribution of VVIQ Scores by Question*

Table 2 sets out the mean scores by question in the VVIQ. It is notable that the answers to some questions involving the manipulation or movement of imagined elements (e.g. Qs 3, 7, 8 and 16) had lower mean response scores and generally higher SDs than other questions, which indicates both that there was a wider range of ability to carry out these instructions, and that participants generally found these images more difficult to summon. Conversely, two questions (Qs 1 and 9, imagining the contours of a familiar face, or a shop front) approach a mean score of '4' across the sample, indicating that participants generally felt that they could summon up an image which was 'Clear and reasonably vivid' for these items.

Table 2

VVIQ Scores by Question, Sequenced by Mean (Highest to Lowest)

Question Description	N	Min	Max	M	SD
q9 Shop from across road	280	1	5	3.87	1.09
q1 Contour of face etc	280	1	5	3.76	1.11
q4 Colours of clothing	280	1	5	3.73	1.18
q2 Char poses of head	280	1	5	3.69	1.09
q5 Sun rises hazy	280	1	5	3.66	1.11
q12 Interaction with assistant	280	1	5	3.63	1.23
q14 Colour and shape of trees	280	1	5	3.49	1.16
q13 Country landscape contours	280	1	5	3.42	1.14
q6 Sky clears to blue	280	1	5	3.41	1.19
q11 Colour and shape of door	280	1	5	3.39	1.13
q15 Colour and shape of lake	280	1	5	3.38	1.20
q8 Rainbow appears	280	1	5	3.20	1.27
q7 Clouds, storm, lightning	280	1	5	3.15	1.34
q16 Strong wind blows; waves	280	1	5	3.13	1.32
q10 Window display, colours shapes	280	1	5	3.05	1.15
q3 Way they walk	280	1	5	2.98	1.19

3.3.3 *Principal Components Analysis of the VVIQ*

A Principal Components Analysis was run on the 16 items of VVIQ for all 280 participants, using Promax rotation with Kaiser normalization to produce a set of loadings reflecting simple structure (McLeod et al., 2001), thus aiding interpretation of the solution. The suitability of PCA was assessed prior to analysis. Inspection of the correlation matrix showed that all variables had at least one correlation coefficient greater than 0.3. The overall Kaiser-Meyer-Olkin (KMO) measure was 0.92 with individual KMO measures all greater than 0.85, classified as 'meritorious' according to Kaiser (1974). Bartlett's test of sphericity was statistically significant ($p < .001$), indicating that the data were suitable for analysis.

Three components, accounting for 64.8% of the total variance (48.2%, 9.3% and 7.2%, respectively), had eigenvalues greater than one, and these met the interpretability criterion for retention. Details of the rotated pattern matrix are shown in Table 3. A brief discussion of these figures, and characterization of the resulting factors then follows.

Table 3

Three-Factor Solution showing loadings of VVIQ Questions to Components

Component	1	2	3
q9 Shop from across road	**0.87**		-0.31
q2 Char poses of head	**0.76**		
q1 Contour of face etc	**0.76**		
q10 Window display, colours shapes	**0.72**		
q4 Colours of clothing	**0.70**		
q11 Colour and shape of door	**0.59**		
q3 Way they walk	**0.54**		0.39
q12 Interaction with assistant	**0.43**		0.33
q15 Colour and shape of lake		**0.93**	
q13 Country landscape contours		**0.86**	
q14 Colour and shape of trees		**0.83**	
q5 Sun rises hazy		**0.58**	
q7 Clouds, storm, lightning			**0.94**
q8 Rainbow appears			**0.93**
q16 Strong wind blows; waves		0.53	**0.56**
q6 Sky clears to blue			**0.53**

Notes: Extraction method: Principal Component Analysis. Rotation method: Promax with Kaiser normalization. Coefficients < .3 have been suppressed for clarity. Factor/item loadings adopted in this study are shown in bold.

3.3.4 *Characterization of the Three Factors: Episodic, Schematic, Controlled Animation*

Factor 1: Episodic/Autobiographic Imagery [Cronbach's α = .88].

Elements mapping onto Factor 1 seem to relate to precise, detailed episodic memories referencing real-life visual experiences, such as a shop window display, the type/colour of clothing worn by a familiar person, and the contours of their face. On Q3 ('Way they walk') and Q12 ('Interaction with a shop assistant') see further Factor 3 below; these items have however been retained within Factor 1 because of the strength of the loading.

Factor 2: Schematic Recall: [Cronbach's α = .87].

This factor includes generic recall of 'a rising sun', 'a lake', 'trees', and 'a country landscape'. These appear to represent stereotypic stock images without a specific reference time-point, which are reminiscent of Paivio and Begg’s (1981) high imageability schematic items. These items could be argued to be neither veridical, nor intensely experienced, in contrast to the items in Factor 1. Q16 ('Strong wind ruffling lake') loaded heavily on this schematic factor, but was retained in Factor 3 'Controlled animation' because of the higher loading.

Factor 3: Controlled Animation [Cronbach's α = .85].

Items in this factor require the participant to control and animate the image: 'Clouds. A storm blows up, with flashes of lightning', 'A rainbow appears', 'A strong wind blows on the trees and on the lake causing waves'. Interestingly, Q3 ('the way they walk' - of a familiar person) and Q12 ('Interaction with a shop assistant') also loaded fairly strongly on Factor 3 and reflect some level of imagined movement, as well as episodic recall; however, these items were retained within Factor 1.

Descriptives for the three factors are given below in Table 4. Participants rated the vividness of imagery pertaining to episodic-related questions most highly (*M*= 3.51, 95% CI [3.41,3.61]), indicating that they were able to generate this type of pictorial image most readily in vivid detail. Schematic recall resulted in the next strongest images (*M*= 3.49, 95% CI [3.37,3.60]), whereas controlled animation resulted in the lowest mean score (*M*= 3.23, 95% CI [3.10,3.35]).

Table 4

Three Factors of the VVIQ - Key Descriptives

Factor	N of Items	M	SD	95% CI (M)	Cronbach's Alpha
Episodic imagery	8	3.51	0.85	3.41-3.61	.88
Schematic Imagery	4	3.49	0.97	3.37-3.60	.87
Controlled animation	4	3.23	1.06	3.10-3.35	.85

3.4 Discussion of Study 1: the Unsuitability of the VVIQ for Creativity Research

Results of the Principal Components Analysis detailed above appear strongly to suggest that the VVIQ is indeed a multi-dimensional measure whose questions appear to tap into three different styles of visual thinking: episodic/autobiographical recall, schematic recall, and the controlled animation of recalled images 'to order'. These correspond with three proposed items in the model of visual imagery set out in

Figure 1: 'Everyday recall - autobiographical life events', 'Schematic recall', and 'Mental rotation/controlled animation'.

This has important implications for the use of the VVIQ in research. While it may indeed still be a valid measure in clinical studies intent upon studying problematic visual recall in disorders such as OCD, PTSD and depression (Holmes et al., 2007; Holmes et al., 2016), where proximal episodic/ autobiographical recall may well be involved, the findings raise a serious concern about its suitability for the study of creative imagination.

As highlighted in the introductory discussion and in Figure 1, those forms of proximal visualization which support somewhat prosaic activities such as semantic interpretation (the recall of generic, schematic images) or the recall of commonplace autobiographical activities (such as shopping or the appearance of acquaintances) are unlikely to correlate strongly with tests of creative abilities. Yet it appears to be exactly these kinds of images which the VVIQ predominantly taps into in the first two factors identified above. In the case of 'Controlled Animation', the third factor, it is possible that the VVIQ is tapping into a more distal 'storyboarding' ability; but more plausible that the types of generated scene (wind ruffling water; thunderstorm; rainbow appears) are proximal in nature, summoned specifically 'to order' at the request of the questionnaire, and no more imaginative than - for example - the controlled motion of the imagined car in the TVIC (Gordon, 1949). Indeed, the scenes appear to be closer in nature to the static schematic images of Factor 2, with the sole difference lying in the animation of the elements: they resemble stereotypic scenes, cinematic in nature, which are passively replayed by the mind’s eye.

There is therefore little evidence in these findings for the VVIQ's ability to predict an individual's capacity to generate hypothetical, distal images supporting 'Conceptual Expansion' (Abraham et al., 2012), or to correlate with novel combinatorial abilities, and it is in precisely these missing activities that we have argued above that the key to creative production may lie. It is entirely plausible, therefore, that the disappointing findings in previous studies of VVIQ and Creativity have arisen from this fundamental mismatch: that those schematic, episodic and animated visual images generated by administration of the VVIQ are too proximal, pedestrian and unremarkable to correlate strongly with creative visual abilities.

Just one potential avenue to creativity remains unaddressed: whether any of these components of the VVIQ represents an ability to recall exceptionally fine detail in a quasi-eidetic manner, argued above (section 1.6) to be potentially relevant to art expertise. This aspect was therefore explored in Study 2.

4. Study 2: Comparison of the VVIQ with a Test of Short-term Recognition Memory

4.1 Background to the Study

As noted above, one hypothesized mechanism for the influence of VIV on artistic creativity lies in the creative individual's ability to visualize the shape, colour and texture of recalled objects with extreme clarity (Kozhevnikov et al., 2013 p.198). See Figure 1: Episodic/Proximal '**Retention/ inspection of detailed image (quasi eidetic)**' and section 1.6 above. In order to explore further whether any of the three newly identified components of the VVIQ related to this ability, a second study was devised in which participants were asked to take part in a prompted picture recall task intended to tap these particular aesthetic dimensions.

Tests of visual memory recall have been carried out in conjunction with the VVIQ previously, most notably by Marks in his original paper (1973). The stimuli used in his trial were coloured photographs, either of everyday scenes such as items laid out on a market stall, or of an array of unrelated objects in a grid formation, in a format commonly referred to as 'Kim's Game' (Wikipedia, n.d.). Participants were invited to scan the briefly presented stimulus, and then to hold in mind a picture of the array while they performed a backwards counting task in threes, intended to prevent phonological rehearsal and to allow the after-image to fade. After the delay (40s) five questions were read to the participants, who chose one of three forced-choice answers. This procedure was carried out 15 times, using 15 different photographs. As a result of these trials, Marks found that performance on the VVIQ reliably predicted recall-accuracy of information, with females outperforming males.

Nevertheless, this research design has faced some criticism, and has proved difficult to replicate (McKelvie, 1995). For example, one study found that scores on the VVIQ showed near-zero correlations with the recall of colour, and an inverse correlation with the recall of spatial location (Cohen & Saslona, 1990). Reporting on a number of studies investigating the relationship of the VVIQ to a picture recall task, McKelvie (1995) suggests that there is commonly no significant relationship (positive or negative) between the VVIQ and the short-term recognition memory for detail or colour if the recall task is difficult (requiring fine distinctions to be made between test items), but that a relationship might exist for easier items.

One limitation of Marks' original paradigm is that it may not be measuring visual imagery exclusively, as the questions are often concerned with the factual details of the content of the pictures ("What was the time on the clock?", "What number was on the golf ball?"). Despite the attempt to discourage verbal processing of this information through the interference task in the delay stage, it is possible that many participants will have laid down their original memory trace in this format, following their preferred strategy of encoding the details in a phonological or propositional form using the language centres of the brain (Keogh & Pearson, 2014). This may also have been encouraged by the cyclical nature of the research paradigm: alerted in round one to the type of questions that were to be asked, participants may have strategically shaped their subsequent approach in later rounds, to explicitly collect factual content of this nature. Furthermore, the three-alternative multiple choice items may have posed a less rigorous challenge of recognition memory than might have been ideal (Chara Jr, 1989).

Additionally, the loading of some questions on the spatial layout of the array ("What was directly below the suitcase?") may in fact be tapping into some individuals' spatial wayfinding abilities (Figure 1: Episodic/Proximal - **Wayfinding**) rather than vividness recall. This was certainly the finding of a study of Australian aboriginal children in desert regions (Kearins, 1981), who excelled at Kim's Game due to their exceptional non-verbal memorization strategies. These were argued to relate to their abilities to navigate around a barren and hostile desert environment using minimal landmarks.

By contrast, white Australian adolescents attempted to recall the same board layout using primarily phonological means.

4.2 Current Study Design

The current study therefore developed a novel paradigm that targeted the recall of colour, detail and object orientation, tapping into Kosslyn's 'imagery inspection' stage (Kosslyn et al., 2006; Pearson et al., 2013), while reducing the interference from spatial/wayfinding challenges and minimising the opportunity for articulation through phonological loop reconstruction. For details see section 4.3.2 below. As indicated above, the intention was to compare performance on this task with scores on the three subcomponents of the VVIQ. The expectation was that none of the VVIQ components would relate to this recall ability, which is identified above (Figure 1) as a discrete facet of visual imagery. For this reason, additional correlational Bayes Factors were computed to establish whether the data support the null hypothesis of no correlation between task performance and the VVIQ or its subcomponents. Bayes Factors provide a measure of how probable the data are under the alternative hypothesis compared to the null hypothesis (Jarosz & Wiley, 2014; van Doorn et al., 2021).

4.3 Methods

4.3.1 *Participants*

As detailed above (Study 1) 133 participants (82 students at the University of XXXX; 51 members of the general public; 95F/38M) took part in trials during 2017/18.

4.3.2 *Materials and Procedure*

All participants completed a demographic sheet and the VVIQ (Marks, 1973) before studying two colourful and detailed artworks (hippy campervan on beach/musical montage) deliberately chosen to be unfamiliar to the participants.[1] These were shown for 90s each on a Powerpoint overhead.

[1] Maciocia, D. (nd). *Hippy campervan on the Beach* [Print]. Artist's website. https://www.dawnmaciocia.com/ourshop/prod_3746977-Hippy-Campervan-on-the-Beach-Medium-Print.html; Seitz, M. (2015, Jan 29). *Kandinsky Instruments*. *Bloglovin'*.

Participants were told that they would be asked questions about the pictures later; however, there was no prior warning of the nature of the questions to be posed. The presentation of the two pictures was counterbalanced among participants.

After the pictures were displayed, participants were occupied for approximately 12 minutes by filling out two questionnaires relating to self-reported creativity (not reported here).

Finally, participants were asked 14 questions (seven for each picture) about visual object attributes of the pictures, intended to explore the ability to 're-imagine' the intact artwork in vivid detail. These involved the colour, shape, size and orientation of specific elements within the pictures (e.g. ‘What shade of blue was the numberplate on the campervan?’, 'What shape were the three flags on top of the beach huts?'; ‘What size was the ball next to the dog?’; ‘What direction was the seagull facing?’). See examples in Figure 3; a full list of all 14 questions is available as supplemental material to this article. Responses were made on a forced choice between four possible images (A-D), not three as in the previous study by Marks (1973), meaning that the average number of correct answers arising by chance was now 3.5/14, a more acceptable proportion. Unlike the object arrays in Mark’s study, object attributes in this task were deliberately selected to circumvent the participants' ability either to use memory traces laid down by articulation or to reassemble the picture schematically. For example it is very difficult to label a specific hue to assist recall, particularly when the nature of the subsequent question was unknown. The paradigm was thus testing for a quasi-eidetic recall of the intact composition. This memory recall task is henceforth referred to as the 'Novel Picture Recall Task', NPRT.

<INSERT FIGURE 3 SOMEWHERE AROUND HERE>

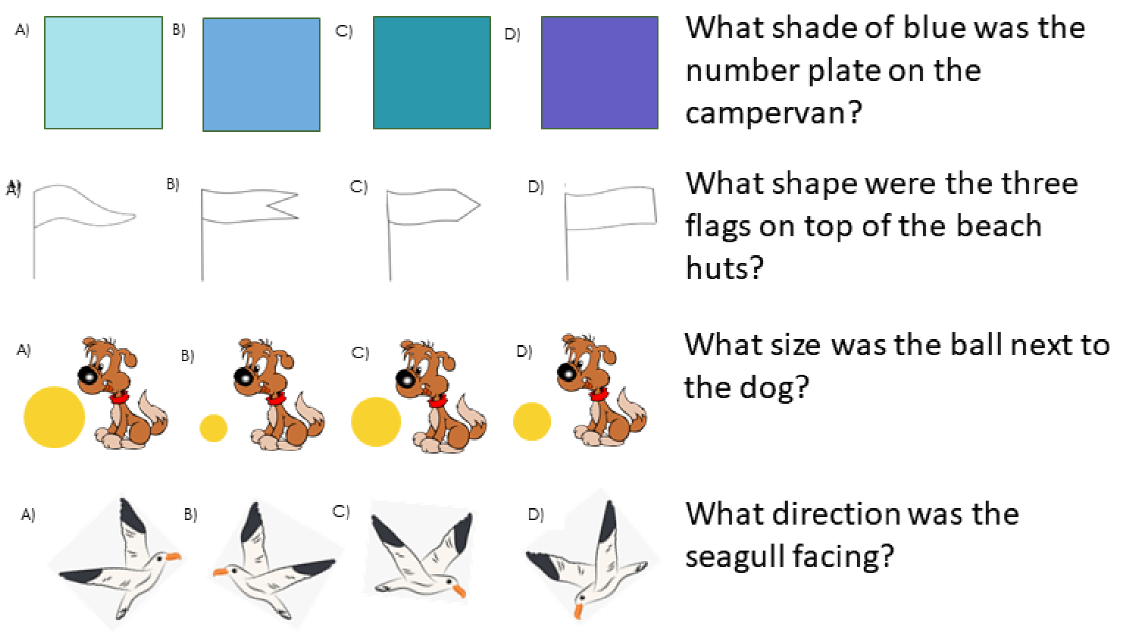

Figure 3: a sample of visual challenges from the NPRT, involving colour, shape, size and orientation of specific elements (actual images have been replaced by clipart items for reasons of copyright)

4.4 Study 2 Results

4.4.1 *Calculation of Mean Scores (VVIQ and NPRT)*

As described earlier (section 3.3.1), scores on the VVIQ were summed for Study 2, and means calculated for individual participants. Descriptives for the VVIQ scores (in total and by the three components identified in Study 1) are shown in Table 5. As noted above (Study 1), VVIQ mean scores typically show moderate negative skew (Study 2: -.64). The overall mean VVIQ score (M = 3.36) was significantly higher than the scale midpoint of 3 (*Mdiff* = .36, 95% CI [0.22, 0.51], $t(132) = 4.80$, $p < .001$, $d = 0.42$) indicating, as before, that participants generally felt that they had good visualizing abilities.

Scores on the NPRT were calculated for each participant by summing the correct responses to the 14 questions described above, and overall means are shown in Table 5. The mean score on this test (6.65) significantly exceeded the score (3.5) that was achievable by chance (*Mdiff* = 3.15, 95% CI

[2.79, 3.51], $t(132) = 17.18$, $p = .001$, $d = 1.49$), and data were approximately normally distributed, suggesting that the task was an appropriately challenging test of individual differences in the ability to recall previously presented images.

Table 5

Mean VVIQ and NPRT Scores for Study 2

	N	Min	Max	M	Std. Dev	95% CI (M)
VVIQ total	133	1	5	3.36	0.87	3.21-3.51
● Episodic	133	1	5	3.43	0.90	3.28-3.59
● Schematic	133	1	5	3.37	1.02	3.20-3.55
● Controlled	133	1	5	3.22	1.06	3.04-3.40
NPRT total	133	1	11	6.65	2.12	6.29-7.02

4.4.2 *Correlation of VVIQ and NPRT Scores*

As the NPRT scores were not expected to correlate with the VVIQ score and VVIQ subcomponent scores, additional Bayesian correlation analyses were conducted in order to establish whether there was evidence for the null hypothesis, H0. Bayes factors are provided in addition to the standard null hypothesis testing information and when reported as BF_{01}, demonstrate evidence for H0. Bayes factors were calculated using a default non-informative stretched beta prior = 1.0 using JASP v0.16 (JASP Team, 2021). Values of BF_{01} above 1 support H0, with BF_{01} values from 1-3 deemed anecdotal evidence and from 3-10 moderate evidence. A Pearson's product-moment correlation was run to assess the relationship between (a) VVIQ scores in total, together with the three components identified above (Study 1); and (b) scores on the NPRT. Preliminary scatterplot analyses showed the relationships to be linear, with no outliers. Given that VVIQ scores were not normally distributed, as for Study 1, all statistics presented below have been bootstrapped [BCa CI 95%].

As expected, bootstrapped NPRT and VVIQ scores were uncorrelated ($r(131) = .10$, $p = .25$, 95% CI [-.08, .27], $BF_{01} = 4.70$). Similarly, none of the three extracted factors correlated with the results of the NPRT: NPRT/Episodic, $r(131) = .07$, $p = .40$, 95% CI [-.11, .24], $BF_{01} = 6.53$; NPRT/Schematic, $r(131) = .08$, $p = .35$, 95% CI [-.10, .24], $BF_{01} = 6.03$; NPRT/Controlled, $r(131) = .13$, $p = .13$, 95% CI [-.05, .31], $BF_{01} = 2.98$. See Table 6 for a summary of these results.

The NPRT thus appears to tap into a form of VIV which is unrelated to factors of VIV measured by the VVIQ. This application of VIV has been termed above (Figure 1) 'Retention/Inspection of detailed image'.

Table 6

Pearson Correlations for the Main Study 2 Variables

	VVIQ total	Episodic	Schematic	Controlled
NPRT - r value	.10	.07	.08	.13
Sig (2-tailed)	.25	.40	.35	.13
BF_{01}	4.70	6.53	6.03	2.98

4.5 Discussion of Study 2

The NPRT was designed specifically to circumvent simple memory recall of facts (such as the time on a clock) which could have been laid down by articulation. Matching the recollected target item with (for example) various shades of blue required a quasi-eidetic recall of the picture presented approximately 12 minutes earlier; and this would appear to tap into the visuo-spatial faculties, rather than phonological rehearsal. There was a wide range of scores with the majority of participants performing above chance; scores were approximately normally distributed, suggesting that this is a valid individual difference.

We argued above (sections 1.6 and 1.8) that the intensely vivid recall of shape, texture or colour might play a role in artistic creativity; and this has found support in studies utilising the OSIVQ as a self-report measure (Kozhevnikov et al., 2013; Pérez-Fabello et al., 2016; Pérez-Fabello et al., 2018). According to this theory, visual artists rely on object visualisation to create “holistic, global images that are enduring, spontaneous and offer a multiplicity of meanings” (Pérez-Fabello et al., 2016, p.68). However, Bayes Factors demonstrate that the data moderately support the absence of any correlation between the NPRT and the VVIQ (in total, and particularly for the episodic and schematic factors, the controlled Bayes Factor only anecdotally suggesting no correlation with the VVIQ), indicating that they are measuring different aspects of VIV. Once again, therefore, the VVIQ appears not to be measuring aspects of visual imagery which might feed into creative processes, perhaps explaining the disappointing results in previous creativity studies employing this measure.

Discussion

This research has proposed two important advances in the understanding of Visual Imagery Vividness (VIV) and its relationship to creativity, which have profound implications for research in this area. These are discussed below.

5.1 A New Multifactorial Model of Visual Imagery and its Relationship with Creativity

In the first place, a review of the literature on visual imagery, its multi-faceted nature and its likely relationship to creativity has led to the development of a new Multifactorial Model of Visual Imagery set out in Figure 1. Whereas previous research has explored visual imagery, and in particular the relationship between VIV and creativity, in terms of simple dichotomies such as object vs spatial visualization (Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2010) or proximal/distal imagery (Meyer et al., 2019), this current study has blended these two approaches in a multi-dimensional model which takes account not only of the pathway employed, but the nature of the imagery task (e.g. proximal, pedestrian and unremarkable visualisation vs. unbounded creative fantasy and story-boarding).

This hypothesised model has enabled the identification of those elements of visual imagery which are likely candidates, on *a priori* grounds, to be associated with creative production. These include an enhanced ability to **recall fine detail**, with visual artists exhibiting particularly sensitive recall of form, shape and colour ('object visualisers' - Kozhevnikov et al., 2013); the ability to **imagine and develop scenes in the mind** with particular clarity, using distal visualization for elements such as character development, perspective taking and mental storyboarding (Meyer et al., 2019); the ability to invoke hypothetical imaginary constructions ('**Conceptual Expansion**') featuring unbounded creative fantasies which deliberately break through pre-existing knowledge structures (Abraham, 2014); and the ability to use the dorsal pathway to explore **novel combinatorial constructions**.

The failure of previous studies to reliably demonstrate a connection between creativity and VIV has been explored in the context of this model. Previous approaches have often tried to establish relationships between psychometric measures of creativity (e.g. the TTCT, Torrance, 1974), and tasks which assess proximal visualisation abilities, such as the ability to mentally rotate or control objects 'to order'. The above model suggests that this approach is doomed to failure, given that those forms of visualization which support more prosaic, everyday activities (such as wayfinding, semantic interpretation, object rotation and the recall of commonplace activities, objects and people) are not expected to show a strong connection with creative production.

5.2 VVIQ is Not Unidimensional, and Measures Proximal, Low-creative Visual Imagery

The use of the VVIQ as a self-report instrument to capture an individual's ability to generate vivid, detailed and lively imagery is particularly problematic in this respect. Aside from the technical weaknesses of the scale discussed above (sections 2.1-2.2), this current study has challenged the previously held assumption that the VVIQ is a unidimensional measure of imagery vividness which could be appropriately utilised across a wide range of study domains, including creativity.

An important finding of this paper (Study 1) was that the VVIQ appears to load to three independent factors relating to vividness of recall of **schematic imagery** (generic, stock images without a specific reference time-point), **episodic/autobiographic** details (relating to detailed real-life visual experiences) and **controlled animation** (allowing an everyday scene to be controlled and animated to a limited degree, in response to a prompt). These were argued to correspond with three proposed items in the model of visual imagery set out in Figure 1: 'Schematic recall', 'Mental rotation/controlled animation', and 'Everyday recall - autobiographical life events'.

Importantly, all three of these somewhat prosaic dimensions have been argued above (section 3.4) to relate to proximal, rather than distal, visualisations, and for this reason they are unlikely to be related to creativity. It is entirely plausible, therefore, that the disappointing findings in previous studies of VVIQ and creativity have arisen from this fundamental mismatch.

Results from Study 2 also indicated that the VVIQ does not appear to measure an ability to recall shape, texture or colour in vivid detail, an ability which was argued above (sections 1.6 and 1.8) to be potentially relevant to art expertise. The lack of correlation between the Novel Picture Recall Task and the VVIQ (in total, or for individual factors), indicates that they are measuring different aspects of VIV, once again calling the use of the VVIQ in creativity studies into question.

Limitations and Way Forward

One of the limitations of this study is that, although grounded firmly in the supporting literature, the model of Visual Imagery proposed at section 1.5 has yet to be tested out experimentally. One goal of future research would therefore be to confirm the existence of these hypothesised functions and their placement in such a model. A key research priority would be to confirm the alignment of the proposed functions with the Object-Spatial dichotomy of the OSIVQ model (Blazhenkova & Kozhevnikov, 2009), taking into account the interaction with the Proximal-Distal model of Meyer et al. (2019), as conceptualised in Figure 1.

It would also be useful to see whether the function of 'Conceptual Expansion' (Abraham, 2014), identified in Figure 1 as a separate construct, is indeed a separate entity from the story-boarding elements of Meyer et al.’s model (2019). Meyer et al. noted that vivid distal imagination of this nature has particular face valid connection to professionals such as novelists, actors and directors who must all work beyond the limits of the ‘here-and-now’, in order to allow characters, plots and settings to come to life within the mind (2019). For this reason, Meyer and colleagues targeted these groups for their studies of creative experts, deliberately avoiding musicians and dancers who were argued to derive inspiration from external sources of stimulation, such as sound and movement, that engage the auditory and sensorimotor systems, rather than those involved in internal counterfactual thinking. Nevertheless, many of the outputs of Meyer~~’s~~ et al.’s expert groups (writers, actors, directors, and visual artists) may still work within the constraints of existing categories and knowledge structures, creating mental narratives which explore the human condition without broadening or breaching existing conventions. In this, their outputs appear to differ from ‘Conceptual Expansion’, which explicitly rejects the tendency to resort to narratives employing the ‘path-of-least-resistance’ (Abraham, 2014; Abraham et al., 2012), instead exploring remote times, places, perspectives and counterfactuals in truly novel frames of reference (Abraham, 2014; Meyer et al., 2019; Ward, 1994). Research by Howard-Jones and colleagues (2005) on creative story generation supports this viewpoint: stories generated from conceptually related prompt-words tended to be less creative than those from sets of unrelated words, suggesting that the more cognitively demanding course of rejecting the 'path-of-least-resistance' may be key to conceptual expansion and frame-breaking creativity (Abraham et al., 2012). The development of a proximal/distal task (spanning a range of temporal, spatial, social and hypothetical situations) by Meyer and colleagues (2019) provides a new avenue to explore these distinctions within the framework of the Multifactorial Model of Visual Imagery proposed above.

Studies could also explore whether artists are indeed qualitatively different from others in their ability to imagine the world using the object pathway in rich colourful detail (Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2013). Although many proponents of the OSIVQ have argued strongly that artistic expertise is more strongly associated with object visualisation than spatial (e.g. Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2013; Pérez-Fabello et al., 2016; Pérez-Fabello et al., 2018), the evidence is not unequivocal. For example, Chamberlain and colleagues found that art students, even at the very beginning of their college studies, outperformed non-art students on a number of visual-spatial tasks, including mental rotation, and that mental rotational abilities moderately correlated with creative and representational drawing abilities (2019; 2021). Again, in a case study of a graphic designer suffering from the effects of posterior stroke, Foley and colleagues (2020) found that – although clearly dissociable in impact – deficits in both object and spatial imagery were jointly responsible for the dramatic changes in artistic expression affecting the complexity, layout, coloration, style and subject matter of her compositions. Finally, it is equally unclear whether the mental visualisation abilities of artists are causally responsible for their enhanced creative abilities, or whether they contribute only to the proficient execution of technical draughtsman skills in the production of an object, whether creative or mundane (see section 1.8 above).

In this context it would also be important to explore the relationship between proximal/distal imagery and other models of creativity such as the 4Cs model of Kaufman and Beghetto (2009). As argued above (section 1.8) those forms of visualization which support more prosaic, everyday activities (such as wayfinding, semantic interpretation, object rotation and the recall of commonplace activities, objects and people) are expected not to show a strong connection with creative production. It is in the novel adaptation of these elements that creativity – however modest – might lie. We would argue therefore that even ‘new-to-me’ forms of creativity involved in mini- or little-c creations (i.e. ideas which are new to the person, regardless of how many other people have had the same idea previously: Boden, 2004; Gilhooly et al., 2007) will go beyond the mere reproduction of proximal images relating to the ‘what already is’, and will explore the distal possibilities of ‘what might be’. Nevertheless, it may be the case that some forms of mental imagery – counterfactual thinking, for example – may be more commonly used in Pro- or Big-C levels of creative output; and that distal imagery might be the favored mode of imagery generation among those achieving creative greatness.

Building on the ratification of the model in Figure 1, the way would be clear to establish a new, better targeted measure of Visual Imagery Vividness which fully reflected the multi-dimensional nature of Visual Imagery, and the Distal/Proximal/Object/Spatial interactions. Such an instrument would be an invaluable tool in future studies of creativity seeking to establish which types of visual imagery, serving which function, might underpin creative production. The current study has suggested that four distinct areas are promising candidates for such a role (retention/inspection of richly detailed image; scene development/storyboarding; conceptual expansion; novel combinatorial ability), but this would need to be confirmed empirically.

Conclusion

The current study has therefore gone some considerable way to explaining one of the enduring puzzles in the study of visual imagery: whether it plays a supportive role in creative production, and, if so, why it has been so challenging to demonstrate that this relationship exists. We argue here that a combination of two factors - the treatment of visual imagery as unidimensional, and the use of the VVIQ, which is suboptimal for such a study - has led to a frustrating lack of clarity, precision and reliability in previous explorations of this controversy, and that this in turn has led to confounded results.

Our research has combined two important approaches which already existed in the field - Object/Spatial imagery (Blazhenkova & Kozhevnikov, 2009) and Proximal/Distal imagery (Meyer et al., 2019) - to create a new multidimensional interpretation of visual imagery. Building on past and present research, we have also made predictions about those functions of visual imagery which seem most likely on *a priori* grounds to have a relationship with creative activities. Having cut through the Gordian knot which previously entangled studies in the area, the opportunity now exists for future research to explore the relationship of creativity and Visual Imagery Vividness using a new multi-dimensional model, the MMVI (see figure 1), while at the same time discarding the VVIQ in favour of a new, better targeted measure of Visual Imagery Vividness in studies of creativity. Freed from the misconceptions of the past concerning the nature of visual imagery, and from over-reliance on a mismatched self-report instrument, we hope that a more secure understanding of the relationship between visual imagery, imagination and creativity can now emerge.

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References

Abraham, A. (2014, 2014-February-24). Creative thinking as orchestrated by semantic processing vs. cognitive control brain networks [Perspective]. *Frontiers in Human Neuroscience, 8*(95). https://doi.org/10.3389/fnhum.2014.00095

Abraham, A. (2016). The imaginative mind. *Human Brain Mapping, 37*(11), 4197-4211. https://doi.org/10.1002/hbm.23300

Abraham, A., Pieritz, K., Thybusch, K., Rutter, B., Kröger, S., Schweckendiek, J., Stark, R., Windmann, S., & Hermann, C. (2012). Creativity and the brain: uncovering the neural signature of conceptual expansion. *Neuropsychologia, 50*(8), 1906-1917. https://doi.org/10.1016/j.neuropsychologia.2012.04.015

Aldworth, S. (2018, 2018/08/01/). The art of imagination. *Cortex, 105*, 173-181. https://doi.org/https://doi.org/10.1016/j.cortex.2018.03.014

Allen, A. D. (2010, 2010/08/12). Complex Spatial Skills: The Link Between Visualization and Creativity. *Creativity Research Journal, 22*(3), 241-249. https://doi.org/10.1080/10400419.2010.503530

Amedi, A., Malach, R., & Pascual-Leone, A. (2005, 2005/12/08/). Negative BOLD Differentiates Visual Imagery and Perception. *Neuron, 48*(5), 859-872. https://doi.org/https://doi.org/10.1016/j.neuron.2005.10.032

Anderson, R. E., & Helstrup, T. (1993). Visual discovery in mind and on paper. *Memory & Cognition, 21*(3), 283-293. https://doi.org/10.3758/BF03208261

Antonietti, A., Bologna, D., & Lupi, G. (1997). Creative synthesis of visual images is not associated with individual differences. *Perceptual and Motor Skills, 85*(3), 881-882. https://doi.org/10.2466/pms.1997.85.3.881

Arntz, A., Tiesema, M., & Kindt, M. (2007). Treatment of PTSD: A comparison of imaginal exposure with and without imagery rescripting. *Journal of behavior therapy and experimental psychiatry, 38*(4), 345-370. https://doi.org/10.1016/j.jbtep.2007.10.006

Aziz-Zadeh, L., Liew, S.-L., & Dandekar, F. (2012). Exploring the neural correlates of visual creativity. *Social cognitive and affective neuroscience, 8*(4), 475-480. https://doi.org/10.1093/scan/nss021

Bainbridge, W. A., Pounder, Z., Eardley, A. F., & Baker, C. I. (2021). Quantifying Aphantasia through drawing: Those without visual imagery show deficits in object but not spatial memory. *Cortex, 135*, 159-172. https://doi.org/10.1016/j.cortex.2020.11.014

Belfi, A. M., Vessel, E. A., & Starr, G. G. (2018). Individual ratings of vividness predict aesthetic appeal in poetry. *Psychology of Aesthetics, Creativity, and the Arts, 12*(3), 341-350. https://doi.org/10.1037/aca0000153

Bergen, B. K., Lindsay, S., Matlock, T., & Narayanan, S. (2007). Spatial and linguistic aspects of visual imagery in sentence comprehension. *Cognitive Science, 31*(5), 733-764. https://doi.org/10.1080/03640210701530748

Blajenkova, O., Kozhevnikov, M., & Motes, M. A. (2006). Object-spatial imagery: a new self-report imagery questionnaire. *Applied Cognitive Psychology, 20*(2), 239-263. https://doi.org/10.1002/acp.1182

Blazhenkova, O. (2016). Vividness of object and spatial imagery. *Perceptual and Motor Skills, 122*(2), 490-508. https://doi.org/10.1177/0031512516639431

Blazhenkova, O., & Kozhevnikov, M. (2009). The new object-spatial-verbal cognitive style model: Theory and measurement. *Applied Cognitive Psychology, 23*(5), 638-663. https://doi.org/10.1002/acp.1473

Boden, M. (2004). *The creative mind* (3rd ed.). Weidenfeld and Nicolson.

Calabrese, L., & Marucci, F. S. (2006). The influence of expertise level on the visuo-spatial ability: differences between experts and novices in imagery and drawing abilities. *Cognitive Processing, 7*(1), 118-120. https://doi.org/10.1007/s10339-006-0094-2

Chamberlain, R., Drake, J. E., Kozbelt, A., Hickman, R., Siev, J., & Wagemans, J. (2019). Artists as experts in visual cognition: An update. *Psychology of Aesthetics, Creativity, and the Arts, 13*(1), 58-73. https://doi.org/10.1037/aca0000156

Chamberlain, R., Kozbelt, A., Drake, J. E., & Wagemans, J. (2021). Learning to see by learning to draw: A longitudinal analysis of the relationship between representational drawing training and visuospatial skill. *Psychology of Aesthetics, Creativity, and the Arts, 15*(1), 76-90. https://doi.org/10.1037/aca0000243

Chamberlain, R., McManus, C., Brunswick, N., Rankin, Q., & Riley, H. (2015). Scratching the surface: Practice, personality, approaches to learning, and the acquisition of high-level representational drawing ability. *Psychology of Aesthetics, Creativity, and the Arts, 9*(4), 451-462. https://doi.org/10.1037/aca0000011

Chambers, D., & Reisberg, D. (1985). Can mental images be ambiguous? *Journal of Experimental Psychology: Human perception and performance, 11*(3), 317-328. https://doi.org/10.1037/0096-1523.11.3.317

Chara Jr, P. J. (1989). A questionable questionnaire: A rejoinder to Marks. *Perceptual and Motor Skills, 68*(1), 159-162. https://doi.org/10.2466/pms.1989.68.1.159

Chara Jr, P. J., & Verplanck, W. S. (1986). The imagery questionnaire: an investigation of its validity. *Perceptual and Motor Skills, 63*(2), 915-920. https://doi.org/0.2466/pms.1986.63.2.915

Chavez, R. A. (2016). Imagery As a Core Process in the Creativity of Successful and Awarded Artists and Scientists and Its Neurobiological Correlates. *Frontiers in Psychology, 7*(351), 1-6. https://doi.org/doi:10.3389/fpsyg.2016.00351

Clark, G. (1989). Screening and identifying students talented in the visual arts: Clark's Drawing Abilities Test. *Gifted Child Quarterly, 33*(3), 98-105. https://doi.org/10.1177/001698628903300301

Cohen, B. H., & Saslona, M. (1990). The advantage of being an habitual visualizer. *Journal of Mental Imagery*, 101-112

Cornoldi, C., De Beni, R., Giusberti, F., & Massironi, M. (1998). Memory and imagery: A visual trace is not a mental image. In M. A. Conway, S. E. Gathercole, & C. Cornoldi (Eds.), *Theories of memory* (Vol. 2, pp. 87-110). Psychology Press. https://doi.org/10.4324/9781315804507

Cross, L., Atherton, G., Wilson, A. D., & Golonka, S. (2017, 2017-October-13). Imagined Steps: Mental Simulation of Coordinated Rhythmic Movements Effects on Pro-sociality [Original Research]. *Frontiers in Psychology, 8*(1798). https://doi.org/10.3389/fpsyg.2017.01798

Cui, X., Jeter, C. B., Yang, D., Montague, P. R., & Eagleman, D. M. (2007, 2007/02/01/). Vividness of mental imagery: Individual variability can be measured objectively. *Vision Research, 47*(4), 474-478. https://doi.org/https://doi.org/10.1016/j.visres.2006.11.013

Cumming, J., & Ramsey, R. (2008). Imagery interventions in sport. In S. D. Mellalieu & S. Hanton (Eds.), *Advances in applied sport psychology: A review* (pp. 5-36). Routledge. https://doi.org/10.4324/9780203887073

Cumming, J., & Williams, S. E. (2012). The role of imagery in performance. In S. Murphy (Ed.), *Handbook of sport and performance psychology* (pp. 213-232). OUP. https://doi.org/10.1093/oxfordhb/9780199731763.013.0011

D'Angiulli, A., Runge, M., Faulkner, A., Zakizadeh, J., Chan, A., & Morcos, S. (2013). Vividness of visual imagery and incidental recall of verbal cues, when phenomenological availability reflects long-term memory accessibility. *Frontiers in Psychology, 4*, 1. https://doi.org/10.3389/fpsyg.2013.00001

Dabrowski, K. (1967). *Personality-shaping through Positive Disintegration*. Little Brown.

Dabrowski, K., & Piechowski, M. M. (1977). *Theory of Levels of Emotional Development: From primary integration to self-actualization* (Vol. 2). Oceanside, NY: Dabor Science Publications.

Daniels-McGhee, S., & Davis, G. A. (1994). The imagery-creativity connection. *The Journal of Creative Behavior, 28*(3), 151-176. https://doi.org/10.1002/j.2162-6057.1994.tb01189.x

Dean, G. M., & Morris, P. E. (1991). Imagery and spatial ability: When introspective reports predict performance. In *Advances in psychology* (Vol. 80, pp. 331-347). Elsevier. https://doi.org/10.1016/S0166-4115(08)60522-1

Dean, G. M., & Morris, P. E. (2003). The relationship between self-reports of imagery and spatial ability. *British Journal of Psychology, 94*(2), 245-273. https://doi.org/10.1348/000712603321661912

Dietrich, A., & Haider, H. (2015). Human creativity, evolutionary algorithms, and predictive representations: The mechanics of thought trials. *Psychonomic Bulletin & Review, 22*(4), 897-915. https://doi.org/10.3758/s13423-014-0743-x

Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). *Manual for Kit of Factor-referenced Cognitive Tests*. Educational Testing Service.

Eysenck, M. W., & Keane, M. T. (2015). *Cognitive psychology: A student's handbook* (7th ed.). Psychology Press. https://doi.org/10.4324/9781315778006

Falk, R. F., Manzanero, J. B., & Miller, N. B. (1997). Developmental potential in Venezuelan and American artists: A cross-cultural validity study. *Creativity Research Journal, 10*(2-3), 201-206. https://doi.org/10.1080/10400419.1997.9651218

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and social psychology review, 2*(4), 290-309. https://doi.org/10.1207/s15327957pspr0204_5

Fine, P. A., Wise, K. J., Goldemberg, R., & Bravo, A. (2015). Performing musicians' understanding of the terms "mental practice" and "score analysis". *Psychomusicology: Music, Mind, and Brain, 25*(1), 69-82. https://doi.org/10.1037/pmu0000068

Finke, R. A. (1996). Imagery, creativity, and emergent structure. *Consciousness and Cognition, 5*(3), 381-393. https://doi.org/10.1006/ccog.1996.0024

Finke, R. A., & Slayton, K. (1988). Explorations of creative visual synthesis in mental imagery. *Memory & Cognition, 16*(3), 252-257. https://doi.org/10.3758/BF03197758

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. Bradford, The MIT Press.

Fissler, P., Küster, O. C., Laptinskaya, D., Loy, L. S., von Arnim, C. A. F., & Kolassa, I.-T. (2018, 2018-October-01). Jigsaw Puzzling Taps Multiple Cognitive Abilities and Is a Potential Protective Factor for Cognitive Aging [Clinical Trial]. *Frontiers in Aging Neuroscience, 10*(299). https://doi.org/10.3389/fnagi.2018.00299

Foley, J. A., Bayraktar, I., Hyare, H., & Caine, D. (2020). Impaired spatial processing in visual perception, imagery and art-making following parieto-occipital infarcts. *Cortex, 126*, 355-367. https://doi.org/10.1016/j.cortex.2020.01.023

Gable, S. L., Hopper, E. A., & Schooler, J. W. (2019). When the muses strike: Creative ideas of physicists and writers routinely occur during mind wandering. *Psychological Science, 30*(3), 396-404. https://doi.org/10.1177/0956797618820626

Galton, F. (1883). *Inquiries into human faculty and its development*. Macmillan.

Ghaem, O., Mellet, E., Crivello, F., Tzourio, N., Mazoyer, B., Berthoz, A., & Denis, M. (1997). Mental navigation along memorized routes activates the hippocampus, precuneus, and insula. *Neuroreport, 8*(3), 739-744. https://doi.org/10.1097/00001756-199702100-00032

Gilhooly, K. J., Ball, L. J., & Macchi, L. (2015, 2015/03/13). Insight and creative thinking processes: Routine and special. *Thinking & Reasoning, 21*(1), 1-4. http://dx.doi.org/10.1080/13546783.2014.966758

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology, 98*(4), 611-625. https://doi.org/10.1348/096317907X173421

Glazek, K. (2012). Visual and motor processing in visual artists: Implications for cognitive and neural mechanisms. *Psychology of Aesthetics, Creativity, and the Arts, 6*(2), 155-167. https://doi.org/10.1037/a0025184

Gordon, R. (1949). An investigation into some of the factors that favour the formation of stereotyped images. *British Journal of Psychology, 39*(3), 156-167.

Grandin, T. (2009). How does visual thinking work in the mind of a person with autism? A personal account. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1522), 1437-1442. https://doi.org/10.1098/rstb.2008.0297

Grandin, T. (2010). *The world needs all kinds of minds* [TED talk]. https://www.ted.com/talks/temple_grandin_the_world_needs_all_kinds_of_minds?language=en

Guilford, J. P. (1967). *The nature of human intelligence*. McGraw-Hill.

Hass, R. W., & Beaty, R. E. (2018). Use or Consequences: Probing the Cognitive Difference Between Two Measures of Divergent Thinking. *Frontiers in Psychology, 9*(2327), 1-15. https://doi.org/10.3389/fpsyg.2018.02327

Hermelin, B., Pring, L., Buhler, M., Wolff, S., & Heaton, P. (1999). A visually impaired savant artist: Interacting perceptual and memory representations. *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 40*(7), 1129-1139. https://doi.org/10.1111/1469-7610.00529

Highben, Z., & Palmer, C. (2004). Effects of auditory and motor mental practice in memorized piano performance. *Bulletin of the Council for Research in Music Education, 159*(Winter), 58-65.

Hocevar, D. (1979, April 16-19). The Development of the Creative Behavior Inventory (CBI). 49th meeting of the Rocky Mountain Psychological Association., Las Vegas, NV.

Holmes, E. A., Arntz, A., & Smucker, M. R. (2007). Imagery rescripting in cognitive behaviour therapy: Images, treatment techniques and outcomes. *Journal of behavior therapy and experimental psychiatry, 38*(4), 297-305. https://doi.org/10.1016/j.jbtep.2007.10.007

Holmes, E. A., Blackwell, S. E., Heyes, S. B., Renner, F., & Raes, F. (2016). Mental imagery in depression: phenomenology, potential mechanisms, and treatment implications. *Annual review of clinical psychology, 12*, 249-280. https://doi.org/10.1146/annurev-clinpsy-021815-092925

Horváth, G. (2018). Visual imagination and the narrative image. Parallelisms between art history and neuroscience. *Cortex, 105*, 144-154. https://doi.org/10.1016/j.cortex.2018.06.007

Howard-Jones, P. A., Blakemore, S.-J., Samuel, E. A., Summers, I. R., & Claxton, G. (2005). Semantic divergence and creative story generation: An fMRI investigation. *Cognitive Brain Research, 25*(1), 240-250. https://doi.org/https://doi.org/10.1016/j.cogbrainres.2005.05.013

Irving, L. T. (2014). *Creativity, imagery and schizotypy: an exploration of similarities in cognitive processing* [PhD, Middlesex University].

Isaac, A. R., & Marks, D. F. (1994). Individual differences in mental imagery experience: developmental changes and specialization. *British Journal of Psychology, 85*(4), 479-500. https://doi.org/10.1111/j.2044-8295.1994.tb02536.x

Ishai, A., Haxby, J. V., & Ungerleider, L. G. (2002). Visual imagery of famous faces: effects of memory and attention revealed by fMRI. *Neuroimage, 17*(4), 1729-1741. https://doi.org/10.1006/nimg.2002.1330

Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. *The Journal of Problem Solving, 7*(1/2), 1-8. https://doi.org/10.7771/1932-6246.1167

JASP Team. (2021). *JASP (Version 0.16).*

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika, 39*, 32-36. https://doi.org/10.1007/BF02291575

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four c model of creativity. *Review of General Psychology, 13*(1), 1-12. https://doi.org/10.1037/a0013688

Kearins, J. M. (1981). Visual spatial memory in Australian Aboriginal children of desert regions. *Cognitive Psychology, 13*(3), 434-460. https://doi.org/10.1016/0010-0285(81)90017-7

Keller, P. E. (2012). Mental imagery in music performance: underlying mechanisms and potential benefits. *Annals of the New York Academy of Sciences, 1252*(1), 206-213. https://doi.org/10.1111/j.1749-6632.2011.06439.x

Keogh, R., & Pearson, J. (2014). The sensory strength of voluntary visual imagery predicts visual working memory capacity. *Journal of vision, 14*(12), 1-13. https://doi.org/10.1167/14.12.7

Keogh, R., & Pearson, J. (2018). The blind mind: No sensory visual imagery in aphantasia. *Cortex, 105*, 53-60. https://doi.org/10.1016/j.cortex.2017.10.012

Kihlstrom, J. F., Glisky, M. L., Peterson, M. A., Harvey, E. M., & Rose, P. M. (1991). Vividness and control of mental imagery: A psychometric analysis. *Journal of Mental Imagery, 15*(3/4), 133-142.

Kosslyn, S. M., Brunn, J., Cave, K. R., & Wallach, R. W. (1984). Individual differences in mental imagery ability: A computational analysis. *Cognition, 18*(1-3), 195-243. https://doi.org/10.1016/0010-0277(84)90025-8

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience, 2*(9), 635. https://doi.org/10.1038/35090055

Kosslyn, S. M., Thompson, W. L., & Ganis, G. (2006). *The case for mental imagery*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195179088.001.0001

Kozbelt, A. (2001). Artists as experts in visual cognition. *Visual cognition, 8*(6), 705-723. https://doi.org/10.1080/13506280042000090

Kozbelt, A., & Seeley, W. P. (2007). Integrating art historical, psychological, and neuroscientific explanations of artists' advantages in drawing and perception. *Psychology of Aesthetics, Creativity, and the Arts, 1*(2), 80-90. https://doi.org/10.1037/1931-3896.1.2.80

Kozhevnikov, M., Blazhenkova, O., & Becker, M. (2010). Trade-off in object versus spatial visualization abilities: Restriction in the development of visual-processing resources. *Psychonomic Bulletin & Review, 17*(1), 29-35. https://doi.org/10.3758/PBR.17.1.29

Kozhevnikov, M., Kozhevnikov, M., Yu, C. J., & Blazhenkova, O. (2013). Creativity, visualization abilities, and visual cognitive style. *British Journal of Educational Psychology, 83*(2), 196-209. https://doi.org/10.1111/bjep.12013

LeBoutillier, N. (1999). *The role of mental imagery in creativity* [PhD, Middlesex].

LeBoutillier, N., & Marks, D. F. (2003). Mental imagery and creativity: A meta-analytic review study. *British Journal of Psychology, 94*(1), 29-44. https://doi.org/10.1348/000712603762842084

Libby, L. K., Shaeffer, E. M., Eibach, R. P., & Slemmer, J. A. (2007). Picture yourself at the polls: Visual perspective in mental imagery affects self-perception and behavior. *Psychological Science, 18*(3), 199-203. https://doi.org/10.1111/j.1467-9280.2007.01872.x

Logie, R. H., & Helstrup, T. (1999, 1999/09/01). Introduction. *European Journal of Cognitive Psychology, 11*(3), 289-293. https://doi.org/10.1080/713752319

Luft, C. D. B., Zioga, I., Banissy, M. J., & Bhattacharya, J. (2019). Spontaneous visual imagery during meditation for creating visual art: an EEG and brain stimulation case study. *Frontiers in Psychology, 10*(210), 1-14. https://doi.org/10.3389/fpsyg.2019.00210

Macintyre, T., Moran, A., Collet, C., & Guillot, A. (2013, 2013-April-01). An emerging paradigm: a strength-based approach to exploring mental imagery [Review]. *Frontiers in Human Neuroscience, 7*(104). https://doi.org/10.3389/fnhum.2013.00104

Maciocia, D. (nd). *Hippy campervan on the Beach* [Print]. Artist's website. https://www.dawnmaciocia.com/ourshop/prod_3746977-Hippy-Campervan-on-the-Beach-Medium-Print.html

Madore, K. P., Addis, D. R., & Schacter, D. L. (2015). Creativity and memory: Effects of an episodic-specificity induction on divergent thinking. *Psychological Science, 26*(9), 1461-1468. https://doi.org/10.1177/0956797615591863

Marks, D. F. (1973). Visual imagery differences in the recall of pictures. *British Journal of Psychology, 64*(1), 17-24. https://doi.org/10.1111/j.2044-8295.1973.tb01322.x

Marks, D. F. (1995). New directions for mental imagery research. *Journal of Mental Imagery, 19*(3-4), 153-167.

McAvinue, L. P., & Robertson, I. H. (2007). Measuring visual imagery ability: A review. *Imagination, Cognition and Personality, 26*(3), 191-211. https://doi.org/10.2190/3515-8169-24J8-7157

McKelvie, S. J. (1986). Effects of format of the Vividness of Visual Imagery Questionnaire on content validity, split-half reliability, and the role of memory in test-retest reliability. *British Journal of Psychology, 77*(2), 229-236. https://doi.org/10.1111/j.2044-8295.1986.tb01997.x

McKelvie, S. J. (1995). The VVIQ as a psychometric test of individual differences in visual imagery vividness: A critical quantitative review and plea for direction. *Journal of Mental Imagery, 19*(3-4), 1-106.

McLeod, L. D., Swygert, K. A., & Thissen, D. (2001). Factor analysis for items scored in two categories. In D. Thissen & H. Wainer (Eds.), *Test Scoring* (pp. 189-216). Erlbaum. https://doi.org/10.4324/9781410604729

McManus, I. C., Chamberlain, R., Loo, P.-W., Rankin, Q., Riley, H., & Brunswick, N. (2010). Art students who cannot draw: Exploring the relations between drawing ability, visual memory, accuracy of copying, and dyslexia. *Psychology of Aesthetics, Creativity, and the Arts, 4*(1), 18-30. https://doi.org/10.1037/a0017335

Meyer, M. L., Hershfield, H. E., Waytz, A. G., Mildner, J. N., & Tamir, D. I. (2019). Creative expertise is associated with transcending the here and now. *Journal of Personality and Social Psychology, 116*(4), 483-494. https://doi.org/10.1037/pspa0000148

Miller, A. I. (1992a). Imagery and intuition in creative scientific thinking: Albert Einstein's invention of the special theory of relativity. In D. B. Wallace & H. E. Gruber (Eds.), *Creative people at work: Twelve cognitive case studies* (pp. 171-188). Oxford University Press.

Miller, A. I. (1992b). Scientific creativity: A comparative study of Henri Poincaré and Albert Einstein. *Creativity Research Journal, 5*(4), 385-414. https://doi.org/10.1080/10400419209534454

Milner, D., & Goodale, M. (2006). *The visual brain in action* (2nd ed., Vol. 27). OUP Oxford. https://doi.org/10.1093/acprof:oso/9780198524724.001.0001

Morrison, R., & Wallace, B. (2001). Imagery vividness, creativity and the visual arts. *Journal of Mental Imagery, 25*(3/4), 135-152.

Moulton, S. T., & Kosslyn, S. M. (2009). Imagining predictions: mental imagery as mental emulation. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 364*(1521), 1273-1280. https://doi.org/10.1098/rstb.2008.0314

O'Craven, K. M., & Kanwisher, N. (2000). Mental imagery of faces and places activates corresponding stimulus-specific brain regions. *Journal of Cognitive Neuroscience, 12*(6), 1013-1023. https://doi.org/10.1162/08989290051137549

Paivio, A. (1978). A dual coding approach to perception and cognition. In H. L. Pick & E. Saltzman (Eds.), *Modes of perceiving and processing information*. Erlbaum, Psychology Press.

Paivio, A. (2014). *Mind and its evolution: A dual coding theoretical approach*. Psychology Press. https://doi.org/10.4324/9781315785233

Paivio, A., & Begg, I. (1981). *Psychology of language*. Englewood Cliffs, NJ: Prentice-Hall.

Palmiero, M., Cardi, V., & Belardinelli, M. O. (2011). The role of vividness of visual mental imagery on different dimensions of creativity. *Creativity Research Journal, 23*(4), 372-375. https://doi.org/10.1080/10400419.2011.621857

Palmiero, M., Nakatani, C., Raver, D., Belardinelli, M. O., & van Leeuwen, C. (2010). Abilities within and across visual and verbal domains: How specific is their influence on creativity? *Creativity Research Journal, 22*(4), 369-377. https://doi.org/10.1080/10400419.2010.523396

Palmiero, M., Nori, R., Aloisi, V., Ferrara, M., & Piccardi, L. (2015). Domain-specificity of creativity: A study on the relationship between visual creativity and visual mental imagery. *Frontiers in Psychology, 6*(1870), 1-8. https://doi.org/10.3389/fpsyg.2015.01870

Palmiero, M., & Srinivasan, N. (2015). Creativity and spatial ability: a critical evaluation. In J. Manjaly & B. Indurkhya (Eds.), *Cognition, experience and creativity* (pp. 189-214). Orient Blackswan.

Pascual-Leone, A. (2003). The brain that makes music and is changed by it. In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 396-412). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198525202.003.0026

Pearson, D. G. (2007). Mental imagery and creative thought. In I. Roth (Ed.), *Proceedings of the British Academy: Imaginative Minds* (Vol. 147, pp. 187-212). OUP. https://doi.org/10.5871/bacad/9780197264195.003.0009

Pearson, D. G., Deeprose, C., Wallace-Hadrill, S. M. A., Heyes, S. B., & Holmes, E. A. (2013). Assessing mental imagery in clinical psychology: A review of imagery measures and a guiding framework. *Clinical psychology review, 33*(1), 1-23. https://doi.org/10.1016/j.cpr.2012.09.001

Pearson, J., & Kosslyn, S. (2013). Mental imagery [Editorial]. *Frontiers in Psychology, 4*(198), 1. https://doi.org/10.3389/fpsyg.2013.00198

Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental imagery: functional mechanisms and clinical applications. *Trends in Cognitive Sciences, 19*(10), 590-602. https://doi.org/10.1016/j.tics.2015.08.003

Pelowski, M., Markey, P. S., Goller, J., Förster, E. L., & Leder, H. (2019). But, how can we make "art?" Artistic production versus realistic copying and perceptual advantages of artists. *Psychology of Aesthetics, Creativity, and the Arts, 13*(4), 462-481. https://doi.org/10.1037/aca0000178

Pérez-Fabello, M. J., Campos, A., & Campos-Juanatey, D. (2016). Is object imagery central to artistic performance? *Thinking Skills and Creativity, 21*, 67-74. https://doi.org/https://doi.org/10.1016/j.tsc.2016.05.006

Pérez-Fabello, M. J., Campos, A., & Felisberti, F. M. (2018). Object-spatial imagery in fine arts, psychology, and engineering. *Thinking Skills and Creativity, 27*, 131-138. https://doi.org/10.1016/j.tsc.2017.12.005

Pidgeon, L. M., Grealy, M., Duffy, A. H., Hay, L., McTeague, C., Vuletic, T., Coyle, D., & Gilbert, S. J. (2016). Functional neuroimaging of visual creativity: a systematic review and meta-analysis. *Brain and behavior, 6*(10), 1-26. https://doi.org/10.1002/brb3.540

Piechowski, M. M., & Cunningham, K. (1985). Patterns of Overexcitability in a Group of Artists. *Journal of Creative Behaviour, 19*, 153-174. https://doi.org/10.1002/j.2162-6057.1985.tb00655.x

Piechowski, M. M., Silverman, L. K., & Falk, R. F. (1985). Comparison of intellectually and artistically gifted on five dimensions of mental functioning. *Perceptual and Motor Skills, 60*(2), 539-549. https://doi.org/10.2466/pms.1985.60.2.539

Pring, L., Hermelin, B., Buhler, M., & Walker, I. (1997). Native savant talent and acquired skill. *Autism, 1*(2), 199-214. https://doi.org/10.1177/1362361397012006

Pylyshyn, Z. W. (2002). Mental imagery: In search of a theory. *Behavioral and Brain Sciences, 25*(2), 157-182. https://doi.org/10.1017/S0140525X02000043

Reisberg, D., Pearson, D. G., & Kosslyn, S. M. (2003). Intuitions and introspections about imagery: The role of imagery experience in shaping an investigator's theoretical views. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 17*(2), 147-160. https://doi.org/10.1002/acp.858

Rosenblatt, E., & Winner, E. (1988). Is superior visual memory a component of superior drawing ability? In L. K. Obler & D. Fein (Eds.), *The exceptional brain: Neuropsychology of talent and special abilities* (pp. 341-363). Guilford Press.

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal, 24*(1), 66-75. https://doi.org/10.1080/10400419.2012.652929

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*(1), 92-96. https://doi.org/10.1080/10400419.2012.650092

Salvi, C., & Bowden, E. M. (2016). Looking for Creativity: Where Do We Look When We Look for New Ideas? *Frontiers in Psychology, 7*(161), 1-12. https://doi.org/10.3389/fpsyg.2016.00161

Schacter, D. L. (2013). Memory: sins and virtues. *Annals of the New York Academy of Sciences, 1303*(1), 56-60. https://doi.org/10.1111/nyas.12168

Seitz, M. (2015, Jan 29). *Kandinsky Instruments*. *Bloglovin'*.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*(3972), 701-703. https://doi.org/10.1126/science.171.3972.701

Soulieres, I., Zeffiro, T., Girard, M., & Mottron, L. (2011). Enhanced mental image mapping in autism. *Neuropsychologia, 49*(5), 848-857. https://doi.org/10.1016/j.neuropsychologia.2011.01.027

Sternberg, R. J., & O'Hara, L. A. (2000). Intelligence and creativity. In *Handbook of intelligence.* (pp. 611-630). Cambridge University Press. https://doi.org/10.1017/CBO9780511807947.028

Torrance, E. (1974). *The Torrance Tests of Creative Thinking. Norms, Technical manual. Research Edition. Verbal and Figural Tests (Forms A and B)*. Princeton, NJ: Prentice Hall.

Treffert, D. A. (2009). The savant syndrome: an extraordinary condition. A synopsis: past, present, future. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1522), 1351-1357. https://doi.org/10.1098/rstb.2008.0326

Tulving, E. (2002). Episodic memory: from mind to brain. *Annu Rev Psychol, 53*, 1-25. https://doi.org/10.1146/annurev.psych.53.100901.135114

van Doorn, J., van den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., Etz, A., Evans, N. J., Gronau, Q. F., Haaf, J. M., Hinne, M., Kucharský, Š., Ly, A., Marsman, M., Matzke, D., Gupta, A. R. K. N., Sarafoglou, A., Stefan, A., Voelkel, J. G., & Wagenmakers, E.-J. (2021). The JASP guidelines for conducting and reporting a Bayesian analysis. *Psychonomic Bulletin & Review, 28*(3), 813-826. https://doi.org/10.3758/s13423-020-01798-5

Ward, T. B. (1994). Structured Imagination: the Role of Category Structure in Exemplar Generation. *Cognitive Psychology, 27*(1), 1-40. https://doi.org/https://doi.org/10.1006/cogp.1994.1010

Wells, T. (Ed.). (2008). *Leonardo da Vinci: Notebooks*. Oxford University Press.

Wikipedia. (n.d.). *Kim's Game*. https://en.wikipedia.org/wiki/Kim%27s_Game

Wilson, R. C., Guilford, J. P., Christensen, P. R., & Lewis, D. J. (1954). A factor-analytic study of creative-thinking abilities. *Psychometrika, 19*(4), 297-311.

Zabelina, D., & Condon, D. M. (2020). The Four-Factor Imagination Scale (FFIS): A measure for assessing frequency, complexity, emotional valence, and directedness of imagination. *Psychological research, 84*(8), 2287-2299. https://doi.org/10.1007/s00426-019-01227-w

Zatorre, R. J., & Halpern, A. R. (2005, 2005/07/07/). Mental Concerts: Musical Imagery and Auditory Cortex. *Neuron, 47*(1), 9-12. https://doi.org/https://doi.org/10.1016/j.neuron.2005.06.013

Zedelius, C. M., & Schooler, J. W. (2016). The richness of inner experience: Relating styles of daydreaming to creative processes. *Frontiers in Psychology, 6*(2063), 1-7. https://doi.org/10.3389/fpsyg.2015.02063

Zeman, A., Dewar, M., & Della Sala, S. (2016, Jan). Reflections on aphantasia. *Cortex, 74*, 336-337. https://doi.org/10.1016/j.cortex.2015.08.015

Zeman, A., MacKisack, M., & Onians, J. (2018). The Eye's mind-Visual imagination, neuroscience, and the humanities [Editorial]. *Cortex, 105*, 1-3. https://doi.org/10.1016/j.cortex.2018.06.012