Imagery: Its measure, trait, source, and utility

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Abstract

Imagery is the "mental" representation of events and states of the external world or body in their physical absence, such as visualizing a past trip, covertly rehearsing dance moves, or imagining a fictional scene described in a novel. For many people, imagery is an integral part of everyday conscious experience. In recent decades, imagery has received renewed attention, particularly through the lens of neuroscience. This chapter explores major themes in the scientific study of imagery, including its measure, its variability across people and factors influencing this variation, its neural underpinnings, and its functional significance, including both its possible innate and acquired utility.

Key points

- *What is imagery?* Imagery is "self-generated" or endogenous conscious perception that arise from "mental" representations of events and states of the external world or body, in the absence of direct sensory or corporeal input. Thus, imagery is distinguished from exogenous conscious perception that are directly caused by concurrent physical sensory or corporeal events and states.
- *Measure:* Imagery is typically studied using self-report methods, such as imagery questionnaires. There is an emerging use of biomarkers to indicate perceptual details of imagery (e.g., conscious content).
- *Trait:* Imagery conscious experience varies across individuals, with the majority indicating moderate imagery ability (mesophantasia or typical imagers), while a minority experience little to no imagery (aphantasia) or exceptionally vivid imagery (hyperphantasia). Possible factors contributing to differences in imagery ability include sex, age, and disease.
- *Source:* Like all other categories of conscious experience, the direct source of imagery is brain activity. The brain regions supporting imagery overlap with those engaged in sensory conscious perception, emotion, and overt action. Yet the neural mechanisms of imagery are also distinct, involving higher-order brain networks and top-down processes.
- *Utility:* Possible innate functions of imagery include supporting perception, memory, and cognition. Acquired applications of imagery are in development, such as facilitating communication in individuals with paralysis and aiding motor rehabilitation following injury.

Consciousness is subjective experience or "what it is like" to be the subject of conscious awareness (e.g., the first-person experience of eating chocolate ice cream or listening to a symphony). Conscious experiences are broadly categorized into two main types (Fig. 1): (1) *exogenous* and (2) *endogenous* conscious perception. Other terminology to describe similar categories of conscious experience

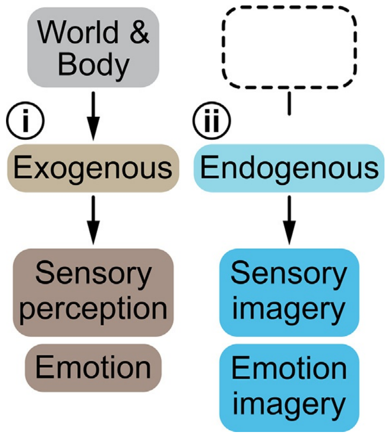

Fig. 1 *Exogenous* versus *endogenous conscious perception.* Conscious experiences can be broadly defined within two categories: **(i)** *exogenous* and **(ii)** *endogenous* conscious perception. Exogenous conscious perception is directly linked with environmental and corporeal events and states that are currently happening in the world or body. Exogenous conscious perception includes sensory perception of the external world (e.g., vision and audition) and corporeal states (e.g., a headache or walking), and emotion (e.g., fear and happiness). Endogenous conscious perception are "self-generated" conscious experiences from brain processes that create "mental" representations of the external world or corporeal events and states in their physical absence. Imagery is an example of endogenous conscious perception, including sensory imagery (e.g., visualizing the image of a flower or jumping on one foot) and emotion imagery (e.g., recalling a previous episode of anxiety or fear).

include external versus internal, outward versus inward, sensory-dependent versus sensory-independent, real versus illusory, and bottom-up versus top-down.

Exogenous conscious perception is directly linked to events in the environment and body. The conscious content or the perceptual objects of exogenous conscious experiences include sensations for events happening in the external world (e.g., vision, audition, and olfaction) and in the body (e.g., kinesthetics, fever, and pain). Even emotions can be considered a form of exogenous conscious perception, as they also reflect current corporeal states (e.g., how anxiety can be linked to increased heart rate, rapid respiration, and sweating).

Endogenous conscious perception is *not* directly linked to events in the environment and body. Rather, endogenous conscious experiences are "self-generated" from brain processes that simulate or create "mental" representations of events or states of the external world and body, but in their physical absence. For example, you can imagine the image and sound of lightning and thunder, even if outside is a perfectly clear day. Similarly, you can dream that you are running while lying still in bed.

While endogenous conscious perception is independent from what is physically present in the world or body, they can be misattributed as real or what is commonly called a hallucination. Possible confusion between exogenous and endogenous conscious perception or perceptual reality monitoring errors has challenged confidence in the human grasp on what is physically present in the world versus what is only a "mental" representation that appears "real". Famously, René Descartes (1596–1650) wondered if we might all be in a permanent dream, convinced by endogenous conscious experiences of a false or totally absent physical world. The idea that conscious experiences can deceive is a perennial source of intrigue and entertainment, frequently reenacted in many television shows and movies.

In summary, exogenous conscious experiences involve the presence of an external world or corporeal event that triggers a cascade of physiological processes, culminating in brain activity that gives rise to conscious awareness. Meanwhile, endogenous conscious experiences *begin* in brain processes in the absence of physical inputs from outside the central nervous system, including those from the body.

To be clear, this schema recognizes that exogenous conscious perception can misrepresent reality, resulting in illusions or misperceptions (i.e., when the subjective features of conscious experience mismatch with the objective features in the world). Yet illusions and misperceptions still depend on sensory signals from physical sources outside the brain. The key point is that, while both exogenous and endogenous conscious perception ultimately arise from brain activity, the causal chain of exogenous conscious perception extends beyond the brain to the body and external world, while endogenous conscious perception is triggered from within the brain, while acknowledging that there can still be an indirect relationship between sensory input and endogenous conscious perception (e.g., a smell triggering a memory).

Endogenous conscious perceptions have been of particular interest by scientists and philosophers for millennia. The goal of this chapter is to review a special category of endogenous conscious perception: *imagery*, which is also called "mental imagery", "mental image", "memory image", "phantasia", and "imagination". Imagery has been examined for millennia from diverse interdisciplinary perspectives. In recent decades, the scientific study of imagery has gained momentum, especially through the lens of neuroscience. From this scientific perspective, the major themes that will be discussed in this chapter include: (1) defining imagery and highlighting its multiple content instantiations, (2) the methods of measuring imagery, (3) how imagery experience varies across humans and factors influencing this variability, (4) the neural mechanisms of imagery, and (5) possible innate and acquired utilities of imagery.

1 What is imagery?

Imagery refers to "self-generated" or endogenous conscious perceptions that arise from "mental" representations of events and states of the body or external world, in the absence of direct sensory or corporeal input. Therefore, whatever is experienced in the conscious content of imagery is not physically present in the world or body. Imagery can reflect previously lived events (e.g., a childhood birthday party), also called *episodic memory*, or can be total fabrication, including imagining future events (e.g., anticipating an upcoming vacation) or fictional scenarios, related to *mind wandering* and *day dreaming*. The perceptual content of imagery is typically associated with the five major human senses. For example, *visual* imagery or "seeing with the mind's eye", includes evoking the imagined image of a famous painting or bucolic landscape, while auditory imagery or "hearing with the mind's ears", includes evoking the sound of a song or familiar voice. Further, *somatosensation* imagery involves imagining tactile sensation, such as, texture, pressure, pain, and temperature, but also includes the ability to imagine body motion and kinesthetics (e.g., imagery of grasping a cup or completing jumping jacks). Finally, while not among the primary human senses, emotion imagery is defined as a unique content category of imagery where emotional experiences can be imagined without their full, physical manifestation (e.g., imagining the happiness you would feel if you completed a marathon).

Notably, imagery appears distinct from abstract or silent verbal thoughts because the key perceptual feature of imagery is that they are felt with sensory or emotive conscious content. For instance, silently thinking the phrase "a yellow car honked", without auditory or speech imagery, is perceptually distinct from a mental image of a yellow car honking, or even the imaginal speech and kinesthetics of speaking this sentence out loud. Highlighting this distinction, if you created an imagined scene of a honking, yellow car, your imagery is likely to include details not specified by the verbal description, such as the car shape, the speed or direction of movement, and the pitch of the car horn—none of these perceptual details specified in the original prompt.

Although many people report that their sensory imagery shares perceptual features with sensory conscious perception, how the brain represents imagery is debated. The "imagery debate" of the 20th century hinged between whether imagery is represented in the brain as either perception-like (e.g., pictorial for visual imagery) or a propositional format (i.e., abstract and conceptual) (Kosslyn et al., 1979; Pylyshyn, 1973). Proponents of the propositional view argue that the common vocabulary of imagery, which equates imagery experiences with sensory conscious perception, is misleading (e.g., "I *saw* her face in my mind, just as if I were directly looking at her picture"). Earlier behaviorist accounts of imagery went further, denying that imagery involves mental representations at all, instead interpreting imagery reports as instances of "covert" behavior (e.g., subvocal speech).

The application of neuroimaging methods in imagery research greatly influenced the debate on what format imagery was represented in the brain, providing evidence consistent with the perception-like view. In particular, neuroimaging studies found overlapping brain networks for imagery and perception. However, recent attention to interindividual differences in imagery conscious experience (See section 3) suggests that there could be multiple formats through which imagery information is represented (Lebon, 2025; Pearson and Kosslyn, 2015).

While imagery is commonly discussed as a conscious experience that is knowingly felt and reportable, there is also consideration of *unconscious* imagery. As some argue, just as a faintly presented image can be consciously perceived in some instances and not perceived in others, perhaps the neural processes underlying imagery can also occur subliminally (Nanay, 2021). Although counterintuitive to the typical conscious experience of imagery, since we are only aware of imagery when it reaches consciousness, the concept of unconscious imagery has thought to be helpful for explaining normal performance on imagery tasks in people who report little to no imagery ability. What might be happening in these cases is unconscious imagery assisting imagery task performance, all the while the individual experiences no imagery content.

A distinctive characteristic of some imagery is its apparent volitional control. On command, most people can—or at least feel that they can—engage their imagery at chosen moments in time and on chosen subjects of imagination. For example, if I ask you to imagine that you are standing on the windswept summit of a high-altitude mountain, many of you can bring the sights, sounds, feelings, and smells of being in thin air, even if you have never previously submitted a mountain. Go ahead and try it now! If you struggle to produce this imagined scene, you may belong to a minority of people with limited or no imagery ability, discussed in a subsequent section.

However, not all imagery is voluntary. For example, by simply reading the phrase "a pink tiger is wearing a party hat" you might find yourself automatically imagining this humorous image, even when given instructions to inhibit that imagery. Similarly, flashbacks are examples of uncontrolled imagery that appear spontaneously, sometimes related to previous traumatic events and can be disruptive in daily life, including impairing mood and sleep quality by their intrusive reoccurrence. Nonetheless, seeming cases of voluntary imagery grant us the power to architect our own conscious experiences. As we will explore in a later section, the voluntary attribute of imagery affords imagery unique applications, including facilitating creativity and problem solving.

2 Measuring imagery

The major challenge for any scientific study of consciousness is that conscious experience is private (Kronemer et al., 2025a). Only you directly experience your subjective states, while unable to access any other person's conscious awareness. For instance, I cannot see *your* sight or suffer *your* pain, nor you mine. In short, you know what it is like to be you—to experience your conscious content and states—but everyone else is a mystery. The philosophy of mind has extensively discussed this challenge in "the problem of other minds". The inherent block between *subjective* or first-person experience and *objective* or third-person observation is also linked to other fundamental questions on consciousness, including how to adequately explain the source of consciousness from physiological processes or *the mind-body problem*.

If unable to directly access the conscious experiences of others, how do we infer the conscious states and experiences of other people? The apparent solution to the problem of subjectivity is to simply ask others about their conscious experiences. In short, if I want to know what you are experiencing, I can ask you. This approach for mounting the subjectivity block of conscious experience is called *overt report*. This kind of reporting is overt because it involves an *observable* action (e.g., speech or body gestures) that we interpret as sharing details on the conscious experiences of others (Kronemer et al., 2025a). Indeed, we encourage overt report in our social interactions and regularly participate in these behaviors to tell others about our conscious experiences. In short, overt report is the common method to access details on the consciousness of others and to share our own conscious awareness.

Reliance on overt report to elucidate conscious experience, broadly defined, likewise extends to research on imagery. The typical approach to access details on imagery conscious experience is by *imagery questionnaires* or surveys. The general approach of the imagery questionnaire is to have respondents engage in guided imagery (i.e., to imagine a particular object, scene, or event) and then to overtly report details on their imagery experience. Depending on the imagery questionnaire, different aspects of the imagery experience are queried. The most common inquired perceptual detail is imagery "vividness" or how "lifelike" or "photolike" imagery experiences are relative to its exogenous conscious perception counterpart. Vivid imagery suggests conscious experiences that resemble the conscious perception for the physical occurrence of a worldly or corporeal event or state. For instance, lifelike imagery for shaking someone's hand is perceived as akin to literally shaking hands.

Of the many early attempts to survey imagery, Francis Galton's (1822–1911) report of imagery conscious experience among healthy individuals is particularly influential in the modern science of imagery, including the use of a structured survey—a predecessor to contemporary imagery questionnaires (Galton, 1880a). Galton asked interviewees to imagine objects, for example, items that might be found on a breakfast table: dishes, utensils, a tablecloth, bread, and more. Once the interviewee attempted to imagine the scene, Galton interrogated the perceptual details of their imagery among several visual categories (e.g., illumination, definition, color, and visual field) by asking questions such as, "Is the image dim or fairly clear?" and "Are the colours of the china, of the toast, bread crust, mustard, meat, parsley, or whatever may have been on the table, quite distinct and natural?"

Later, George Herbert Betts (1868–1934) designed an imagery questionnaire that expanded on previous imagery interviews by inquiring on both visual and non-visual imagery (Betts, 1909). Betts asked participants to engage in auditory imagery (e.g., think of the sound of a whistling locomotive, slam of a door, and the humming of a mosquito), cutaneous imagery (e.g., think of touching velvet, wet soap, the pain of a burn, and the clasp of a hand), kinesthetic imagery (e.g., thinking of running upstairs, writing your name, reaching up to a high shelf, and passing a heavy dish), gustatory imagery (e.g., think of tasting salt, lemons, coffee, and watermelon), olfactory imagery (e.g., think of smelling roses, onions, cigar smoke, roast beef, and new leather), and "miscellaneous and organic" imagery (e.g., thinking of a headache, hunger, a sore throat, drowsiness, thirst, and nausea).

A key feature of Betts' questionnaire that would become common in subsequent imagery surveys was to have responses on imagery conscious experience made along a rating scale. Specifically, respondents rated their imagery vividness on a 7-point scale from "perfectly clear and as vivid as the actual experience" to "no image present at all". A constant scale along which to report imagery conscious experiences offered improved reliability and comparison across respondents relative to previous surveys that involved open or close-ended questions.

The general approach of prompting respondents to imagine an object, scene, or emotion and then having that person reflect on its vividness or resemblance to its corresponding exogenous conscious perception is shared among many imagery questionnaires. For example, a middle 20th century imagery questionnaire asked participants to imagine scenes and objects from words and phrases like violin, throwing a book on the table, heat from the sun, type writer, and ice cream in the mouth (Cohen, 1938). Another imagery questionnaire of the same period asked interviewees to "Think about your bedroom at home. Do you get a mental picture of it? Is the picture clear and distinct?", or "Think of eating a lemon. Do you get the actual taste in your mouth? Is it different from the way you imagine a lime would taste?" (Roman and Landis, 1945).

In the past half-century, a popular visual imagery measure is the *Vividness of Visual Imagery Questionnaire* (VVIQ) (Marks, 1973). In the VVIQ, participants are asked to rate the vividness of imagined objects and scenes (e.g., the "contour of face, head, shoulders and body" of a familiar person) on a 5-point scale from "no image at all" to "perfectly clear and as vivid as normal vision".

Taking a different approach, the *Spontaneous Use of Imagery Scale* (SUIS) asks respondents to judge along a 5-point scale from "never appropriate" to "completely appropriate" statements that probe how often they engage in imagery during daily life (Reisberg et al., 2003). For example, "before I get dressed to go out, I first visualize what I will look like if I wear different combinations of clothes", "when I first hear a friend's voice, a visual image of him or her almost always springs to mind", and "if I am looking for new furniture in a store, I always visualize what the furniture would look like in particular places in my home". Similarly, the *Object-Spatial Imagery Questionnaire* (OSIQ) measures object visual imagery by having interviewees rate statements on a 5-point scale between "totally disagree" to "totally agree" (Blajenkova et al., 2006). Statements include, "When reading fiction, I usually form a clear and detailed mental picture of a scene or room that has been described", "I am a good Tetris player", "sometimes my images are so vivid and persistent that it is difficult to ignore them", and "in high school, I had less difficulty with geometry than with art". Both the SUIS and OSIQ aim to uncover how a person normally engages imagery during their everyday life as indication of imagery vividness, these measures assuming that more daily usage of imagery indicates more vivid imagery.

Beyond visual imagery, the *Plymouth Sensory Imagery Questionnaire* explores multiple modalities of imagery, including all five human senses, bodily sensations, and emotions (Andrade et al., 2014). Using a 10-point scale, interviewees rate their imagery from "no image at all" to "image as clear and vivid as real life" on a range of items (e.g., the appearance of a cat climbing a tree, the sound of children playing, the smell of burning wood, the taste of toothpaste, the touching of icy water, the bodily sensation of having a sore throat, and feeling scared).

Additionally, the *Motor Imagery Vividness Scale* explores kinesthetic and emotive imagery (Yamaki, 2025). Respondents are instructed to imagine performing a jump, completing a full rotation in mid-air, and landing smoothly. After imagining this action, they are asked questions, such as "when imagining this movement, how strongly do you feel emotions such as enjoyment or a sense of accomplishment?", "when imagining this movement, how closely does its timing and rhythm match the actual movement?", and "after imagining this movement, how confident do you feel about successfully performing it?". Responses are made on a 7-point scale from "not at all" to "very much".

The above imagery questionnaires were developed for use with healthy adult participants. To study imagery in special populations, questionnaires have been adapted to better accommodate the cognitive and behavioral needs of certain developmental and impairment groups. For instance, the *Kinesthetic and Visual Imagery Questionnaire* was developed for people with sensorimotor impairments (Malouin et al., 2007). Meanwhile, the *Kids Imaging Ability Questionnaire* (Kwekkeboom et al., 2000) and the *Sport Imagery Questionnaire for Children* (Hall et al., 2009) were adapted for use in children.

2.1 The limits of imagery questionnaires

Imagery questionnaires are practical because they are easy to administer and allow for the person who is the only direct subject of their imagery conscious experiences to disclose its perceptual details. However, there are notable limitations of imagery questionnaires that challenge their efficacy in the scientific study of imagery.

First, all methods of overt report, including imagery questionnaires, are limited because what is reported may not always accurately reflect conscious experience. For instance, a person who engages in shallow introspection on their imagery may provide an incomplete report of their conscious experience. Even if a person intends to provide a faithful account of their imagery, recall errors may result in fallacious reporting without the participant even knowing their responses are inaccurate. See (Kronemer et al., 2025a) for a full review on the limits of overt report as a method to access states and contents of consciousness.

Second, imagery questionnaires and the interpretation of their results often treat imagery as a global trait and an ability that is consistent overtime. For example, it is common to administer a single modality imagery survey (e.g., the VVIQ that measures visual imagery) to indicate a person's imagery as a whole. While there is evidence that imagery ability is shared across modalities, imagery conscious experience may differ by modality (e.g., visual versus auditory imagery) and within modality (e.g., face imagery versus motion imagery). Furthermore, imagery may vary on a trial-by-trial basis and fluctuate with physiological state (e.g., dynamic perceived vividness with spontaneous fluctuations in attentiveness and arousal). This possible heterogeneity in imagery conscious experience is not well-captured in the results from an imagery questionnaire acquired at a single time point.

Third, imagery questionnaires may be sensitive to cognitive ability or simply how able someone is at completing a questionnaire. For instance, a participant who is better at comprehending instructions may respond differently than someone with less understanding, even if both individuals share identical features of imagery conscious experience. Similarly, introspection ability may differ among individuals, such that some people are better at engaging the metacognitive processes necessary to reflect and report on their imagery. Again, two people may experience identical imagery but respond differently on imagery questionnaires due to different abilities for reflecting and reporting on their conscious experiences.

Fourth, ambiguity in how participants interpret instructions and reporting scales when judging their imagery conscious experience is a potential confound. Participants may use different internal perceptual thresholds when making their imagery judgments (Larner et al., 2024). For example, in the VVIQ, the threshold for determining when imagery is "perfectly clear" may differ across respondents. A similar concern is that imagery questionnaires often employ ambiguous language, such as "vividness" or "normal vision" that is challenging to define concretely and to confirm consistent understanding across respondents (Schwarzkopf, 2024). Also, the common use of sensory perception as the perceptual anchor for judging the conscious experience of imagery (e.g., measuring the vividness of visual imagery against how closely it matches to conscious vision of physical light sources) is problematic because imagery and sensory conscious perception may not be perceptually comparable. For example, typical vision owns a strong sense of spatial occupancy (i.e., vision is felt projected in the world), which is often distinct from imagery that is commonly but not always felt to be interior (i.e., not "seen" in the world but a kind of "inner" experience). However, there are examples of imagery being mistaken for sensory conscious perception (e.g., someone believing that they are imagining an image when, in fact, they are seeing an image that is physically displayed), suggesting that perception and imagery may share perceptual characteristics (Perky, 1910; Dijkstra and Fleming, 2023).

Fifth, salience, familiarity, or meaningfulness of the imagery content may be a source of both variability in imagery conscious experience and reporting bias on imagery questionnaires. For example, if two people are asked to imagine a beach scene and one person has just returned from a vacation in the Caribbean, the recency of the beach vacation for one respondent may impact how they experience their imagery, perhaps felt as more vivid for the person with the more recent real world exposure to a beach. Notably, even if imagery vividness does not differ based on the imagined content, salience and familiarity cues might act on the introspection and recall processes that are involved in reporting on imagery conscious experience. For instance, the imagery of visualizing your friend may *seem* clearer than a stranger due to salience and ease of memory access cues (e.g., speed of retrieval), even if both are experienced with equal perceptual vividness.

Finally, general methodological concerns with self-report methods also apply to imagery questionnaires. For instance, *demand characteristics* remain a challenge, as participants may consciously or unconsciously infer the experimental hypotheses and adjust their responses to align with what the experimenter expects in an effort to be a "good" participant (Orne, 1962; Kronemer et al., 2024). Additionally, the imagery questionnaire literature is limited by inconsistent reporting standards, with studies omitting procedural details necessary for replication (Van Caenegem et al., 2022). Furthermore, although results from imagery questionnaires are often used to define subgroups of imagery experience, there is currently no standard threshold or cutoff for designating these groups either within or across questionnaires. This lack of standardization is problematic when comparing studies that ostensibly investigate the same imagery groups but use different classification criteria.

Together, the limits of imagery questionnaires are concerning because participant scores may not accurately reflect imagery conscious experience. Accordingly, some encourage caution for interpreting results from studies that rely on imagery questionnaires or similar overt reporting methods (Schwarzkopf, 2024; Larner et al., 2024). Emphasizing this concern are findings that questionnaire scores do not always correspond with performance on imagery tasks, nor do these scores always correlate or predict physiological responses that are linked with imagery (Pounder et al., 2024).

Nonetheless, imagery questionnaires can be informative despite their limits. For example, people who report low imagery ability also show an expected reduction in imagery-based priming relative to normal imagery individuals (Keogh and Pearson, 2018). Also, self-reported imagery vividness is related to performance on imagery and perception tasks (Liu and Bartolomeo, 2023). In addition, imagery ability determined by questionnaires can predict physiological responses according to imagery vividness, although there are conflicting findings.

2.2 Alternative measures of imagery

The limits of imagery questionnaires and other overt reporting methods have encouraged exploring new approaches for interrogating the conscious experience of imagery. For instance, some groups have asked participants to physically draw their visual imagery (Hewitt et al., 2023; Bainbridge et al., 2021). Also, behavioral metrics, such as chronometric measures (e.g., imagery timing and temporal pattern) can be informative of imagery conscious content (Decety et al., 1989). For instance, people with presumed absent or poor imagery ability respond with slower reaction times on imagery tasks (Liu and Bartolomeo, 2023).

Priming effects have also been used to infer imagery strength. In one study, participants were instructed to imagine one of two images (red or green circles) followed by the physical presentation of each image, one in either eye (Keogh and Pearson, 2018). While both images are simultaneously present, during binocular rivalry, participants typically report seeing only one image at a time (i.e., either the red or green circle), conscious perception occasionally switching between each image. People with typical imagery revealed imagery-based priming, that is, whichever image they were asked to imagine was subsequently more likely to be perceived under binocular rivalry, but people with vague or absent imagery did not show priming. Similarly, imagery of motion influences the subsequently perceived direction of movement for images with ambiguous movement direction, an effect known as a motion aftereffect (Winawer et al., 2010).

Furthermore, *covert measures of consciousness* or involuntary physiological markers of conscious awareness have been explored as a source of information on imagery (Kronemer et al., 2025a). For instance, pupil size during imagery of light and dark shapes may infer imagery vividness—imagery-induced pupillary responses absent in people who report no visual imagery (Kay et al., 2022). In addition, sniffing during olfactory imagery matches sniffing behavior when smelling a physically present odorant. For example, larger sniff volumes are observed for both real and imagined smelling of a pleasant aroma (Bensafi et al., 2003). In addition, respiration, cardiac, and skin conductance signals are altered with motor imagery (Collet et al., 2011).

Yet, a critical caveat is that covert measures or biomarkers of imagery or any other conscious experience are not conclusive of consciousness (Kronemer et al., 2025a). For example, stimulus-induced blinking is present for not perceived images in cerebral blindness, indicating that this eye response can be the result of unconscious neural processing (Kronemer et al., 2025b). Nor can we currently determine with full confidence which imagery-related neural activity predicts imagery conscious experience.

Ultimately, further research is needed to disentangle the neural and non-neural physiological signals that reflect conscious experience in general (i.e., unconscious versus conscious processing), and imagery in particular. As the understanding for the neural mechanisms of imagery advances, so too do methods for predicting imagery conscious experience from neural activity, the most direct approach for accessing perceptual details of imagery. Already, neuroimaging research shows that brain activity can predict the content of imagery (e.g., (Naselaris et al., 2015); See section 4).

3 Variation in imagery conscious experience

Is imagery a variable human trait? Early attempts to measure imagery conscious experience suggested differences across people. For instance, Galton's survey of 100 men to determine "degrees of [visual imagery] vividness" found that some interviewees reported clear imagery, one respondent indicating that "The mental image appears to correspond in all respects with reality. I think it is as clear as the actual scene", and another stating that "I can see my breakfast table or any equally familiar thing with my mind's eye, quite as well in all particulars as I can do if the reality is before me" (Galton, 1880a). However, an intriguing minority of the people Galton surveyed reported weak imagery, one person stating that "My powers [of visual imagery] are zero. To my consciousness there is almost no association of memory with objective visual impressions. I recollect the breakfast table, but do not see it."

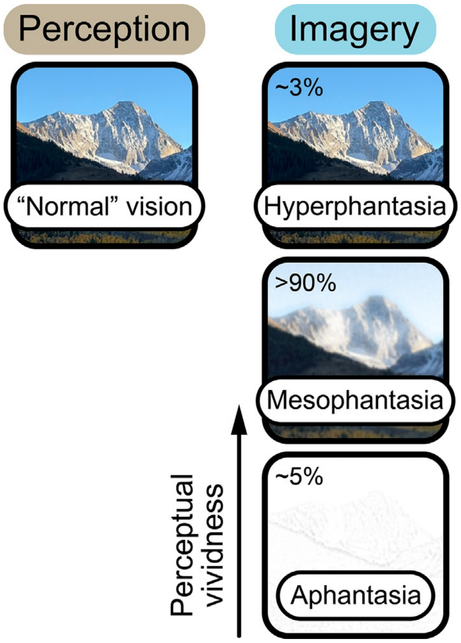

Fig. 2 *Variation in imagery conscious experience*. Healthy adults report varying degrees of imagery conscious experience, such as how closely imagination resembles exogenous conscious perception (i.e., imagining seeing an image versus physically viewing that image). Most individuals (approximately over 90%) experience moderately vivid imagery that shares some features with the direct perception of physical events, yet falls short of the rich, lifelike appearance of "normal" vision. This majority group is called typical imagers or *mesophantasia*, denoting an intermediate degree of imagery vividness. A minority of people report either exceptionally vivid imagery, known as *hyperphantasia* (approximately 3%), or faint to absent imagery, known as *aphantasia* (approximately 5%). This figure illustrates a hypothetical example of visual imagery of a mountain scene across hyperphantasia, mesophantasia, and aphantasia relative to the normal conscious vision of physically viewing an image. For individuals who report hyperphantasia, imagining a mountain produces photolike perceptual content nearly indistinguishable from physically viewing it. In contrast, aphantasics experience only faint visual imagery or none at all. The imagery conscious experience of mesophantasics falls between the highly vivid imagery of hyperphantasics and the vague or absent imagery of aphantasics.

These early findings of heterogenous vividness for imagery conscious content encouraged the framing of imagery as a variable trait or ability. Broadly, imagery ability in healthy individuals is summarized by three groups (Fig. 2): (1) faint or absent, (2) intermediate or midrange—considered "typical" or "normal"—and (3) exceptional or high imagery vividness.

It is worth noting at the outset that there is criticism for defining imagery trait or ability groups. As noted among the limitations of imagery questionnaires, there is currently no standardized method for categorizing individuals based on their imagery conscious experience. Different questionnaires and cutoff scores are often used to define imagery groups, adding uncertainty to the boundaries for separating degrees of imagery ability. Similarly, some argue that defining imagery groups is limited because they often rely on self-report that cannot be easily validated, although emerging objective measures of imagery ability are under investigation, examples of these approaches highlighted above (Larner et al., 2024). Even if classifying imagery ability through subjective reporting accurately reflects the conscious experience of imagery, some raise concerns that framing the extremes of imagery ability as a "condition" that can be "diagnosed" may lead to unnecessary stigmatization and distress (Blomkvist and Marks, 2023). Indeed, although the extremes in imagery ability are not recognized as disorders in healthy individuals, discourse surrounding people with imagery experiences at the extremes has been framed in terms of pathology, particularly in popular press.

Most healthy people—estimated as more than 90%—fall within the intermediate range of imagery ability. In the imagery research literature, there is no consensus nomenclature for this majority group, which is referred to by various terms, including "controls", "normals", "typicals", or "phantasics" (Dupont et al., 2024). For clarity, one possible shorthand is *mesophantasia*, referring to an intermediate imagery vividness. For typical imagers or mesophantasics, likely including yourself, imagery may share features with exogenous conscious perception, yet falls short of the rich perceptual details that distinguish, for example, actually seeing a physically present image or experiencing the overt movement of a limb.

However, not everyone can relate to an intermediate range of imagery conscious experience. There is a subset of people, accounting for less than 3% of the healthy adult population, who report exceptionally vivid, highly realistic, or lifelike imagery. This imagery experience is known as *hyperphantasia*. These people describe their visual imagery is akin to watching a video or gustatory imagery as if they are actually eating the food item only being imagined, including the somatosensory experience of chewing and swallowing. For hyperphantasics, imagining a mountain and seeing the mountain in person are nearly, or even entirely, perceptually identical (Fig. 2). Note that hyperphantasia is distinct from *eidetic memory* or what is sometimes colloquially called a *photographic memory*, which is specific to visual recall, particularly for recently viewed images.

At the other end of the imagery ability spectrum are people who report impoverished, faint, or entirely absent imagery, a phenomenon known as *aphantasia*. While aphantasia was coined recently, there is a long history of recognizing people with limited imagery conscious experience but by different names (e.g., "defective revisualization" and "loss of visualization") (Zeman et al., 2015; Botez et al., 1985; Brain, 1954). The most extreme version of aphantasia may account for less than 1% of healthy adults who report no imagery conscious experience whatsoever. However, up to approximately 5% of individuals may experience only vague imagery. Notably, aphantasia is typically not experienced as an abnormality or something to be overcome. In fact, individuals with faint imagery are often unaware that their imagery conscious experiences differ from most people. Thereby, they assume that common phrases like "seeing with my mind's eye" or "forming a mental image" are merely figures of speech. Anecdotally, I once tested a young man who scored very low in visual imagery vividness (VVIQ score below 30) (Kronemer et al., 2024). When I explained that his score was lower than typical, he was surprised to learn that most people can voluntarily generate and utilize mental images in daily life.

Still unresolved is whether all aspects of imagery are impaired or absent in aphantasia. While there is evidence to suggest that impoverished imagery in one sensory domain (e.g., visual imagery) indicates impairments in other imagery modalities (e.g., auditory and olfactory imagery), this is not always the case. Also, imagery can be categorized between voluntary and involuntary imagery. Voluntary imagery appears to occur by volitionally evoking a particular content of mental representation. Involuntary imagery are spontaneous imagery conscious experiences without apparent volitional control (e.g., flashbacks and earworms or songs you cannot stop replaying in your head). Voluntary and involuntary imagery have been considered separate abilities, suggesting that a dissociation between the two can occur. Similarly, the notion of conscious versus unconscious imagery is relevant because there may be people with impaired conscious but unimpaired unconscious imagery. For instance, it is speculated that aphantasics might show deficits in voluntary and conscious imagery, while their involuntary and/or unconscious imagery remains intact. This dissociation might explain why people who report poor imagery may still successfully perform imagery tasks. Likewise, some have argued that the deficit in aphantasia could be independent of the process of forming mental representations, instead related to introspection or reporting deficits. Ultimately, further research is required to account for how conscious experiences may differ across imagery ability subtypes.

3.1 Factors influencing imagery conscious experience

What accounts for the variability in the conscious experience of imagery? Early speculation considered a wide range of factors, many unsubstantiated and questionable, including race and profession. For instance, Galton suggested that scientists might develop weaker visual imagery to accommodate the abstract thoughts involved in scientific reasoning (Galton, 1880a). However, Galton also noted that imagery seemed disconnected from obvious personal traits, so he was left "puzzled to guess" based on general knowledge of a person whether they possess strong or weak imagery (Galton, 1880b). More than a century later, a survey of hundreds of participants who reported either aphantasia or hyperphantasia found that people with weak imagery tend to have occupations in the sciences and mathematics, while those with especially vivid imagery are often in "creative" professions, such as the arts and entertainment (Zeman et al., 2020).

Since these early speculations on the traits that might predict imagery conscious experience, there is now evidence that imagery ability is related to sex and age, with some studies reporting that certain types of imagery are more vivid in women and young people, however, there are inconsistent findings (Zeman, 2024; Gulyas et al., 2022). Also, autistic traits and cognitive deficits have been linked with weaker imagery (Dance et al., 2021; Courbois, 1996). Furthermore, there is evidence that traits of sensory conscious perception and linked cognitive ability correlate with imagery, including susceptibility to hallucinations, visual working memory, afterimage perception, and object memory (Konigsmark et al., 2021; Jacobs et al., 2018; Bainbridge et al., 2021; Kronemer et al., 2024; Wallace, 1990; Krempel and Monzel, 2024). There is also support for a link between brain anatomy and individual differences in imagery. For example, gray matter volume of frontal and parietal brain regions, including supplementary motor area and middle frontal gyrus, correlates with auditory imagery vividness (Lima et al., 2015). Meanwhile, visual imagery vividness is linked to the volume of the hippocampus and primary visual cortex (Tabi et al., 2022).

In addition, genetics may be an important variable in explaining imagery ability. While the genetic basis of imagery remains poorly understood and requires further investigation, evidence suggests that imagery vividness has a hereditary component, as aphantasia appears to be shared among family members (Zeman et al., 2020).

Differences in imagery have also been observed in the context of disease, including imagery content contributing to symptoms in certain psychiatric disorders. In fact, imagery has long been considered the source of certain mood disorders and psychosis. Prominently, early models for the hallucinations and delusions of schizophrenia suggested changes in imagery vividness so that they appeared more lifelike, thereby confusable with real sensory conscious perception (Roman and Landis, 1945; Seitz and Molholm, 1947; Cohen, 1938).

While lifelike or photolike imagery is no longer considered the cause of the positive symptoms in schizophrenia, there is evidence of changes in imagery in schizophrenia and other psychiatric disorders that influence their symptoms (Fig. 3). For instance, people with depression report less positive and more negative imagery, and their negative imagery tends to be felt as more vivid, therefore resulting in intense affect or greater emotional impact and disruptiveness in daily life. Likewise, more frequent and vivid negative imagery can support the maintenance of depressed mood and anxiety. Also, imagery of future events or flashforwards are commonly reported in depression and bipolar disorder as a major component of suicidal thoughts and future planning of self-harm. For example, some might imagine an act of self-harm or the aftermath of their death (e.g., their funeral). This flashforward imagery is reported by some individuals as motivating for the engagement in self-harm behaviors, thereby negative imagery a possible contributing factor in future suicide attempts (Lawrence et al., 2022).

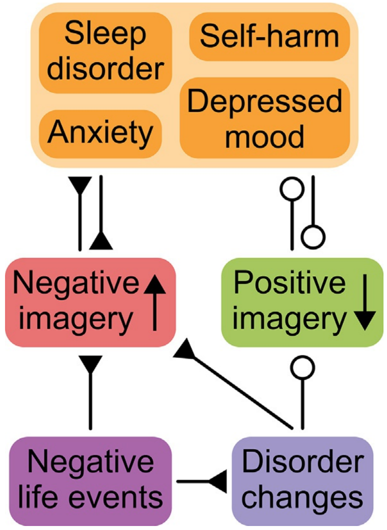

Fig. 3 *Linking imagery with symptoms in psychiatric disorders.* Negative life events (e.g., childhood abuse and life-threatening experiences) can contribute to physiological changes associated with psychiatric disorders (e.g., phobias and post-traumatic stress disorder) and become a source of negative imagery (e.g., flashbacks). Also, the physiological basis of psychiatric disorders can directly influence imagery behavior and experience, including the increased prevalence and vividness of negative imagery, while decreased positive imagery. Negative imagery can influence a number of symptoms and behaviors linked with psychiatric disorder, including anxiety, depressed mood, sleep disorder (e.g., nightmares disrupting sleep), and self-harm. Experiencing these symptoms may amplify changes in imagery, including increasing the frequency and vividness of negative imagery, while decreasing the frequency and vividness of positive imagery, thereby creating a negative feedback loop. Supporting this model are interventions involving exposure to and rescripting of negative imagery that can reduce symptoms of psychiatric disorders. Filled triangles indicate "enhances"; open circles indicate "inhibits".

Intrusive negative and distressing imagery have also been reported in post-traumatic stress disorders, phobia, obsessive-compulsive disorder, and eating disorder. Imagery of past traumatic or negative life events or the imagery of future negative events (i.e., catastrophizing) can reinforce feelings of mood instability and anxiety and contribute to poor sleep quality. Interestingly, there is evidence that people with faint or absent visual imagery are protected from certain adverse effects of negative imagery (Dance et al., 2025). This may be because they engage in less negative imagery and their negative imagery is less emotionally salient and intrusive. Nonetheless, there is little evidence that psychiatric disorders occur less frequently in people with weak or absent imagery (Dawes et al., 2020). Noting this, it is also possible that the physiological, affective, and behavioral changes observed in psychiatric disorders directly cause anomalies in imagery, rather than the other way around.

A model illustrating the relationship between imagery and common symptoms in psychiatric disorders is presented in Fig. 3. In summary, negative life events may contribute to the development of psychiatric disorder, for instance, how experiencing a life-threatening event can lead to post-traumatic stress disorder or a phobia, and may also form the content of future negative imagery. In addition, the physiological changes associated with psychiatric disorders may increase the frequency and vividness of negative imagery, while reducing positive imagery. This imbalance between negative and positive imagery may drive and maintain symptoms, such as anxiety, depression, and poor sleep, and motivate future self-harm behaviors. These symptoms can then create a negative feedback loop by further intensifying negative imagery and suppressing positive imagery. This model aligns with evidence that imagery-based therapies, such as imagery exposure and rescripting (e.g., a therapeutic technique of modifying negative imagery to be less distressing) can help alleviate symptoms of certain psychiatric disorders (See section 5 for further discussion).

4 The neural mechanisms of imagery

Like all conscious experiences, imagery arises from brain activity. However, the precise neural mechanisms of imagery remain under investigation. Before modern neuroimaging, lesion case studies were influential in elucidating the brain basis of imagery. For instance, the classic case report of two adults with hemispatial neglect resulting from right parietal hemisphere lesions not only showed the expected field-specific visual impairment in the left visual field but also demonstrated deficits in visual imagery (Bisiach and Luzzatti, 1978). Curiously, when these people were asked to imagine a familiar scene, they also appeared to neglect visual imagery on the left side of *imagined* space. These neglected details could be recovered if they switched their perspective on the imagined scene, so everything previously on the left was now positioned to the right in visual imagery.

Acquired impairments of imagery following brain injury indicate the role of the brain in forming mental representations that underly imagery conscious perception. More specifically, simultaneous deficits in sensory conscious perception and sensory imagery suggests *shared* neural mechanisms. This interpretation is further supported by behavioral findings demonstrating a relationship between sensory conscious perception and sensory imagery. For example, sensory imagery can influence the likelihood of perceiving a sensory event, depending on imagery timing and content (Farah, 1989; Djordjevic et al., 2004; Chang and Pearson, 2018). These results give evidence that imagery engages neural processes that overlap with those involved in the conscious perception of real sensory events.

Further supporting this interpretation are spontaneous behaviors (e.g., eye movements and sniffing) that exhibit similar patterns of activity during both real sensory conscious perception and sensory imagery (e.g., nasal airflow dynamics shared between real versus imagined smells) (Bensafi et al., 2003; Brandt and Stark, 1997). Even respiratory behaviors during imagined exercise or physical exertion scales with the level of imagined effort, with heart and respiration rate increasing with greater speed of imagined running (Decety et al., 1991). This research shows that imagery activates many of the same physiological processes and behaviors observed during the conscious perception of real sensory events and physical actions, further supporting common neural mechanisms.

Neuroimaging experiments affirm that imagery activates similar brain areas as involved in the processing of physical sensory events and overt behavior. Likewise, it is possible to decode the content of imagery from the same brain regions that predict sensory conscious perception (e.g., inferring visual imagery content from visual cortex), suggesting that it is in these brain regions where the neural activity linked to the content of imagery is processed. Similarly, emotion imagery activates affective brain regions.

In addition, the vividness of imagery correlates with brain activity. For example, fMRI signal magnitude and decoding of imagery content in the visual cortex corresponds with visual imagery vividness (Cui et al., 2007; Cabbai et al., 2024). Also, functional connectivity is shown to distinguish between hyperphantasia and aphantasia, with greater connectivity for hyperphantasics between visual and frontal networks (Milton et al., 2021).

Nevertheless, neuroimaging also indicates imagery involves distinct neural activity. For instance, there are conflicting results on the role of primary sensory and motor cortices in imagery (Van Caenegem et al., 2024). Thereby, in certain contexts sensory imagery may not engage primary sensory or motor brain regions that are vital in sensory conscious perception and overt action. This interpretation corresponds with brain lesion cases that show injury to primary visual cortex can result in *both* intact and impaired visual imagery, and people with intact primary visual cortex might still experience impaired imagery.

Furthermore, neural information flow differs between sensory conscious perception and sensory imagery. In cortical layer-dependent studies of visual imagery, activity in visual cortical layers is suggestive of top-down, feedback processing, distinct from the bottom-up, feedforward processing dominant in visual conscious perception (Carricarte et al., 2024; Bergmann et al., 2024; Persichetti et al., 2020). Correspondingly, higher-order brain activity is associated with imagery across modalities, suggestive that these regions may act in the imagery generative process independent of imagery conscious content (Van Caenegem et al., 2024; Zvyagintsev et al., 2013). Highlighting a possible causal role of these higher-order brain regions in imagery, the temporary impairment of the frontal executive network was shown to result in slowed motor imagery, but with no impact on overt movement (Martel and Glover, 2023). These results conforms with a top-down model of imagery (Pearson, 2019). Notably, a possible distinction between voluntary and involuntary imagery is relevant for interpreting how higher-order networks are involved in the formation of imagery conscious experience, perhaps a unique role for either imagery type.

Integrating findings across studies on the neural basis of imagery indicates that imagery is a complex, multifaceted process, supported by a distributed neural network. The *imagery network* encompasses sensory, memory, and higher-order, associative brain regions. These different brain areas may serve in facilitating the distinct processes of imagery (e.g., image generation and inspection) (Farah, 1984). For example, metacognitive processes that initiate and guide imagery may be facilitated by higher-order, associative brain regions, while sensory or motor networks provide the imagery content.

5 The utility of imagery

5.1 Innate utility

Does imagery possess an innate biological function? A popular hypothesis is that imagery is adaptive to help future sensing of the environment. For instance, visual imagery may prepare the visual system to see real world examples of the imagined content, thus improving visual acuity. In other words, if you repeatedly imagine a bear, you might become better at seeing a bear in the wild, possibly saving your life. Furthermore, imagery may act to enhance or plan future behaviors by allowing for the “pre-experience” of these activities to anticipate their potential consequences (Moulton and Kosslyn, 2009). Therefore, imagery may be an integral component of the “prospective brain” that works to anticipate the future (Schacter et al., 2007). Similarly, imagery might be helpful for learning because mental representations act to reinforce memory and skill development (e.g., mentally practicing a behavior) by reinstating the central neural systems associated with sensing and behavior.

In addition, imagery may be motivational. For example, positive imagery of reward may serve to encourage behaviors that help to achieve an imagined positive outcome. For instance, imagery of winning a race or achieving a personal best time can motivate a runner to remain consistent in their daily training routine. Conversely, imagery of negative outcomes can urge avoidance of risky or maladaptive behaviors.

Finally, imagery may facilitate certain kinds of cognition. The link between imagery and cognition was apparent in early studies of imagery. Galton noted that some individuals attributed their mathematical abilities to visual imagery of numerals that allowed them to visualize arithmetic, just as if they were written on paper (Galton, 1880b). Later research highlighted that imagery may help in generating and evaluating ideas (e.g., simulating objects or events). Also, imagery ability is correlated with measures of creativity, which corresponds with anecdotal accounts by scientists and artists who claimed that imagery plays an important role for achieving insight (LeBoutillier and Marks, 2003). For instance, Nikola Tesla (1856–1943) explained in his autobiography "My Inventions" (1919) that imagery played an important role in his creative process, writing "My method is different. I do not rush into actual work. When I get an idea I start at once building it up in my imagination. I change the construction, make improvements and operate the device in my mind. It is absolutely immaterial to me whether I run my turbine in thought or test it in my shop." In this way, imagery may function as a "mental laboratory", enabling innovation and discovery by allowing the combination of ideas and objects into novel forms and relationships (Verstijnen et al., 1998).

Imagery may also be informative in the cognitive processes linked to decision making (e.g., the imagery of possible future positions of chess pieces). In addition, imagery is linked with the cognitive processes associated with language generation and comprehension. Taken together, more than an epiphenomenon of perceptual and cognitive processes, imagery appears assistive, if not essential, for a wide range of cognitive functions.

5.2 Acquired utility

Whether or not imagery has an innate biological function, there is a growing number of applications of imagery explored and developed in experimental, clinical, and daily settings. These uses highlight that imagery can serve as a practical tool for achieving goals in everyday life, research, and health care.

5.2.1 Imagery for restoring communication and volitional control

Speech, facial expressions, and body gestures underlie the behaviors of overt report that provide insight on the subjective experiences of others (Kronemer et al., 2025a). When people cannot engage in overt report (e.g., under general anesthesia or after brain injury) it becomes more challenging to assess conscious awareness. Determining a patient's level of consciousness has clinical and ethical implications, including determining prognosis, administering adequate pain management, and continuation of life support. Most concerning are possible cases of misdiagnosed conscious level, particularly falsely assuming a patient is unconscious. In fact, some estimates suggest high misdiagnosis rates by the current standard methods for determining conscious level in patients with impaired behaviors of overt report (Childs et al., 1993). Therefore, alternative approaches for detecting conscious awareness in these patients have been explored.

Among emerging approaches for detecting covert consciousness (i.e., conscious awareness that is not overtly apparent due to the absence of overt behaviors), imagery has been leveraged as a tool for determining conscious awareness. One approach involves using the association between imagery and physiological activity. Patients can be instructed to imagine specific subjects or scenes, and the engagement of that imagery can be objectively confirmed by observing the expected physiological patterns linked to the imagery content. For example, one study instructed a patient meeting the clinical criteria for unresponsive wakefulness syndrome (previously called a vegetative state) to engage in imagery of a tennis match or walking through a familiar space, these contents of imagery were shown to evoke distinct patterns of brain activity in healthy individuals (Owen et al., 2006). Likewise, the patient activated on command the brain regions predictive for each imagery content, suggesting that they were consciously aware and able to voluntarily guide the conscious content of their imagery.

Imagery has also been used to restore language communication. This method involves coding language responses to specific imagery content. For example, one study asked patients to answer close-ended questions by imagining a tennis match for "yes" and imagining walking through a familiar space for "no", and then using the distinct patterns of brain activity for each imagery condition to indicate the patient's intended response (Monti et al., 2010). Similarly, another experiment asked a patient to imagine tasting lemon or milk to respond "yes" and "no" to close-ended questions (Wilhelm et al., 2006). In this case, imagery taste content was determined by salivary pH, decreasing when imagining lemon and increasing when imagining milk.

Furthermore, imagery is valuable in the development and application of *brain-computer interphase* (BCI) systems that can allow for the restoration of volitional control after paralysis. BCI uses brain signals to guide the overt behavior of software and robotics. A common BCI approach is based on imagery-linked brain activity. This method involves a person engaging in imagery while brain activity is simultaneously recorded. In real time, these neural signals are decoded to predict the imagery content and trigger controllable actions, all without overt behavior by the patient. For example, motor imagery has been used to allow people with paralysis to control a cursor on a computer screen or move a robotic arm or electric wheelchair (Zhang and Wang, 2021). The decoding of speech imagery has also been explored as a method to restore communication in people with disorders of language (Bhadra et al., 2025). In summary, imagery-based BCI offers exciting opportunities to allow people with paralysis to regain their autonomy.

5.2.2 Imagery for symptom management

Another promising translational application of imagery is for managing symptoms of numerous health events and disease. For instance, imagery has been shown effective in the treatment of pain (e.g., as a result of amputation, arthritis, and central neuropathy), anxiety, nightmares, depression, tics, and insomnia. A common approach of imagery-based symptom management is to have a person engage in guided imagery. For example, for people who experience phantom limb pain, imagery of moving the amputated limb reduces pain (MacIver et al., 2008). Moreover, imagery has helped treat chronic nightmares by imaginal exposure to intrusive imagery and imagery rescripting or reimagining the nightmare scenarios and rehearsing imagery that involve alternative, positive outcomes (Wesslau and Steil, 2014). A similar approach of engaging positive imagery or rescripting negative imagery can improve symptoms of depression, including anhedonia and low mood. Moreover, emotive and sensory imagery has been shown effective in treating phobia. Imagery has also been explored to manage emotions in daily life through emotive imagery techniques (e.g., reducing the anxiety felt in preparation of a performance). However, further research is necessary to build confidence in these applications.

5.2.3 Imagery for motor rehabilitation

Imagery has been explored as a method for rehabilitation, particularly to encourage recovery of motor function after brain injury and disease (e.g., stroke or Parkinson's disease), or a direct injury to the body (e.g., athletic injuries or amputation). Motivating imagery-based therapies to recover motor function is evidence that motor imagery engages similar brain networks as overt motor actions. Thereby, motor imagery may tune activity in the motor network that can enhance overt behaviors. Correspondingly, motor imagery (e.g., rehearsing movement without overt action) has been shown to improve motor function after stroke and in multiple sclerosis, although, there are some conflicting results on the efficacy of motor imagery (Ietswaart et al., 2011). In the context of athletic injuries, imagery during physical therapy (e.g., emotive imagery to manage pain and motor imagery to practice rehabilitating exercises) can improve outcomes, including improving adherence to the treatment regime and recovery rate (Driediger et al., 2006). Notably, imagery-based rehabilitation is particularly valuable during post-injury periods of immobilization (e.g., when in a cast after a bone break or surgery) where physical movement of the injured body cannot be easily performed.

5.2.4 Imagery for learning and memory

If imagery can assist in regaining an ability impaired or lost after injury, can it also encourage new learning and memory? The answer seems to be yes. Across a variety of skill types, from athletic performance to surgical methods, imagery can assist in learning new or training in overt actions, although there are some inconsistent findings. Similarly, imagery for playing a musical instrument, including mentally representing the sound and somatosensory experiences, is a common training approach among professional musicians that research supports can improve overt motor performance (Lotze, 2013). Also, motor imagery has shown to improve muscle strength and balance (Taube et al., 2014; Ranganathan et al., 2004). The advantage of using imagery for learning motor skills is that imagery-based training can be performed in many environments and without the equipment necessary for engaging in the overt action. For instance, imagery for playing the violin can be performed without the instrument physically present.

Imagery is also employed to support memory. The method of loci or a "memory palace" is a mnemonic approach dating back millennia that involves imagining a space (e.g., a room or city streets) and associating objects and locations in this imaginal space with specific memories or points of information. Subsequent retrieval or recall of this information involves imagery of navigating through this scene. The method of loci has been attributed to exceptional feats of memory, including memorizing hundreds to thousands of digits and letters over a short period of time. Likewise, people have long reported using the imagery of symbols and mental landscapes to assist their memory (Galton, 1880b). The application of imagery as a memory tool is supported by evidence that people with weak imagery perform worse on memory tasks compared to those with typical or vivid imagery (Dawes et al., 2022; Marks, 1973).

6 Conclusions

Imagery is the mental representation of sensory and bodily events and states, including movement and emotion. The study of imagery spans millennia and has traditionally relied on surveys or questionnaires that probe the conscious experience of imagery. More recently, physiological markers of imagery have been explored as objective indicators of imagery conscious experience. Research on imagery ability in healthy individuals shows that while most people report moderate imagery vividness, a minority experience either lifelike imagery—imagery that appears akin to perception—or faint to absent imagery. Factors that may influence imagery ability include sex, age, genetics, and disease. Furthermore, the relationship between brain anatomy and function with imagery vividness corresponds with recent efforts to detail the neural mechanisms of imagery. Evidence from neuroimaging, neuromodulation, lesion case studies, and behavioral research support that imagery involves similar but not identical brain networks as with sensory conscious perception, overt behavior, and emotion. Finally, the innate biological function of imagery has been long debated, with proposed roles such as anticipating future sensory events and facilitating cognition. In addition, imagery has been applied as a practical tool in research, clinical, and everyday contexts, including enabling communication with people who are paralyzed and assisting in learning and memory. Continued scientific research promises to deepen knowledge on the biology of imagery and to expand imagery-based applications.

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