The diversity of consciousness: Interindividual differences in mental imagery

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Abstract

Imagine a single color. Hold it in your mind's eye, as if the entire world had been soaked in that hue. Now, imagine a shape. It could be a circle, a triangle, or even a cloud that refuses to be defined. Watch it take form inside your mind. Next, let the two meet. Allow the color to pour into the shape until the two become a unified image. Observe it closely: Is it glowing or still, transparent or solid, peaceful or alive with energy? Does it resemble a familiar object? Now, travel backwards in time. Where have you seen such an object before? Picture a scene from your past. See the light, the people, the movement. Listen to the sounds that surround you. You may smell or taste something. And finally, look ahead. Imagine the future, realistic or not. One that draws you forward, that whispers of what could be.

1 Mental imagery: A brief taxonomy

Mental imagery is commonly defined as the quasi-perceptual experience of sensory events in the absence of external stimuli (Nanay, 2021a). Yet, even this seemingly simple definition leaves room for interpretation. As illustrated in the introduction, imagery may involve isolated properties such as colors or shapes, integrated combinations of these properties, whole objects, or even entire multimodal scenes. For instance, the Multifactorial Model of Visual Imagery (MMVI) distinguishes between proximal and distal mental imagery (Friedlander et al., 2022). Proximal imagery refers to the quasi-eidetic recall of past perceptual impressions, closely tied to episodic memory. Distal imagery denotes more generative and inventive forms of imagination that support creativity, hypothetical reasoning, and counterfactual thinking (Meyer et al., 2019). At the same time, the MMVI refers to the two-stream hypothesis of visual perception, proposing a ventral stream for object imagery concerned with shape, color, and object identity, and a dorsal stream for spatial imagery concerned with layout, motion, and spatial relations. This dichotomy reflects previous research by Blazhenkova and Kozhevnikov (2009) that object and spatial imagery can be dissociated.

Importantly, visual imagery is not the only form of mental imagery. Imagination can also be used to simulate other sensory experiences, such as sound (auditory imagery), smell (olfactory imagery), taste (gustatory imagery), touch (cutaneous imagery), and bodily sensations, both static and kinetic (somaesthetic and kinesthetic imagery). Some frameworks even include emotional imagery (Andrade et al., 2014). Independent of modality, research distinguishes between voluntary and involuntary imagery. Voluntary imagery describes internally generated sensory experiences that are created deliberately, whereas involuntary imagery refers to internal simulations that are beyond voluntary control, such as hallucinations or dreams (Bilzer and Monzel, 2025; Fazekas et al., 2021). There are also some intermediate cases, such as imagery induced by reading fiction, often referred to as mental simulation (Speed et al., 2025).

Besides these conscious forms of mental imagery, the existence of unconscious imagery is debated, referring to neural mental imagery representations without corresponding mental imagery experiences (Nanay, 2021b; Scholz, 2024). Scholz et al. (2025) argue that neural representations of unconscious imagery should have the same properties as neural representations of conscious imagery: (1) they should occur in the corresponding sensory system (e.g., in the visual system for visual imagery), (2) they should be stimulus specific (e.g., imagining an apple should lead to a different neural representation than imagining a banana; see Cabbai

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et al., 2024; de la Cruz et al., 2024), and (3) they should be similar to perceptual neural representations (e.g., the neural representation of imagining an apple should be similar to the neural representation of seeing an apple; see Chang et al., 2025). In addition, Scholz et al. (2025) argue that unconscious imagery should lead to the same functional profile as conscious imagery (see section: performance-based measures of mental imagery). However, before discussing these behavioral differences, we should first discuss how mental imagery is created, to understand how individual differences can occur.

2 Neural models of mental imagery

One of the most influential neural accounts of visual imagery is the Reverse Hierarchy Model (Pearson, 2019). It proposes that imagery is initiated in the frontal cortex, leading to the retrieval of stored perceptual information from the temporal memory system, which is then projected back to the early visual cortices. In this view, imagery is the top-down reactivation of the perceptual system, contrasting with the bottom-up flow of perception. Evidence for the neural overlap of perception and imagination comes from the observed cross-decodability between multivoxel activation patterns of perceived and imagined objects in the early visual cortices (Naselaris et al., 2015) and the observed source confusion between perception and imagination (Dijkstra et al., 2021). In line with this, Sulfaro et al. (2023) showed that computational models of hierarchical networks with neural competition between veridical perception and mental imagery were more suitable to explain imagery phenomenology than non-competitive models. Further evidence for the top-down control of mental imagery comes from studies investigating interindividual differences in mental imagery. Those with lower mental imagery exhibit reduced top-down connectivity compared to those with higher mental imagery abilities (Liu and Bartolomeo, 2025; Milton et al., 2021; Monzel et al., 2024b). Sulfaro et al. (2023) model these differences as a shift in the representational equilibrium of internally and externally generated representations. Overweighting feedback information lowers the equilibrium point, causing the imagined stimulus to penetrate towards lower layers of the hierarchy (i.e., towards the early visual cortices), as a result of which more vivid mental imagery is produced. Importantly, the Reverse Hierarchy Model further distinguishes between a ventral stream for object imagery, which denotes the ability to represent high-resolution images of objects, and a dorsal stream for spatial imagery, which denotes the ability to represent spatial relations among objects, to account for the empirical dissociability of object and spatial imagery (Blazhenkova and Kozhevnikov, 2009).

The significance of temporal regions in reconstructing mental imagery from memory is further highlighted in the Constructive Episodic Simulation Hypothesis by Schacter and Addis (2007), which was originally developed to explain similarities between remembering the past and imagining the future. Using this model, Blomkvist (2023) extended the Reverse Hierarchy Model explicitly to non-visual and non-spatial modalities. In addition to projecting visual information to the visual cortex, other sensory information is thought to be projected to other sensory cortices (e.g., auditory imagery to the auditory cortex). Blomkvist (2023) also highlights the recombination process introduced in the Constructive Episodic Simulation Hypothesis (initially developed to explain the recombination of past experiences to hypothetical future scenarios), explaining more generative and inventive forms of mental imagery, as presented in the introduction. Moreover, a separate semantic retrieval process was incorporated to explain the existence of non-episodic and non-spatial memories that are commonly observed even in people without mental imagery (e.g., knowing the capital of France). Notably, a similar but not identical distinction has been made by Balaban and Ullman (2025) who suggest physical simulation and graphical rendering as an organizing dichotomy in cognition. While graphical rendering encompasses the creation of sensory phenomenology, thereby reflecting object imagery (Blazhenkova and Kozhevnikov, 2009) or episodic retrieval (Blomkvist, 2023), physical simulation combines aspects of spatial imagery *and* semantic (or propositional) information, including many object properties such as material and knowledge of color. Similar to the distinction of object and spatial imagery, Balaban and Ullman (2025) also draw on the two-stream hypothesis of vision as their neuroscientific foundation.

Spagna et al. (2024) challenge the hierarchical perspective of the Reverse Hierarchy Model, proposing a model with heterarchical interactions among domain-general and domain-preferring imagery networks (HeXaGen model). Rather than a strict top-down hierarchy, the HeXaGen model suggests a heterarchical organization in which imagery arises from dynamic interactions between distributed cortical networks. They identified the fusiform imagery node (FIN) in the left temporal lobe as a domain-general hub integrating perceptual and mnemonic information, alongside domain-specific patches for colors and faces, among others. Based on case reports of patients with V1 lesions but intact mental imagery (Bartolomeo et al., 2020) and additional meta-analytical findings (Kutsche et al., 2025; Spagna et al., 2021), they argue against the early visual cortex being a prerequisite for mental imagery. Interestingly, however, people with low vividness of visual imagery show an increased excitability of the visual cortex (Keogh et al., 2020; Monzel et al., 2024b) and more brain-wide activation (Fulford et al., 2018) during imagery attempts, which is often explained by worse neural efficiency and the attempt to solve this task with alternative strategies. Overall, the HeXaGen framework preserves the idea of top-down activation of mental imagery but embeds it within a wider, more flexible network architecture that interfaces with other cognitive systems such as working memory and semantic control.

More recent models have retained this general architecture, but shifted their focus from a global understanding of imagination to its local mechanisms. In the attention-based neural model, Liu (2025) proposes three processing stages comprising (1) generation, (2) integration, and (3) amplification of conscious mental imagery, supported by a fronto-parietal-fusiform network. Generation produces basic visual features from conceptual knowledge (e.g., color or shape); integration binds these into coherent object representations; and amplification involves attentional enhancement that renders imagery experiences phenomenally reportable. Silvanto and Nagai (2025) propose that mental imagery arises from the integration of sensory features with interoceptive signals. The insula and anterior cingulate cortex serve as neural hubs for this integration, binding sensory features with physiological and emotional states to create embodied mental images that are experienced as self-generated, unlike hallucinations or dreams. Scholz et al. (2025) synthesized these complementary perspectives in their integration-based model, in which attention is first shifted from external to internal stimuli via the regulation of the dorsal and ventral attention systems through the salience network. Imagery generation is then initiated by the inferior frontal gyrus, followed by three integration stages: (1) mono-sensory integration within domain-general hubs such as the FIN; (2) multi-sensory integration in the posterior insular cortex; and (3) self-referential integration within the anterior insula and cingulate areas that confer agency. The final amplification phase re-engages dorsal attention circuits, producing the conscious ignition of the integrated representations that are then experienced as mental imagery.

3 Interindividual differences in mental imagery

Since brain development is shaped by genetic factors and experience-dependent plasticity (Berardi et al., 2015), there is a wide variability in the structure, function and connectivity of the imagination network (Fulford et al., 2018; Koenig-Robert and Pearson, 2020) that leads to interindividual differences in the propensity to generate conscious imagery. For instance, variability in visual imagery vividness is correlated with the relative neuroactivity of the early visual cortex during visual imagery (Cui et al., 2007) and with specific activation patterns across a brain-wide network involved in visual perception (Dijkstra et al., 2017; Tullo et al., 2022). In the following section, we will present the various tools at our disposal to chart these individual differences. Evidently, measuring these extremely private, subjective, and conceptually diverse constructs presents its challenges.

3.1 Measuring differences in mental imagery

Mental imagery can be assessed on a set of independent dimensions that each represent a different aspect of imagery. *Vividness*, or the subjective clarity, colorfulness, and liveliness of imagery, is one of the core constructs measured in imagery research (Marks, 2023). In visual imagery, vividness can range from vague images to images as sharp and realistic as actual perception. In contrast, mental imagery *strength* refers to the imagery's objective ability to induce measurable changes in physiological markers such as pupil size, heart rate, skin conductance and neural activity akin to perception (Pearson et al., 2008). Importantly, subjective vividness and objective imagery strength seem to be dissociated (Lequerica et al., 2002; McAvinue and Robertson, 2007).

Emotional salience refers to the emotional charge of imagery and its ability to affect one's conscious emotional state (Holmes and Mathews, 2005). This dimension is particularly relevant in the clinical context, for example, in the recovery from traumatic events (Pearson et al., 2015). *Agency* refers to how easily a person can conjure a mental experience (Cumming and Eaves, 2018; Nanay, 2021a), with some people being able to create images on demand, while others can do so only when triggered by an external stimulus, when asleep, or in the form of intrusive imagery. Once these mental experiences are present, the *controllability* of mental imagery becomes measurable (Cumming and Eaves, 2018). Indeed, while some people can deliberately maintain, transform, or, in the case of images, rotate what they are imagining, others feel they do not have any control over their mental experiences, beyond generating them. This concept illustrates the close ties between mental imagery and executive skills, that is, the set of processes we use to maintain our working memory and to focus on, inhibit, and switch between information.

People also differ in the *frequency* of mental imagery use (McCarthy-Jones et al., 2012; Nelis et al., 2014). Independent from the vividness of their imagery, some people are more reliant than others on imagery when, for example, planning future tasks or events, remembering, or writing imagined conversations, reflecting differences in cognitive styles rather than abilities. Importantly, this spontaneous use can be considered across all sensory modalities; for example, one can frequently and spontaneously rely on visual and auditory imagery but rarely on olfactory and gustatory imagery. When considering all these dimensions and modalities of imagery, it is evident that imagery skills do not vary along a one-dimensional spectrum from poor to good imagers, but are a multidimensional constellation of possible imagery experiences. As such, capturing individual diversity is a challenging task.

3.1.1 Self-report questionnaires

The vast majority of instruments to record imagery experiences are self-report questionnaires (Lacey and Lawson, 2013), which usually take the form of statements that respondents rate on a Likert scale according to the extent to which they agree with or experience the statement. These self-reports can focus on one (e.g., the Vividness of Visual Imagery Questionnaire [VVIQ], Marks, 1973) or several (e.g., the Plymouth Sensory Imagery Questionnaire [PSIQ], Andrade et al., 2014) sensory modalities, and track one or more imagery dimensions as described below and summarized in Table 1.

3.1.1.1 Vividness of mental imagery

The *Vividness of Visual Imagery Questionnaire* (VVIQ, Marks, 1973) is the most commonly used measure of visual imagery vividness, thanks to its straightforwardness and its high reliability and internal consistency (Campos and Pérez-Fabello, 2009). Respondents are presented with a series of four scenes to imagine (i.e., a relative or friend, a sunrise, a familiar shop, and a natural landscape), each being prompted with four statements focused on specific details of the scene (e.g., the sun rising, the sky clearing, a thunderstorm flashing, and a rainbow forming), equalling a total of 16 items. Using a 5-point Likert scale ranging from "No image at all" to "Perfectly clear and vivid as normal vision", respondents indicate how vivid their visual imagery of these scenes is. Importantly, the VVIQ exists in three forms: the original 16-statements version; an expanded 32-statements version, the VVIQ-2 (Marks, 1995), which repeats the items once requesting the respondent to keep their eyes open during imagery, and once with their

Table 1 Overview of self-report questionnaires for assessing various dimensions and modalities of mental imagery.

Dimension	*Modality*	*Instrument*	*Source*
Vividness	Visual	VVIQ	Marks (1973)
		VVIQ-2	Marks (1995)
		VVIQ-R	McKelvie (1995)
		VVIQ Single item screener	Monzel et al. (in press)
	Visual, kinaesthetic	VMIQ-2	Roberts et al. (2008)
	Multisensory, kinaesthetic, emotional	PSIQ	Andrade et al. (2014)
Vividness, controllability	Auditory	BAIS	Halpern (2015)
Intrusiveness, controllability, beliefs, realness, valence	Visual	MIQ-N	Oaie et al. (2025)
Frequency	Visual	SUIS	Reisberg et al. (2003)
Cognitive style	Visual, spatial	OSIQ	Blajenkova et al. (2006)
	Visual, spatial, verbal	OSIVQ	Blazhenkova and Kozhevnikov (2009)
Emotional valence	Emotional	EIQ	Williams et al. (2025)
Controllability, vividness, emotional valence	Multisensory	DImS	Berg et al. (2020)
Intrusiveness, emotional valence	Emotional, future events	IFES	Deeprose and Holmes (2010)
Vividness, emotional valence	Emotional, future events	PIT	Holmes et al. (2008)

eyes closed; and an edited version of the VVIQ-2 using a 7-point Likert scale instead of the original 5-point Likert scale (VVIQ-R, McKelvie, 1995). These latter versions allow for isolating the specific ability to form mental images during visual perception, or in other words, when conflicting images are also present through actual vision. All three versions show comparable psychometric characteristics (Campos, 2011), and version choice should be driven by researchers' aims and practical limitations. Recently, Monzel et al. (in press), proposed a single-item screener derived from the VVIQ to reliably assess the absence of mental imagery (i.e., "Visualize a place that you know very well in every possible detail (e.g., your workplace, your bedroom or your favorite bar). How vivid is the picture that comes before your mind's eye?"). However, this screening tool should not be used to differentiate in the typical imagery spectrum, but just to distinguish between those with and without mental imagery (see section: aphantasia).

The *Vividness of Movement Imagery Questionnaire-2* (VMIQ-2, Roberts et al., 2008), combines visual and kinaesthetic imagery, all of which exclusively focus on movements. Using the same 5-point Likert scale as the VVIQ (though with reverse scores) and a list of 12 movements (e.g., running downhill), respondents indicate how vividly they can—with their eyes closed—imagine watching themselves perform a given movement (external visual imagery), seeing through their own eyes as they are performing this movement (internal visual imagery), and feeling themselves, in their body, doing the movement (kinaesthetic imagery). This tool is particularly relevant in that its explicit instruction and format ensure no ambiguity in its measure of kinaesthetic imagery. Indeed, as "imagine yourself dancing" can be interpreted as both imagining the internal sensation and imagining seeing oneself dance, this tool ensures both cognitive processes are addressed clearly and independently. The VMIQ-2 has robust validity and high internal reliability (Roberts et al., 2008), with a factor analysis showing that it does discriminate between three different concepts. As such, it does achieve its aim to disentangle external visual imagery, internal visual imagery, and kinaesthetic imagery.

When aiming to compare skills across modalities, it is indeed beneficial to rely on tools that capture several modalities with otherwise consistent parameters, such as the response scale and the number of statements. Indeed, multidimensional scales capture more complex, multidimensional variability missed by single scales (Andrade et al., 2014), and they reduce the risks of modality biases (Blazhenkova and Kozhevnikov, 2009). In addition, some conclusions can only be reached when a given skill is interpreted within a wider context, relative to other constructs (Roberts et al., 2008). Even when the aim is to understand how imagery relates to or predicts other cognitive features, multidimensional tools are more robust in their ability to draw these relationships (Ji et al., 2016). The *Plymouth Sensory Imagery Questionnaire* (PSIQ, Andrade et al., 2014) is such a tool, addressing vividness across seven modalities (visual, auditory, olfactory, gustatory, tactile, kinaesthetic, and emotional) with five statements each (three in the short form) on a 11-point Likert scale ranging from "nothing at all" to "as vivid as real life". Through a factor analysis, Andrade et al. (2014) were able to demonstrate that the PSIQ successfully differentiates between those modalities. However, this also implies that total PSIQ scores should be interpreted with caution, as the total score could hide modality-specific patterns of strengths and difficulties.

3.1.1.2 Controllability and intrusiveness of mental imagery

As detailed above, there is value in using a single tool measuring several characteristics in a consistent format. While the VMIQ-2 and PSIQ allowed the measurement of vividness across several modalities, other tools were designed to measure several dimensions within a single modality. The *Bucknell Auditory Imagery Scale* (BAIS, Halpern, 2015) is a short instrument measuring both vividness and control of auditory imagery. Specifically, it uses a 7-point Likert scale to indicate how vividly respondents can generate a prompted sound (e.g., gentle rain), and how easily they can change from one prompted sound to another prompted sound (e.g., first a trumpet beginning a piece, then a violin continuing the tune), with 14 items in each subsection. The validation of the BAIS showed acceptably high internal consistency and a robust ability to tease out individual differences, though both subscales are highly correlated, suggesting that the control items also rely on vividness (Halpern, 2015).

In addition to controllability, it can also be relevant to distinguish between straightforward controllability, i.e., the ability to alter and interrupt imagery, and intrusiveness, i.e., the lack of agency in the generation of imagery. This approach exists in the Negative Mental Imagery Questionnaire (MIQ-N, Oaie et al., 2025), which uses 16 items across four domains (intrusiveness, controllability, beliefs, and realness) on a 7-point Likert scale to address the different elements that can cause negative imagery to have clinical repercussions on one's mental health.

3.1.1.3 Frequency and usage of mental imagery

The *Spontaneous Use of Imagery Scale* (SUIS, Reisberg et al., 2003) is a common measure of people's tendency to rely on visual imagery for everyday cognitive tasks. Using 12 statements (e.g., "When I think about a series of errands I must do, I visualise the stores I will visit") and a 5-point Likert scale, the SUIS has good internal consistency and test-retest reliability (Nelis et al., 2014).

Importantly, the frequency of imagery usage is related to cognitive styles, or in other words, the mental strategies individuals spontaneously use to approach concepts, acquire and process information, and solve cognitive tasks (Ausburn and Ausburn, 1978). Cognitive styles can be measured using the *Object-Spatial Imagery Questionnaire* (OSIQ, Blajenkova et al., 2006), which lists 15 object-domain (e.g., "My visual images are in my head all the time") and 15 spatial-domain items (e.g., "I can easily imagine and mentally rotate 3-dimensional geometric figures"), answered on a 5-point Likert scale. The expanded version, the *Object-Spatial Imagery and Verbal Questionnaire* (OSIVQ, Blazhenkova and Kozhevnikov, 2009), has 15 additional verbal-domain items (e.g., "When remembering a scene, I use verbal descriptions rather than mental pictures"). The three subscales show robust validity in their ability to discriminate between the cognitive styles, more so than previously available tools, especially in their ability to disentangle object and spatial imagery (Blazhenkova and Kozhevnikov, 2009; Höffler et al., 2017).

3.1.1.4 Emotional valence of mental imagery

Emotionally-charged imagery can have strong clinical relevance, be that as a symptom of ill-health or as part of a therapeutic strategy. As such, measuring the emotional valence of imagery, as well as capturing the different correlates of positive, negative, and neutral imagery, is often crucial in clinical contexts. While the PSIQ (Andrade et al., 2014) includes an emotional imagery subscale, it does not capture the imagery valence. The MIQ-N (Oaie et al., 2025) also addresses emotional imagery, though it focuses exclusively on general negative imagery experiences. In contrast, the *Ease of Imagery Questionnaire* (EIQ, Williams et al., 2025) is a recent instrument that simultaneously measures ease of generating positive and negative imagery as well as ease of engagement or disengagement with this emotionally charged imagery. It uses 16 items across four domains: relent imagery (i.e., imagining giving up when facing issues), negative affect (i.e., imagining negative emotions with context), positive affect (i.e., imagining positive emotions with context), and grit imagery (i.e., imagining perseverance when facing issues), with ease of imagery rated on a 7-point Likert scale. While validating this tool, Williams et al. (2025) found associations with mental ill-health (i.e., maladaptive strategies, stress appraisal, and anxiety), suggesting its relevance for clinical contexts.

The *Dutch Imagery Survey* (DImS, Berg et al., 2020) approaches the emotional aspects of imagery from another angle. This multi-scale instrument contains one "Imagery Frequency" statement, 12 "Imagery Quality" statements (five related to image properties, such as fantasy, flashbacks, flashforwards, or viewer's perspective, and seven related to vividness), 14 "Appraisal" statements (six related to "Encapsulated Beliefs", i.e., whether the imagery has a positive or negative meaning, and eight related to "Metacognition", i.e., whether the imagery is related to positive or negative future events or future consequences), six "Effect on emotion" statements (related to the respondent's emotional response to experiencing those mental images), and five "Effect on Behavior" statements related to whether experiencing those mental images influenced the respondent's behavior and actions. All statements are rated with a 9-point Likert scale. The relationship between visual imagery and emotion is addressed both in terms of the valence of the imagery itself, and in terms of its impact on the respondent's emotional state. While further validation and replication are still needed for this tool, it provides a valuable step forward in the discrimination between the various emotional components of imagery.

In addition to general emotional imagery, emotional valence can also be relevant in the context of future thinking. For instance, the *Impact of Future Events Scale* (IFES, Deeprose and Holmes, 2010) focuses on involuntary, intrusive, spontaneous positive or negative imagery of future events. In this tool, respondents are prompted to list three positive or stressful future events which they have been thinking about recently, before indicating on a 5-point Likert scale their agreement with 24 statements in relation to their imagery of self-generated future events. This self-generation increases the personal relevance of the task for the respondents as well as the ecological validity of the tool. While the IFES is generally used to assess maladaptive and distressing pre-experiencing, the *Prospective Imagery Task* (PIT, Holmes et al., 2008), addresses positive and negative imagery of future events. It uses 10 negative (e.g., "You will have health problems") and 10 positive (e.g., "You will have lots of good times with friends") standardized future scenarios as cued statements, with respondents rating the vividness of these experiences on a 5-point Likert scale. While less grounded in real-life experiences than the IFES, the PIT is more suitable to address emotionally charged imagery capacity, rather than intrusive anticipation.

3.1.2 Performance-based measures of mental imagery

The biggest limitation of the above-presented self-report questionnaires is that people cannot reliably judge how 'good' their imagery is in comparison to others' mental imagery, apart from those with no mental imagery at all (Monzel et al., in press). Two people experiencing the same quality of imagery might, in good faith, rate it differently, one believing it could be better, and the other believing it could be worse (Suggate, 2024). Another key limitation of self-reports is their subjectivity to social biases and misinterpretation from respondents (Jobe, 2003; Pearson et al., 2013). Thus, many self-report measures have only moderate to weak psychometric properties (McIntyre et al., 2024; Suica et al., 2022). As such, scores on these self-report measures can only show faint relationships with their performance-based counterparts (e.g., see Lequerica et al., 2002, for discrepancies in mental imagery control). Yet, performance-based cognitive assessments can offer a complementary approach to measuring mental imagery on several dimensions.

3.1.2.1 Mental imagery generation

To measure visual mental imagery generation, binocular rivalry paradigms can be used. Binocular rivalry denotes a visual phenomenon that happens when each eye is stimulated with a different visual stimulus (e.g., a pattern or a color) in such a way that they seem to coexist in the same place (hence "rivalry"). One stimulus dominates over the other, and becomes the one the participant is dominantly aware of. This can be manipulated experimentally: when the participant is first asked to imagine one of the two stimuli, before being exposed to the actual stimuli, the imagined stimulus is more likely to become dominant and "win" the rivalry (Pearson, 2014; Pearson et al., 2008). For example, if a participant is first asked to imagine green horizontal lines, and is then presented with green horizontal lines in one eye and red vertical lines in the other, they are more likely to be aware of the green horizontal lines, and unaware of the red vertical lines. This suggests that mental imagery can prime the following dominance and influence our visual awareness. Indeed, self-reported visual imagery vividness is correlated with the strength of this dominance (more vivid visual imagery is linked to a stronger priming effect), at least as long as the whole imagery spectrum, including the absence of mental imagery, is considered (Keogh and Pearson, 2018, 2024; Monzel et al., 2025d). However, when only the typical imagery range is considered, the correlation with the self-reported visual imagery vividness disappears (Bouyer et al., 2025), suggesting that it's actually the generation or non-generation of mental imagery that drives the effect. Within the typical imagery range, this technique is sensitive to trial by trial variations in imagery vividness within a single subject, but not to differences between individuals.

3.1.2.2 Mental imagery maintenance and exploration

Visual imagery scanning paradigms focus on the ability to spatially explore mental images (Borst and Kosslyn, 2008). These tasks involve presenting a simple image to the participant (e.g., a blank screen with a black dot), before removing it, and replacing it with another simple image (e.g., a blank screen with an arrow). The participant is then asked questions that can only be answered by recalling visual details of the original image and/or mentally overlapping it with the new image (e.g., whether the arrow points towards the previous location of the dot). With the example of the dot and the arrow, the response time normally increases with the distance between the arrow and the dot. Performance in such designs is usually not correlated with imagery vividness, but with a spatial cognitive style (Borst and Kosslyn, 2010). This suggests that visual imagery scanning paradigms are particularly suitable to address spatial imagery.

In contrast, mental comparison tasks involve asking participants to mentally compare two absent items in terms of their standard sensory characteristics (Moyer, 1973). These comparisons can address a range of sensory experiences, for example: "Which is shinier, a spoon or a spatula?" (visual), "Which is louder, a doorbell or a knock?" (auditory), "Which is softer, a cat's tongue or a cat's fur?" (tactile) (Suggate, 2024). These cues are presented on a computer or tablet, with participants selecting their answers by clicking or tapping on the corresponding word. Response times and accuracy of the responses are thought to measure mental imagery, with the hypothesis that those with better mental imagery abilities can mentally re-create, experience, and compare those items faster and more accurately than those with worse mental imagery abilities. In these tasks, the items are selected in large numbers to reduce the risk of participants being able to answer quickly thanks to the knowledge of specific facts about these items. Mental comparison tasks have reliable internal consistency, and their ability to address multiple sensory modalities simultaneously allows for a meaningful exploration of imagery. Nevertheless, mental comparison tasks only correlate weakly with self-reported mental imagery and can also be completed without mental imagery, conceptually comparing the absent items, limiting their overall validity (Suggate et al., 2026).

3.1.2.3 Mental imagery manipulation and transformation

Spatial manipulation and transformation paradigms track people's ability to manipulate mental images. Mental rotation tasks (Metzler and Shepard, 1974) are straightforward examples of such tasks, generally taking the form of multiple-choice questionnaires. Participants are presented with two- or three-dimensional target shapes (i.e., geometrical shapes, letters, digits, or figures) and must select which shape among the response options matches the target in a different orientation. Accuracy and response times over multiple trials are recorded as proxies of visual imagery manipulation skills. As the angular disparity between the target shape and the correct answer increases, so does response time, suggesting increased transformation efforts. However, these tasks can also be completed using different cognitive strategies, for example, verbal, motor, feature-based, and orientation-based strategies (Hegarty, 2018; Tomasino and Rumiati, 2004), limiting their validity in measuring mental imagery (Kay et al., 2024).

3.1.2.4 Phenomenological matching and recreation

Another class of performance-based measures asks participants to recreate or match specific properties of their mental imagery to an external display, rather than to rate those properties on a verbal scale or to perform a cognitive transformation task. The underlying rational is that verbal methods (e.g., questionnaires) are constrained by the limitations of linguistic labels, while many performance-based measures require training (Singhal and Srivastava, 2025). As such, tasks completed by directly matching one's inner experience to a continuously adjustable external stimulus bypass both issues, using the phenomenology of the imagery itself as the dependent variable. Recently, Morales and Firestone (2023) reintroduced the original approach by Finke and Kurtzman (1981), which was then extended to explore various properties of imagery, such as temporal imagery (Singhal and Srivastava, 2025) or object tracking (Balaban and Ullman, 2025), using vignettes as prompts to imagine an event or object. A key advantage of this matching method over free recreation is that it does not require participants to generate imagery "from scratch" or to retrieve a stored trace, thus reducing confounds from memory retrieval and production skills. Nevertheless, this technique remains susceptible to demand characteristics, and its sensitivity to individual differences in imagery ability has yet to be established.

3.1.3 Neurophysiological assessments

Beyond self-report questionnaires and behavioral paradigms, neurophysiological signatures of mental imagery can be used to assess differences in mental imagery, ranging from pupil and skin conductance responses to imaginary content to neural signatures in fMRI and EEG.

3.1.3.1 Pupillometry

Pupillometry is the measure of pupil size and reactivity to different situations and can be used to infer a wide range of cognitive processes, as it is not possible to control our pupils consciously (Hartmann and Fischer, 2014). Just as pupils constrict in the light and dilate in the dark, research has shown that our pupils also contract when we imagine bright lights, and dilate when we imagine darkness (Laeng and Sulutvedt, 2014). This phenomenon not only demonstrates that imagined and perceived stimuli lead to similar neural responses, which is in line with the prediction of the Reverse Hierarchy Model that both perception and imagination use the same neural processes, but it can also be used as a proxy of imagery strength. As such, the pupils' reactivity to mental imagery of different brightness is associated with both mental imagery vividness and mental imagery priming in a binocular rivalry task (Kay et al., 2022).

3.1.3.2 Skin conductance response

In addition to the pupil response to imagined stimuli, the affective response to emotional imagery can be assessed using electrodermal activity. Due to emotion-evoked sweating (Dawson et al., 2000), skin conductance level increases when stimuli evoke emotions in their observer. Using fear-inducing pictures and verbal descriptions, Wicken et al. (2021) were able to show that mental imagery did not influence the skin conductance level in response to pictures but in response to verbal descriptions, most likely due to the verbal descriptions being internally translated to mental imagery. People with mental imagery had a stronger increase in skin conductance level than people without mental imagery. The same effect could be replicated using sympathy-inducing stimuli instead of fear-inducing stimuli (Monzel et al., 2024c).

3.1.3.3 Imagery decoding

Mental imagery can also be measured using neuroimaging techniques (Koenig-Robert and Pearson, 2020). Functional magnetic resonance imaging (fMRI) showed that during visual imagery, similar brain areas are activated as during vision (Liu et al., 2025). In addition, electroencephalography (EEG) used during visual and auditory imagery showed that while cortical activation is weaker and noisier during imagery compared to perception, imagery and perception do share neuroactivity markers specific to sensory modalities (Proverbio et al., 2023). Given that these overlaps between imagination and perception are not present in people without mental imagery (Chang et al., 2025) and mental imagery vividness increases with the strength of this overlap (Dijkstra et al., 2017), the accuracy of shared representations can potentially be used to quantify the propensity to create mental imagery.

3.1.4 Choosing the right instrument

No measure is perfect at assessing imagery, and all must be considered in the light of their own strengths and limitations. Self-reports are the most straightforward to administer and capture people's subjective experiences, but they often correlate poorly with objective performances and are sensitive to response biases. In contrast, performance-based and neurophysiological measures are more precise, less subject to bias, and can more readily discriminate between different cognitive skills. However, they are costly and time-consuming and ignore the richness of introspective experiences. As such, instruments should be selected based on their alignment with theoretical considerations and combining instruments provides convergent validity. Multimodal and multidimensional frameworks allow us to build a richer, more naturalistic representation of people's inner worlds, which are probably just as diverse as our external appearances.

3.2 The heterogeneity of mental imagery profiles

As already mentioned several times, there is a great variability in mental imagery experiences, which can be characterized in various sensory modalities across a wide range of dimensions (Floridou et al., 2022; Schwarzkopf, 2024). Within each sensory modality and each dimension, these differences fall along a continuum ranging from one extreme to the other. As such, the diversity of mental imagery is less a unidimensional spectrum, and more a multidimensional constellation. Within this diversity of imagery experiences, two main extremes have been described—originally in terms of extremes of mental imagery vividness: aphantasia and hyperphantasia.

3.2.1 Aphantasia

Aphantasia is the absence or near-absence of mental imagery (Zeman et al., 2015, 2025). Originally investigated for visual imagery, its estimated prevalence is around 3–5% (Dance et al., 2022; Wright et al., 2024). Those reporting faint but existing imagery (i.e., hypophantasia) represent the majority of the group, whereas a total absence of visual imagery (i.e., core aphantasia) is relatively rare (2.6% and 0.7% of the population, respectively; Zeman et al., 2020). While most experience congenital aphantasia, so called because those affected cannot remember ever having had mental imagery, aphantasia can also be acquired (Knowles et al., 2021), for example, following medical procedures (Bumgardner et al., 2021; Zeman et al., 2010), emotional trauma (de Vito and Bartolomeo, 2015; Gao et al., 2025), or neurological injuries (Thorudottir et al., 2020). Oftentimes, aphantasia extends outwith the visual domain into other sensory modalities (Dawes et al., 2020, 2024), with most aphantasic people reporting faint or absent imagery in several to all sensory modalities (Digard et al., 2026a; Zeman et al., 2020). This led to the proposal of "unisensory", "multisensory" and "global" subtypes of aphantasia, whereby unisensory subtypes can be further characterized by sensory prefixes (Monzel et al., 2022a, 2022b). Only 10% of aphantasics report exclusively the absence of visual imagery (i.e., visual aphantasia; Zeman et al., 2025). Although there is some evidence that certain involuntary forms of mental imagery are preserved in aphantasia (e.g., dream imagery; Dawes et al., 2020), this matter is still debated (see Krempel and Monzel, 2024).

Recent evidence suggests that aphantasia is linked to additional cognitive differences (Jin et al., 2024; Zeman, 2024). For example, many aphantasics report poor episodic and autobiographical memory, poor face recognition and poor navigation skills (Digard et al., 2026a; Zeman et al., 2020). In fact, episodic memory reports of aphantasics are, on average, less detailed (Dawes et al., 2022; Milton et al., 2021), which is also reflected in neural differences during autobiographical memory recall (Monzel et al., 2024b), but not less accurate (Dando et al., 2023). Some studies even found differences in visual (Bainbridge et al., 2021) and verbal (Monzel et al., 2021b) working memory, but these differences are relatively small and not found consistently (e.g., Knight et al., 2022). Based on findings that face recognition of aphantasics is only impaired under suboptimal conditions (e.g., noisy images), Monzel et al. (2023c) propose that (working) memory differences may only occur in very difficult trials, where a lack of mental imagery cannot be compensated for by using non-imagery-based strategies (e.g., verbal strategies; Monzel et al., 2024a; Zeman et al., 2010; see *puzzle of aphantasia competency*https://www.zotero.org/google-docs/?BMYo9W, Scholz, 2024).[1] Dance et al. (2023) were able to replicate the face recognition deficits in aphantasics but did not find any differences in their ability to construct facial composites from memory. Regarding spatial navigation skills, only sub-skills have been investigated to date. For example, Bainbridge et al. (2021) found that people with aphantasia are capable of replicating spatial layouts, and Monzel et al. (2021a) and Monzel and Reuter (2024) found that aphantasics are significantly slower in visual search tasks, suggesting that mental imagery may be important for attentional guidance in space.

Importantly, most of the above-described cognitive differences were only found in lab-based experiments, and many aphantasics do not report any difficulties in daily life, suggesting that it is not a pathological phenomenon (Monzel et al., 2025c).[2] In fact, the absence of mental imagery also comes with some advantages. For example, people with aphantasia may be protected from emotional intrusions (Keogh et al., 2023; Monzel et al., 2023b), may benefit from being less distracted by unnecessary sensory details when solving complex reasoning problems (Knauff and Johnson-Laird, 2002; Le Clézio et al., 2026), and being less impulsive (e.g., measured in a Stroop task; Monzel et al., 2025c), potentially leading to less craving in addictive disorders (Kavanagh et al., 2005; May et al., 2008) and being less prone to committing suicide (Crane et al., 2012; Hales et al., 2011).

Overall, aphantasia is not a monolith. Instead, there seems to be several subtypes of aphantasia characterized by three dimensions: the number of sensory modalities with faint to absent imagery, the amount of imagery experienced in these modalities, and the presence (or absence) of additional correlates (Dawes et al., 2024; Digard et al., 2026a; Zeman et al., 2025). Independent of the strength of these correlates, evidence from qualitative studies is starting to emerge that many aspects of aphantasics' experiences are shaped by their lack of imagery. Aphantasics report how aphantasia can be both protective and disruptive in relation to other aspects of their life, especially in education (e.g., learning, mind-wandering, reading, creativity) and mental health (e.g., memory accessibility, therapies) (Digard et al., 2026b). Indeed, recent data suggest that mental illnesses and psychiatric conditions might present differently in aphantasic people, and that standard therapies may be less effective due to the frequent use of imagery (Mawtus et al., 2024; see also Monzel et al., 2025a for an effective application of imaginal extinction to aphantasics). They also describe how they feel as though they intuitively "just know" something, and how they conceptualize their past and future without images. Recently, Zeman et al. (2026) proposed that social cognition may be especially influenced by mental imagery. For example, aphantasics often describe a mismatch in communication with visualizers as well as a lack of confidence in their own abilities (Monzel et al., 2023a). Some associations were found with autism (Dance et al., 2021) and alexithymia (Kvamme et al., 2025; Monzel et al., 2024c), suggesting proximity to other neurodivergences.

[1]This perspective is functionally equivalent with the dissociation between the articulatory loop and the visuospatial sketchpad in Baddeley's (1986) model of working memory, in which the visuospatial sketchpad is used for mental imagery (e.g., Bruyer and Scailquin, 1998).

[2]Interestingly, in contrast to core aphantasia, hypophantasia seems to be associated with mental ill-health, suggesting compensatory strategies when mental imagery is absent but no compensatory mechanisms when mental imagery is existent but faint (Kvamme et al., 2025).

3.2.2 Hyperphantasia

At the opposite end of the visual imagery vividness spectrum lies hyperphantasia, characterized by a richness of visual imagery akin to perception. This extreme has been much less researched so far than its counterpart, and appears to exist only in a congenital form (Zeman et al., 2020). Like aphantasia, the moderate form of hyperphantasia (with near life-like imagery) is more common (11.2% of the population) than the extreme form (with life-like imagery, 2.6%) (Zeman et al., 2020). Most hyperphantasics report that several to all sensory modalities are as vivid as perception (multisensory or global hyperphantasia; Digard et al., 2026a; Zeman et al., 2020), with only 10% reporting that only their visual imagery was vivid (visual hyperphantasia). In contrast to aphantasics, they are more likely to report high face recognition skills and spatial imagery (Palermo et al., 2022), as well as synaesthesia (Digard et al., 2026a; Zeman et al., 2020).

3.2.3 Correlates of interindividual mental imagery differences

As described above in the case of aphantasia, mental imagery is associated with a range of other cognitive skills (for an overview, see Pearson, 2019). These are two-way relationships, with these other skills supporting and being supported by mental imagery. For example, imagery and working memory partially share cognitive mechanisms (Borst et al., 2012), and visual imagery is correlated with visual working memory skills (Keogh and Pearson, 2014).[3] In addition, imagery skills are often used to conceptualize situations and address a variety of problems (Blazhenkova and Kozhevnikov, 2009).

Imagery variabilities also have emotional correlates. As emotional imagery is linked to a stronger recruitment of the emotional system than verbal representations, more vivid imagery is associated with heightened emotional reactivity (Monzel et al., 2023b; Wicken et al., 2021). When combined with lower control over one's imagery, this can lead to frequent and distressing intrusive imagery (Holmes and Mathews, 2010; Pearson et al., 2013). Together, this makes imagery a key feature of mental illnesses such as anxiety, depression, post-traumatic stress disorders, or schizophrenia.

Overall, imagery abilities entail trade-offs, rather than uniform benefits or costs. While vivid imagery allows for memory richness, mental rehearsals, and the creation of imagined scenes, it can also lead to increased emotional reactivity, distracting thoughts, and a greater susceptibility to perceptual distortions (Reeder et al., 2024).

3.2.4 The significance of interindividual mental imagery differences

The correlates of mental imagery differences introduced above have practical significance in several domains. In the education context, standard practices often rely on imagery skills to enhance understanding or processing speed (Höffler, 2010; Koning and Schoot, 2013). Imagery-based simulation is also used as a practice method in a range of domains requiring highly specialist skills, such as sports (Lindsay et al., 2023), music (Keller, 2012), dance (Muir and Munroe-Chandler, 2025), or surgery (Anton et al., 2017). Tailoring instructions and practice methods, and offering a range of strategies, would therefore ensure support for all learners regardless of their propensity to create mental imagery. The clinical relevance of imagery variability has already been mentioned in several sections above (e.g., Pearson et al., 2013). Considering the link between mental imagery and mental health, high imagers are likely to experience distressing aspects of imagery. Similarly, while low imagery might have protective effects, it is likely that low imagers experience and exhibit mental distress differently from typical and high imagers, at the risk of not being recognized. Once accessing therapeutic support, strategies relying on visualizations may not be suitable to improve their mental health. As such, personalized interventions that take into consideration and leverage each individual's imagery skills are recommended.

4 Intraindividual differences in mental imagery

In addition to interindividual differences in mental imagery, there are intraindividual differences, reflected in changes in trial-by-trial vividness ratings (Barnett et al., 2026; Runge et al., 2015) and relatively low test-retest reliabilities (McKelvie, 1995). Thus, mental imagery is often considered a dynamic construct whose features depend on several factors such as the content of imagination and the respondent's situational affect, efforts, knowledge and cognitive capacities. For example, visualizing a potoo (sic!) will be difficult unless one knows what a potoo looks like. At the same time, even visualizing an apple may be difficult, if the respondent is completely exhausted.

Given that intraindividual differences in mental imagery exist, the question arises whether the quality of mental imagery can be influenced deliberately. Kind (2020) argues that imagination is a skill that is "under one's intentional control, can be done more or less well, and is improvable via practice/training". Blomkvist (2022) disagrees with this, arguing that current findings only suggest that abilities associated with mental imagery can be trained (e.g., mental rotation; Habacha et al., 2014), but not mental imagery itself. In fact, Rademaker and Pearson (2012) were not able to show improvements in visual imagery strength despite several days of training. Instead, metacognition improved over the course of training, leading to higher associations between subjective imagery vividness and objective imagery strength. Preliminary evidence from a more recent VR-based imagery training showed improvements for acquired visual imagery impairments and mild aphantasia (Wang et al., 2025), and Suggate and Martzog (2020) found evidence that children's screen time influences their mental imagery performance longitudinally, possibly due to unlearning using their own imagination. Yet, further evidence is needed to state whether mental imagery can be influenced by training or not.

[3]Since the same effect is less consistent when contrasting aphantasics and non-aphantasics, this may be once again an indication of compensatory cognitive strategies in the absence of mental imagery.

Besides these training-based approaches, there are some experimental accounts derived from the finding that aphantasics have higher activity in the visual cortex during mental imagery tasks than typical imagers (Keogh et al., 2020; Monzel et al., 2024b). This finding is often interpreted as a bad signal-to-noise ratio, where the imagery signal gets drowned by remaining perceptual activation in the visual cortex (Pace et al., 2023; Zhang et al., 2026). Reducing the excitability of the visual cortex using tDCS, on the other hand, increases the imagery strength of typical imagers (Keogh et al., 2020). In contrast, exciting visual neurons using incoming luminance, disrupted visual imagery in typical imagers (Sherwood and Pearson, 2010). It remains unclear, however, whether reducing noise in the visual cortex also works for people with aphantasia.

Instead of reducing neural noise using tDCS, Scholz et al. (2025) propose that similar effects could also be achieved by mindfulness-based interventions. Changing the attentional focus from external to internal signals, while simultaneously strengthening interoception, could, in theory, improve the signal-to-noise ratio, especially since reduced subjective interoception was shown to mediate several outcomes of aphantasia (Kvamme et al., 2025; Monzel et al., 2025b). While this hypothesis remains to be tested, Kjaer et al. (2002) were already able to show that meditation increased mental imagery, mediated by an increased endogenous dopamine release during meditation. Testing the concrete dopaminergic mechanisms of mental imagery using pharmacological interventions has already been preregistered but has yet to be carried out (Monzel et al., 2024d). Interestingly, however, there are two single case reports documenting the emergence of mental imagery after a single dose intake of ayahuasca (dos Santos et al., 2018) or psilocybin (Rebecchi, 2023), both psychedelics acting as serotonin agonists.

Regardless of whether it is possible to "switch on" imagery in people with aphantasia, some ethical implications have to be discussed. Koenig-Robert et al. (2025) caution against using psychedelic therapies to open the mind's eye due to unpredictable negative effects on the psyche and mental health. They conclude that "the sudden onset of visual imagery in individuals who have not previously experienced it could result, for some, in challenges involving intrusive thoughts and anxiety." Thus, informed consent should be the top priority of corresponding experiments.

5 Conclusion

The present chapter aimed to outline the wide variety of mental imagery experiences, their neurological foundations, and the methodological tools available to characterize them across modalities and dimensions. Mental imagery varies not only between individuals but also within individuals, depending on situational demands and the content being imagined, making a comprehensive description particularly challenging. Taken together, these observations underscore that mental imagery and consciousness in general can no longer be treated as uniform phenomena within general psychology; rather, individual differences are central to understanding these processes. Whatever mental imagery you may have formed while reading the introduction to this chapter, it is almost certain that it differed from that of everyone else.

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