discussion

The Two Eyes of the Blind Mind: Object vs. Spatial Aphantasia?

Olesya Blazhenkova
Faculty of Arts and Social Sciences, Sabancı University, Istanbul, Turkey

Ekaterina Pechenkova
Laboratory for Cognitive Research, National Research University Higher School of Economics, Moscow, Russia

Abstract. Individual variability in imagery experiences has long attracted the interest of philosophers, educators, and psychologists. Since Aristotle's time, it was assumed that imagery is a universal ability, so everyone possesses it. Galton first measured the vividness of subjective imagery experiences, and discovered that some individuals reported zero imagination. Recent research has coined the term "aphantasia" — an inability to form mental imagery, or having a "blind mind's eye" (Zeman, Dewar, & Della Sala, 2015). We argue that there may be more than one type of aphantasia. Substantial behavioral and neuropsychological evidence has demonstrated a distinction between visual-object imagery (mental visualization of pictorial properties such as color, shape, brightness, and texture) and visual-spatial imagery (mental visualization of spatial locations, relations, and transformations). Notably, visual imagery is not a unitary ability, so individuals who excel in object imagery do not necessarily excel in spatial imagery, and vice versa. Here we argue that the commonly described "aphantasia" is not a general imagery deficit but rather a visual-object deficit of imagery (as aphantasic people are often identified by low scores on the Vividness of Visual Imagery Questionnaire, which assesses object imagery only). We hypothesize that "spatial aphantasia" (the inability to imagine spatial properties and relationships) can be a separate type of imagery deficit. Individuals with spatial aphantasia may not necessarily have a deficit in object imagery. We discuss future research directions examining how spatial aphantasia may manifest behaviorally and neurologically, and how object and spatial aphantasia may be related.

Correspondence: Olesya Blazhenkova, olesya@sabanciuniv.edu, Faculty of Arts and Social Sciences, Sabanci University, Orta Mahalle, Üniversite Caddesi No: 27 Tuzla, 34956 Istanbul, Turkey; Ekaterina Pechenkova, evp@virtualcoglab.org.

Keywords: aphantasia, hyperphantasia, extreme imagination, individual differences in imagery, object imagery, spatial imagery, visualization abilities

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Received November 6, 2019, accepted December 28, 2019.

Is Aphantasia a Unitary Deficit?

Recent research has coined the term "*aphantasia*" to refer to an inability to form mental imagery or having a "blind mind's eye" (Zeman, Dewar, & Della Sala, 2015). People with aphantasia comprise roughly 2–3 % of the population (Faw, 2009; Zeman et al., 2015). The identification of an "aphantasia condition" has attracted global media coverage and raised renewed scientific and public interest in individual differences in imagery. Cutting-edge research examining differences between people with aphantasia and those with hyperphantasia (individuals with extremely vivid imagery, Cossins, 2019; Zeman, MacKisack, & Onians, 2018) was initiated by Adam Zeman's lab in the UK and Joel Pearson's lab in Australia. In April 2019, the world's first conference for people with "extreme imagination" took place at the UK (Extreme Imagination Conference, 2019). Since 2015, aphantasia has become a popular topic discussed in newspapers, TV, blogs, podcasts, as well as in online aphantasia awareness and support groups. Still, scientific exploration of this new topic is only taking its first steps. According to Google Scholar, there were only about twenty publications with "aphantasia" in the title between 2015–2019 (and none before), while there were about fifteen thousand publications with "imagery" in title in the same period.

In this opinion paper, we argue that there may be more than one type of aphantasia and that previous aphantasia research considered only one facet of imagery deficits while neglecting the other. Our "two eyes of the blind mind" hypothesis is based on the established distinction between visual-object and visual-spatial processing. Contrary to the widespread assumption that imagery is a unitary mental faculty, a substantial body of evidence has demonstrated a distinction between *visual-object* imagery (mental visualization of pictorial properties such as color, shape, brightness, and texture) and *visual-spatial* imagery (mental visualization of spatial locations, relations, and transformations). Evidence from neuroscience and neuropsychology has demonstrated that, in terms of neural substrate, this distinction is based on the dorsal and ventral visual cortical pathways (Farah, 1988; Farah, Hammond, Levine, & Calvanio, 1988; Kosslyn & Koenig, 1992; Mazard, Tzourio-Mazoyer, Crivello, Mazoyer, & Mellet, 2004) while individual differences research described these two aspects of visual imagery as two dissociable abilities: individuals who excel in object imagery were found to not necessarily excel in spatial imagery and vice versa (Blazhenkova & Kozhevnikov, 2010; Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov, Kosslyn, & Shepard, 2005).

While aphantasia is typically characterized as a general inability to conjure a mental image, it is operationally defined as an inability to produce vivid pictorial mental representations assessed by vividness questionnaires. Individuals with aphantasia report extremely low imagery vividness (Zeman et al., 2010; Zeman et al., 2015), and they are commonly identified as those who report no (and sometimes weak and vague) imagination on the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) or similar self-report assessments. The VVIQ instrument assesses the ability to mentally picture objects and scenes in color and detail (face of a friend, interior of a shop, beautiful landscape) on the basis of verbal descriptions such as "The sun is rising above the horizon into a hazy sky". For each item, participants rate the vividness of their images on a 5-point scale from "perfectly clear and as vivid as normal vision" to "no image at all, you only 'know' that you are thinking of the object". So, the common operational definition of aphantasia poses a limitation since the VVIQ only measures the object facet of visual imagery (Blazhenkova, 2016). Remarkably, people with aphantasia, identified by the VVIQ, do not necessarily report a deficit in spatial imagery (Keogh & Pearson, 2018). The renowned case described by Zeman and colleagues (2010), patient MX, who lost the imagery ability, was still able to perform well on a visuo-spatial task (mental rotation of 3D geometric shapes).

Therefore, research on aphantasia implies that aphantasic individuals, while being critically low in object visualization power, may preserve intact spatial imagery or even excel in spatial mental visualization. However, no studies have examined the possibility of the opposite case: the complete absence of spatial imagery. Here we argue that "spatial aphantasia" (the inability to mentally visualize spatial relationships and spatial properties) can be separate from the commonly described "aphantasia" type of imagery deficit. Individuals with spatial aphantasia may not necessarily have a deficit in object imagery or may even have object hyperphantasia (extreme vividness of object imagery). In the further sections of the paper, we review the existing psychometric and neuropsychological evidence for imagery abilities and imagery deficits in light of the possibility of spatial aphantasia. We discuss future research directions examining how spatial aphantasia may manifest behaviorally and neurologically, and how object and spatial aphantasia may be related.

Individual Differences in Imagery: A Psychometric Approach

Imagery experiences and their role in cognitive performance have long attracted the interest of scholars. The idea that imagery is a universal ability which everyone possesses and which is crucial for thought was present in the works of early philosophers such as Aristotle, who claimed that "the soul never thinks without a phantasma" (Aristotle, ca. 350 B.C.E./1968; see more in Faw, 2009). The inability to create mental images was first described in empirical research during the 19th century. In 1880, Galton developed a self-report questionnaire to measure the vividness of subjective experience of mental images and discovered a great variability in responses (the contemporary VVIQ questionnaire was developed on the basis of Galton's original instrument). Surprisingly, Galton found that while most people reported somewhat vivid imagery experiences, some individuals had "zero" powers of imagination. Scientists, in particular, reported extremely low imagery vividness or even the denial of having imagery experiences. Galton concluded that the ability to form vivid mental images is antagonistic to abstract thinking.

Subsequently, in a psychometric approach, individual differences in visualization have been commonly assessed with tools based on a visual-verbal conceptual distinction, popular in psychology and education. This distinction between visual and verbal processing systems underlies a commonly acknowledged (Pashler, McDaniel, Rohrer, & Bjork, 2009) visual-verbal model of cognitive style (e.g., Paivio, 1971; Richardson, 1977; Mayer & Massa, 2003) that portrays a preference to verbal vs. visual ways of information processing as two contrasting poles. According to this model, individuals can be classified as either visualizers, who rely primarily on visual thinking, or verbalizers, who rely primarily on verbal-analytical thinking. In this bipolar approach, the capacity for visual imagery has been considered as a unitary construct, so individuals were categorized as either "good" or "bad" visualizers, also called "high" vs. "low" imagers (e.g., Hollenberg, 1970; Paivio, 1983). The distinction between visual and verbal abilities is also reflected in theories of intelligence (Carroll, 1993; Cattell, 1971; Thurstone, 1938). Spatial visualization has been assessed as a separate nonverbal dimension of intelligence (Smith, 1964; Eliot & Smith, 1983; Wechsler, 1955). However, a psychological measurement of visual-spatial abilities, using factor analyses of visual ability tests, did not reveal a single spatial dimension; instead, it points to both spatial factors (such as spatial visualization and speeded rotation) and also non-spatial factors (such as speed of closure or flexibility of closure) (e.g., Carroll, 1993). Such findings challenged the idea of visualization as a unitary general ability. Blazhenkova and Kozhevnikov (2010) subsequently demonstrated that not only visual-spatial ability, but also object visualization, can be considered as a separate facet of visual intelligence.

Furthermore, a number of instruments developed to measure visualizer-verbalizer cognitive style (e.g., the most common self-report assessments of experiences, learning preferences, and problem solving strategies; but also some accuracy or response times on verbal vs. visual performance tasks) failed to establish good psychometric properties. Self-report questionnaires that asked participants to rate their preferences in the use of imagery versus verbal thinking (e.g., "I often use mental pictures to solve the problem") were criticized for their relatively low internal reliability (Antonietti & Giorgetti, 1998; Boswell & Pickett, 1991; Sullivan & Macklin, 1986) and poor construct validity (e.g., Alesandrini, 1981; Green & Schroeder, 1990). Factor analyses failed to show a clear factor structure with visual items forming a homogenous scale (e.g., Green & Schroeder, 1990; Boswell & Pickett, 1991), which was not acceptable for measuring a unitary visualization construct. Moreover, visual cognitive style self-reports did not correlate with visual-spatial ability measures (e.g., Alesandrini, 1981; Edwards & Wilkins, 1981; Green & Schroeder, 1990; Parrott, 1986; Mayer & Massa, 2003). Numerous correlational studies on imagery vividness, mostly based on VVIQ or similar measures, also showed that self-report imagery vividness assessments often failed to correlate with imagery performance measures (McKelvie, 1995), such as spatial visualization. Such results cast doubt on the validity of self-report assessments of imagery (Lohman, 1979; Richardson, 1980). In addition, objective measures of visual cognitive style did not show a clear relationship with performance on spatial ability tests, and thus their validity has been questioned as well (Peterson, Deary, & Austin, 2005; Lean & Clements, 1981; Massa & Mayer, 2005). Overall, such evidence questioned the usefulness of a visual-verbal model of cognitive style.

Kozhevnikov and colleagues (2005) challenged the assumption underlying the traditional two-dimensional visual-verbal model of cognitive style: that visual imagery is a unitary and undifferentiated construct. Instead, based on behavioral and neuropsychological evidence that distinguish between object and spatial visual processing, they proposed a new object-spatial-verbal model of cognitive style, which in addition to the verbal considered two separate dimensions of visual style. Subsequently, this model was empirically validated by Blazhenkova and Kozhevnikov (2009), who used a confirmatory factor analysis and demonstrated that the overall fit to the data of the new three-dimensional model of cognitive style was significantly better than that of the traditional model. Furthermore, the approach discriminating between object and spatial visual imagery provided a theoretically guided background for the development of valid and reliable self-report imagery instruments. Based on this approach, Blajenkova, Kozhevnikov, and Motes (2006) developed the Object-Spatial Imagery Questionnaire (OSIQ), which consisted of two independent scales separately assessing object (e.g., "My images are very colorful and bright") and spatial (e.g., "My images are more like schematic representations of things and events") imagery abilities, experiences, and preferences. Unlike many previous imagery questionnaires that lacked criterion validity, the object imagery scale of the OSIQ significantly correlated with performance on object imagery tasks and predicted interest and membership in artistic specializations, while the spatial imagery scale significantly correlated with performance on spatial imagery tasks and predicted interest and membership in STEM (science, technology, engineering, and math) specializations.

In the same vein, Dean and Morris (2003) asked participants to rate the vividness of schematic "spatial" stimuli, similar to those used in standard mental rotation tasks that require to mentally rotate 3D geometric shapes composed of cubes in order to identify whether the figures are the same or different (Vandenberg & Kuse, 1978). Vividness ratings for these shapes correlated with performance on the mental rotation tests (Dean & Morris, 2003).

Continuing this line of research, Blazhenkova (2016) created the Vividness of Object and Spatial Imagery (VOSI) questionnaire, separately assessing vividness ratings of the evoked mental images ratings on an object scale (e.g., "Fine details of a zebra's skin") and a spatial scale (e.g., "Mechanism of a door handle"). It was found that vividness that refers to the imagery of spatial properties (locations, spatial structure, and relationships) versus pictorial object properties (color, texture, and shape) constitute different — spatial and object — vividness dimensions, and discriminatively correlate with object (e.g., identifying hidden or fragmented objects) vs. spatial imagery (e.g., paper folding or mental rotation) performance measures. Overall, this research demonstrated that imagery self-reports, per se, do not appear to be poor instruments unrelated to objective measures; instead, subjective reports may be correlated with performance tests when a specific dimension of imagery is associated with the corresponding type of imagery assessed by a performance measure (for a review, see McAvinue & Robertson, 2007). Such tools that differentiate object vs. spatial image quality may become important instruments in the identification and in-depth study of spatial aphantasia, as well as in comparisons between spatial and object aphantasia and hyperphantasia.

Extreme Imagination Cognitive Correlates

Previous research on variability in imagery was more focused on the object imagery dimension, and mostly on the high end of the distribution. More recent aphantasia research is focused on the low end — individuals with critically low or absent imagery phenomenological experience.

Extremely *high object imagery*, recently labeled *hyperphantasia* and commonly assessed by self-reports measuring phenomenological experiences of vivid pictorial imagery, were found to be associated with various cognitive correlates. Research has established the association between high vividness of pictorial imagery experiences and some cognitive measures (see McKelvie, 1995 for a review), such as the ability to identify incomplete, distorted, or hard-to-see objects (Vannucci, Mazzoni, Chiorri, & Cioli, 2008; Wallace 1990); memory for picture details (Marks, 1983); retrieval of sensory traces from long-term memory (D'Angiulli et al. 2013); detecting salient changes (Rodway, Gillies, & Schepman, 2006); synaesthesia (Barnett & Newell, 2008); high object imagery scores of the OSIQ (Blazhenkova, 2016); and art expertise (Morrison & Wallace, 2001; Blazhenkova & Kozhevnikov, 2010).

In contrast, aphantasia research has demonstrated that *low* (*object) vividness* is associated with a syndrome of Severely Deficient Autobiographical memory (Palombo, Alain, Soderlund, Khuu, & Levine, 2015), prosopagnosia (Grüter, Grüter, & Carbon, 2009), loss of the usual priming effect of imagery in binocular rivalry (Keogh & Pearson, 2018), reduction in the precision of visual working memory (Jacobs, Schwarzkopf, & Silvanto, 2018), an absence of the usual autonomic response to stories that normally excite emotive imagery (Wicken, Keogh, & Pearson, 2019), and lower object imagery scores on the OSIQ (Jacobs et al., 2018; Keogh & Pearson, 2017). According to Kendle (2017; cited by Tween, 2018), people with aphantasia differ in their imagery abilities in other modalities: some report similar difficulties across modalities while others report having "mind's ear" or tactile imagery.

Extremely *high spatial imagery* is typically measured by mental spatial rotation, transformation, and spatial relations performance tasks such as the Paper Folding Test (requiring participants to identify how a folded and hole-punched paper would look like when fully opened) by Ekstrom, French, Harman, and Dermen (1976), and the Mental Rotations Test by Vandenberg and Kuse (1978). High performance on such spatial visualization tests are correlated with successful occupational and academic performance in various domains, including physics, organic chemistry, geology, and mathematics (Casey, Nuttall, & Pezaris, 1997; Coleman & Gotch, 1998; Ferguson, 1977; Keehner et al., 2004; Kozhevnikov, Motes, & Hegarty, 2007; Orion, Ben-Chaim, & Kali, 1997; McGee, 1979; Paterson, Elliott, Anderson, Toops & Heidbreder, 1930; Presmeg, 1986; Smith, 1964; Wai, Lubinski, & Benbow, 2009) as well as surgery, architecture, and mechanical reasoning (Hegarty & Waller, 2005). Spatial transformation ability tests also showed positive correlations with tests of general fluid ability (Lohman, 1996). Spatial intelligence tests use similar measures such as mental rotation, mental transformation, and spatial relationships. High spatial ability was associated with high spatial working memory, and spatial executive control (Colom et al, 2009; Salthouse, Babcock, Mitchell, Palmon, & Skovronek, 1990; Shah & Miyake, 1996).

Vice versa, *low spatial imagery* was associated with inferior performance in STEM domains, such as mathematics learning disabilities (Passolunghi & Mammarella, 2012), and in spatial working memory tasks (but not visual-object imagery tasks), poor spatial orientation and navigational skills (Hegarty & Waller, 2005), and motor coordination difficulties (Voyer & Jansen, 2017).

Extreme imagery cognitive profiles may also include different strategies. Individuals with low spatial imagery were found to use different strategies from those with high spatial imagery when solving spatial tasks, and to interpret spatial visualizations as picture-like representations (Kozhevnikov et al., 2007). Different strategies were also used by high vs. low object imagers when solving object tasks. Marks (1973) found that individuals with low imagery vividness had a higher eye movement rate during picture recall than those with high vividness. Johansson et al. (2011) detected specific characteristics of eye movements (i.e., spatial dispersion) during mental visualization in relation to individual differences in spatial but not object imagery ability.

Therefore, both low and high poles of both object and spatial visual imagery abilities seem to be associated with a distinct profile of cognitive abilities and styles. We expect that individuals with spatial aphantasia may be discovered as extreme cases among the population of neurologically unimpaired individuals with low spatial imagery abilities and may demonstrate cognitive profiles similar to this low spatial imagery group.

Object vs. Spatial Imagery Variability in Professional Fields

Spatial imagery has long been considered an important predictor of real-life task performance such as professional success, while object imagery only recently gained attention as a dimension relevant for professional fields (Blazhenkova & Kozhevnikov, 2010). As discussed above, different object vs. spatial imagery ability profiles are associated with occupational preferences and success in such professional fields as STEM and the arts. These findings shed light on Galton's puzzling findings that scientists have deficient mental imagery (1880). Galton's conclusions led to subsequent doubts about the functional role of imagery in cognition, contested in a renowned "imagery debate" about pictorial (Kosslyn, 1980, 2005; Pearson & Kosslyn, 2015) vs. propositional (Pylyshyn, 1981, 2003) formats of imagery representations. Blajenkova, Kozhevnikov, and Motes (2006) first proposed an explanation of Galton's results in light of the distinction between object and spatial visual imagery abilities. It was shown that scientists are not generally deficient in mental imagery; they may lack object (but not spatial) imagery. As known from other studies, successful performance in the visual art domain requires the ability to depict objects' pictorial appearances in terms of vivid color, texture, and shape (Lindauer, 1983; Patrick, 1937; Roe, 1975; Rosenberg, 1987), whereas successful performance in STEM domains requires profound spatial imagery ability such as imagining schematic structures or performing mental spatial transformations (Ferguson, 1977; Kozhevnikov et al., 2007; McGee, 1979; Paterson et al., 1930; Presmeg, 1986; Wai, Lubinski, & Benbow, 2009).

Furthermore, research on individual differences in imagery has demonstrated that natural scientists and engineers tend to be spatial imagers while visual artists tend to be object imagers (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009, 2010; Kozhevnikov et al., 2005; Kozhevnikov, Blazhenkova, & Becker, 2010). Such studies showed that visual artists not only *report* imagery experiences mostly representing pictorial properties of objects and scenes, but also *perform* better on tasks that require object visualization (e.g., creating vivid representation of textures and colors, recognizing degraded objects); spatial visualizers *report* a use of imagery predominantly for representing spatial relations and transformations and *perform* better in tasks that require spatial visualization (e.g., mental rotation, finding locations). Besides this, Kozhevnikov, Kozhevnikov, Chen, and Blazhenkova (2013) found that object vs. spatial visualization imagery assessments were discriminatively associated with artistic vs. scientific creativity assessments, correspondingly. Moreover, Kozhevnikov, Blazhenkova, & Becker (2010) showed across five different age groups and four different specialization groups that visual artists had above-average object visualization abilities but below-average spatial visualization abilities, whereas scientists showed the inverse pattern. None of the professional groups (artists, scientists, architects, or humanities specialists) demonstrated both above-average object and above-average spatial visualization abilities, and it was proposed that there can be a trade-off between object and spatial visualization abilities. Consistently, later aphantasia research found that while hyperphantasic individuals with extremely vivid and bright imagery were more likely to specialize in the arts, individuals with aphantasia were more likely to specialize in STEM domains (Crowder, 2018). These findings on aphantasic individuals are in accordance with previous research on individual differences in object and spatial imagery in artistic and scientific specializations.

Overall, the above reviewed research on imagery variability in different professional fields support the claim that aphantasia in object imagery experiences reported by scientists may not involve a loss of spatial imagery. Furthermore, based on these findings, we expect that there might be a separate condition of spatial aphantasia which may not be accompanied by a loss of object imagery. It is also possible that individuals with spatial aphantasia are less likely to specialize in STEM domains but may succeed in the arts.

Neuropsychological Studies: Imagery Loss due to Brain Lesion

Neuropsychological research has documented cases of imagery loss due to brain damage (see Zago et al., 2011 for a comprehensive list of patients and symptoms). Most of these cases show close resemblance between perceptual and imagery deficits, advocating for shared neural substrates of imagery and perception (Farah, 1988; Dijkstra, Bosch, & Gerven, 2019). Nonetheless, in some cases imagery might be intact while perception is impaired and vice versa, demonstrating a possible dissociation of visual perception and imagery. Collectively, such evidence implies that the functional neuroanatomy underlying visual perception and imagery is overlapping but not identical (Behrmann, Moscovitch, & Winocur, 1994; Bartolomeo, 2002; Dijkstra et al., 2019).

On the basis of the then-new but nowadays common distinction between the ventral and dorsal pathways in the visual system (Ungerleider & Mishkin, 1982), and taking into account the overlap of the neural substrates of visual perception and visual imagery (Farah, 1988), Farah and colleagues (Levine et al., 1985; Farah et al., 1988) suggested that the two aspects of visual imagery — object and spatial — are also likely to be implemented along the ventral ("what") and dorsal ("where") visual pathways in the same way as their corresponding aspects of perception. Brain damage to the ventral pathway impairs *imagery* performance that involves the visualization of an object's colorful, pictorial appearances and object identity, such as faces. In contrast, dorsal (parietal) damage may lead to impairments in spatial *imagery* performance, such as mental rotation or drawing a map (Farah, 1988). Levine, Warach, and Farah (1985) reported a pair of patients who provided evidence for a possible double dissociation of object and spatial imagery. One patient suffered from a left-sided occipito-temporal and right-sided fronto-temporal lesions, and the other had a bilateral occipito-parietal lesion. The first patient demonstrated pronounced object identification difficulties and was unable to describe or to draw the appearance of objects, faces, or animals from memory, whereas drawing a map or describing landmark locations remained intact. For the second patient, the pattern was inverse. At least two more distinctive cases of selectively impaired spatial but not object imagery after a parietal lesion were reported in the subsequent literature: patient RT (Farah & Hammond, 1988) and patient MG (Morton & Morris, 1995), who both showed difficulties in mental rotation but performed well when imagining color and shape (Bartolomeo, 2002).

Notably, a right parietal lobe lesion often leads to unilateral neglect, as was also the case for patient RT (Farah & Hammond, 1988). The unilateral neglect may manifest not only in the perceptual domain but also be imaginal, or representational (Bartolomeo, 2002), as in 15 patients who were studied by Bisiach, Capitani, Luzzatti, and Perani (1981) and were inclined to imagine mostly those details of a familiar city location (Piazza del Duomo in Milan) that were on their right but not left side, given a specific imaginary viewpoint. One may suppose that hemi-neglect may be accompanied by more profound spatial imagery deficits. Such deficits would be selective (i.e., not accompanied by object imagery difficulties) when no additional temporal lesion is engaged. Indeed, Palermo, Piccardi, Nori, Giusberti, and Guariglia (2010) showed that patients with right-hemisphere damage and perceptual as well as representational neglect had difficulties with the mental paper folding task and imagery navigation tasks while performing reasonably well on a vividness task which requires imagining an everyday object.

Remarkably, while evidence for spatial imagery deficit in patients with unilateral neglect is clear, Palermo et al. (2010) mentioned that, of their patients, "none spontaneously reported a deficit in mental imagery" (p. 121). This remark demonstrates the paradox that spatial imagery deficits may not be labeled and discussed as mental imagery deficits in the visual imagery literature. This is likely due to a commonly used assessment of spatial imagery by tasks that measure spatial performance but not spatial vividness, and the assessment tapping into only object imagery vividness which may remain within a normal range in patients with impaired spatial imagery. This problem in the imagery literature may also be illustrated by the fact that the list of imagery loss cases by Zago et al. (2011) includes only one patient with a purely spatial deficit explicitly recognized as an imagery deficit in the original paper (the second case described in Levine et al., 1985). But spatial imagery deficits are not rare, as may be seen from the literature cited above. It rather seems that spatial imagery deficits are neglected by imagery researchers because object imagery deficits are more obvious and "vivid" in subjective experience, and supposedly are more likely to be reported by patients and by researchers, even when both imagery subsystems are affected. The description by Brain (1954) of a patient who mainly complained about the loss of pictorial (object) imagery while having both spatial and object imagery impaired provides an example:

> When seen for the first time five years after the accident, the patient complained that what he called his "picture memory" was gone. He could no longer form a visual image of his first wife nor of his second wife,

> nor, indeed, of anyone he knew. ... As a builder's manager he found it a handicap as he could not visualize a plan or an elevation, in consequence of which he had to keep referring to the specifications when dealing with a house. ... Similarly if he was going on a journey by car, although he had travelled on the same route before, he would have to look it up afresh on maps and retrace it because he could no longer picture the route... (p. 288).

Neuropsychological data on acquired aphantasia mostly are represented by a thorough assessment of the renowned aphantasic individual, MX, who complained about the loss of his ability to visualize the faces of family and friends as well as buildings, and about losing visually rich dreams (Zeman et al., 2010). At the same time, MX performed normally in comparison with control participants on a variety of *object* imagery performance tasks (e.g., requiring judgements about colors or visual details of animals' tails, letter shapes, and the features and emotional expressions of faces), although his brain activation during these tasks measured as with fMRI deviated from a pattern typical for controls. His spatial imagery accuracy (assessed with mental rotation and Brooks tasks) was in the normal range. Yet, the response time was considerably greater than typical, and the pattern of reaction time vs. rotation angle dependence was somewhat different from the typically found linear function (which is a robust finding in mental rotation experiments, interpreted as evidence for the analogous format of mental imagery preserving spatial information; Shepard & Metzler, 1971). MX's task performance was also impaired during articulation suppression. Overall, this evidence indicates strategic changes such as relying on verbal rather than visual processing (Zeman et al., 2010). Similar inferences were made about a congenitally aphantasic individual, AI, who performed as well as controls but qualitatively differently from them in working memory and imagery tests (Jacobs et al., 2018).

Thus, aphantasia research has demonstrated that subjective imagery deficits may not be accompanied by obvious changes in perceptual imagery, visual imagery, or visual memory task performance. This led to a conclusion about the possible dissociation between phenomenological experience of visual imagery and successful performance on imagery tasks which may be rooted in either the possibility of visual imagery tasks to be solved by alternative non-imagery strategies or the possibility of non-conscious visual imagery work (Zeman et al., 2010). Given the proposed function of the ventral vs. dorsal processing stream as "vision for perception" vs. "vision for action" (Goodale & Milner, 1992), and that the latter operates predominantly without conscious awareness (Norman, 2002), it is no surprise that people may be more sensitive to alterations in object rather than spatial imagery subjective experience. To date, it is unknown whether the hypothetical loss of conscious access to image representations may occur selectively for the object and spatial visual imagery subsystems.

Interestingly, MX's altered subjective experience was paralleled by his altered fMRI data, thus providing hints that the phenomenological dimension of imagery may be associated with its own neural correlates that are potentially separate from those of imagery task performance. The question of neural correlates of imagery vividness has been addressed in the neurotypical population in several studies using VVIQ and object-based tasks (Amedi, Malach, & Pascual-Leone, 2005; Cui, Jeter, Yang, Montague, & Eagleman, 2007; de Araujo et al., 2012; Rumshiskaya, Vlasova, Pechenkova, & Mershina, 2013; Fulford et al., 2018). This body of research demonstrated that VVIQ score positively correlates with greater activation in the occipital lobes (primary and extrastriate visual cortices), medial temporal lobe, and precuneus, but negatively correlates with activation in the superior temporal gyrus and frontal areas (see Fulford et al., 2018, for a review). In light of the spatial aphantasia hypothesis, the search for neural correlates of spatial imagery vividness (e.g., measured by OSVIQ or VOSI tools) seems to be a promising direction of future research.

Spatial vs. Object Aphantasia: Research Questions and Future Directions

The reviewed evidence from psychometric correlational studies and neuropsychological evidence supports the claim that spatial aphantasia may be a behaviorally and neurologically separate type of imagery loss. Neuropsychological studies have shown that spatial imagery can be selectively impaired, independent of object imagery. The psychometric literature describes individual variability in spatial imagery, and indicates that critically low spatial imagery (often associated with learning difficulties in STEM domains) is not necessarily associated with low object imagery (and difficulties in art domains).

Even though the existing evidence implies the possibility of separate types of mind blindness (object and spatial aphantasia), measurement tools and theoretical conceptualization in this research area remains rather limited. A serious challenge for research on object and spatial aphantasia is posed by the dissimilarity of their nature and traditions in assessment approaches (subjective for object vs. performance for spatial imagery), so that it is hard to find comparable instruments and methods to examine them simultaneously.

Research has indicated that variability in object and spatial imagery does not follow the same pattern, which further supports their distinction. In particular, the distribution of object and spatial scores on OSIQ is different: people tend to rate themselves higher on object imagery than on spatial imagery (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009; Chabris et al., 2006) and high object vividness is more frequent than high spatial vividness (Blazhenkova, 2016). This is consistent with other reports (e.g., Betts, 1909; for more see Faw, 2009) showing that the mean of (object) imagery abilities on a low-high continuum is much closer to the high, so that up to 30 % of individuals reported strong imagery, while only about 2 % reported weak or absent imagery. There are no published data of such a distribution for spatial vividness dimension. Besides, multiple qualitative differences have been proposed between object vs. spatial imagery across various dimensions: perceptual vs. amodal, conscious vs. unconscious (Norman, 2002; Palmiero et al., 2019); holistic vs. sequential, emotionally-bounded vs. emotionally-neutral (Blazhenkova & Kozhevnikov, 2010).

This problem of measurement is complicated by the non-unitary nature of spatial and object imagery constructs, as each of them consists of different sub-abilities. In particular, pictorial (object) visual imagery includes the processing of colors, shapes, faces and letters, each of which may be impaired independently (Goldenberg, 1993). Spatial ability can as well be further divided (McGee, 1979); for example, into egocentric vs. allocentric components (Hegarty & Waller, 2004; Kozhevnikov, Motes, Rasch, & Blajenkova, 2006; Zacks, Vettel, & Michelon, 2003), or location vs. location transformation (Thompson, Slotnick, Burrage, & Kosslyn, 2009), or a motor coordination component may be taken into account (McAvinue & Robertson, 2008). Since the prevalent traditions in aphantasia research predominantly employ mental rotation tests to assess spatial visualization and the VVIQ to assess object visualization, an elaborate investigation, using a variety of spatial imagery measures, should be devoted to specific changes in spatial imagery performance in cases of object aphantasia, and vice versa for object imagery performance in cases of spatial aphantasia.

There might be a difference between the visibility of object and spatial aphantasia. Spatial imagery deficits have not attracted as much attention as the object imagery deficits described in recent aphantasia research, and they often are not labeled as imagery deficits in the neuropsychological literature. As noted in the review of neuropsychological data above, individuals with simultaneous spatial and object imagery deficits mostly complain about their object imagery impairments. This may explain the neglect of spatial imagery vividness by aphantasia researchers. Also, as discussed above, there are parallel lines in imagery research coming from different traditions of imagery conceptualization and measurement, and different aspects of imagery receive different attention in these diverse areas. Thus, some studies (including the milestone study by Farah et al., 1988) used somewhat different terminology; that is, object imagery was called "visual", but spatial was not called "visual", even though the tasks labeled as "spatial" required visual imagery. Indeed, spatial processing may not be entirely visual, and there is evidence that blind people are capable of performing some spatial tasks such as mental rotation (Barolo, Masini, & Antonietti, 1990).

In the psychometrics literature, the "presence" or "absence" of imagery has been traditionally identified by questionnaires assessing object but not spatial imagery vividness, while the lack of spatial imagery was commonly identified by objective performance measures such as mental rotation. Until recently, an inability to perform visual-spatial tasks was not related to subjective imagery experiences. Historically, this also led to the wrongful conclusion that experience and ability are not connected. However, with the correct choice of measures, self-reports do predict objective performance. For example, validation studies with VOSI and OSIVQ questionnaires showed that abilities and phenomenological experiences are correlated when they assess the same construct. Similarly, the study with art and science professionals (Blazhenkova & Kozhevnikov, 2010) demonstrated the consistency between the subjectively reported object imagery experiences and enhanced object imagery performance in visual artists, and the consistency between the subjectively reported spatial imagery experiences and enhanced spatial imagery performance in scientists. Currently, in the field of imagery research, there is a critical need for developing measurement tools that assess spatial imagery subjective experience measures and object imagery performance measures. Moreover, there is a need for finer tools that assess variability in different imagery processes (e.g., generation, maintenance, inspection, and transformation; Kosslyn et al., 2006) across both object and spatial dimensions, such as spatial imagery inspection or object imagery transformation (e.g., color mixing). Such instruments would be very useful for the identification and study of object and spatial aphantasia; moreover, they will be practical for broader imagery research as well as clinical, educational, and other applied fields.

A number of theoretical questions remain unanswered. First of all, little is known about the variability of spatial imagery in people with object aphantasia as well as the variability of object imagery in people with spatial aphantasia. Currently, there is no sufficient evidence for how low imagery abilities in one domain affect the other: whether it is intact, altered, strengthened, or weakened. For example, data from patient MX may be interpreted as if the loss of pictorial object imagery does not affect spatial imagery performance or as if it is actually the cause of the noted change in mental rotation strategy (Zeman et al., 2010). There is also evidence that both systems can be simultaneously impaired (as in cases described by Brain, 1954); however, it is not yet known whether these impairments are independent (i.e., explained by selective brain damage) or whether the loss of one ability may result in the impairment of the other (and if this is the case, it is not known whether the impairment is on the level of altered strategy or more basic cognitive and neural mechanisms). There is an indication that enhanced imagery in one (object vs. spatial) domain may lead to weakened imagery in the other domain (Kozhevnikov, Blazhenkova, & Becker, 2010). This possible trade-off between the two abilities is supported by evidence that aphantasic individuals with object imagery loss tend to specialize in STEM domains that require profound spatial imagery (Crowder, 2018). Also, Khooshabeh and Hegarty (2008) found that during a mental rotation spatial task, individuals with low spatial imagery (as compared to individuals with high spatial imagery) were more likely to represent color, which is a characteristic of object imagery.

An imagery deficit in one domain may lead to compensatory strategies in the other domain (altered processing). More research is needed to examine the strategies used during spatial imagery tasks in individuals with (object) aphantasia, and vice versa during object imagery tasks in individuals with spatial aphantasia.

Moreover, it is not clear whether object and spatial aphantasic individuals experience difficulties in other cognitive and social domains such as verbal intelligence or theory of mind. The compensatory strategic changes can extend beyond imagery tasks and manifest in other domains as well. For example, Keogh and Pearson (2017) have shown that low-vividness (object) imagers probably rely more on semantic information in working memory tasks. This idea is consistent with Olivetti Belardinelli and colleagues (2009), who found that low-vividness imagers activated a different neural network compared to high-vividness imagers, probably because, in their attempt to generate mental images, they relied on semantic representations rather than on sensory-modality representations.

Even though there are some studies reporting that individuals with aphantasia have distinct cognitive profiles (e.g., in terms of their memory, autonomic response to emotional narratives, or implemented strategies), different aspects of their cognitive functioning (e.g., verbal processing, susceptibility to illusions, and multisensory experiences) as well as other factors such as personality correlates, sex, and age differences are yet to be comprehensively investigated.

A related intriguing research question concerns the possible dissociation between perceptual abilities and imagery experiences in individuals with object and spatial aphantasia. Unlike the majority of patients who acquired imagery impairments as a result of brain lesion and suffered from difficulties in both imagery and perception, in aphantasics perception may remain intact as in the case of MX (Zeman et al., 2010) and some other aphantasics (Dijkstra et al., 2019). Given that no brain lesion is documented in these aphantasia cases, questions may arise as to whether a specific deficit of imagery but not perception is characteristic for aphantasia, and to what extent the origins of imagery impairments are similar in aphantasics and brain lesion patients.

The origins of spatial aphantasia is another important unexplored question. Is it always acquired, or can it be congenital and run in families in a way similar to object aphantasia (Zeman et al., 2017)? The latter seems plausible, given that spatial abilities rely on a genetic component (McGee, 1979). The proportion of congenital and acquired cases is yet undetermined for any type of aphantasia. It is also unknown how and to what extent object and spatial imagery may be trained in individuals with spatial and object aphantasia.

Neuroimaging research may also help to answer the question of any specific neural correlates of congenital and acquired spatial vs. object aphantasia. Currently, even for the object dimension, little is known about the possible differences in symptoms of acquired vs. congenital aphantasia. Creating a detailed description of the neural correlates of both subjective experience and imagery performance in object and spatial aphantasic and hyperphantasic individuals would be crucial for understating extreme, object and spatial, imagination.

Implications

There is a great public interest in aphantasia as well as an eagerness for the research participation of individuals with (object) aphantasia. As is evident from reports of these individuals, though they experience a number of difficulties due to their extremely low or absent imagery, many of them live "normal" lives, successfully perform in various professions (surprisingly, including visual arts), engage in healthy social relationships, and may even use their aphantasia as an opportunity. Many of them have lived for years without being aware of their unusual imagery characteristics until the recent popularization of research findings on imagery loss and the introduction of the term "aphantasia". Less is known about individuals with spatial aphantasia, their life experiences, their cognitive strengths and weaknesses, and what kind of possible compensatory strategies they may develop. It seems that object imagery is more important for everyday life (which is also indicated by its skewed distribution in the population towards the higher end), while spatial imagery may be important only for some tasks. According to interviews with natural scientists and engineers who tend to be high spatial visualizers, they use it from time to time, mostly for technical problem solving (Blazhenkova & Kozhevnikov, 2010). It may be less likely that spatial aphantasia would attract a similar public interest since it may be less essential for everyday life. Depending on a specific deficit of spatial imagery, individuals with spatial aphantasia may experience difficulties in STEM domains, motor coordination, or large-scale navigation. It is important to note that even though aphantasia is sometimes referred to as a "condition", there is no such clinical diagnosis: it reflects a different way of experiencing life, rather than a disability. Research on this intriguing variability in imagery experiences and different forms of aphantasia will have direct applications for improving the quality of life for people with aphantasia. Theoretical understanding of the mechanisms underlying these imagery deficits (or abundance in case of hyperphantasia) and proper measurement methods will help to create best practices for imagery training techniques, implementing efficient ways of information processing and learning, as well as developing coping strategies.

Conclusions

Recent aphantasia research is focused on people who report an absence of visual imagery, or "blind mind's eye". In light of the dissociation between object and spatial visual imagery abilities supported by cognitive and neuroscience data, we suggest that there are actually two "mind's eyes", and each of them can be blinded. Currently, aphantasic individuals are identified on the basis of object imagery vividness assessment, while spatial imagery loss remains neglected. While contemporary research on aphantasia has attended to extremely low object imagery, research on the cognitive and neural correlates of low spatial visualization is rather limited. The identification and in-depth description of spatial aphantasia as well as of spatial hyperphantasia would require theoretical and methodological advances in the targeted assessment of spatial and object imagery loss. Promising research directions in this area include the search for origins of the proposed spatial aphantasia, its neural and cognitive correlates, related deficits and compensatory strategies, as well as the interplay between object and spatial imagery strengths and weaknesses.

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ДИСКУССИЯ

Два типа афантазии: объектная и пространственная?

Олеся Блаженкова
Факультет искусств и социальных наук, Университет Сабанджи, Стамбул, Турция

Екатерина Печенкова
НУЛ когнитивных исследований, Национальный исследовательский университет «Высшая школа экономики», Москва, Россия

Аннотация. Индивидуальные различия в области воображения с давних пор привлекали внимание философов, педагогов и психологов. Со времен Аристотеля предполагалось, что воображение — универсальная способность, присутствующая у каждого человека. Когда Ч. Гальтон впервые начал измерять яркость (живость) образов представления, он обнаружил, что у некоторых людей, согласно их субъективным отчетам, воображение отсутствует. В современной психологической литературе недавно был введен термин «афантазия», который обозначает неспособность формировать мысленные образы, или «невидящий внутренний взор» (Zeman et al., 2015). Мы утверждаем, что может существовать более одного типа афантазии. Данные как психометрических и экспериментально-психологических, так и нейропсихологических исследований указывают на необходимость различения объектного и пространственного зрительного воображения (т. е. мысленного представления изобразительных свойств объекта, таких как цвет, форма, яркость, текстура поверхности, или же его пространственных характеристик — местонахождения, взаимного расположения с другими объектами, пространственных преобразований). При рассмотрении зрительного воображения как индивидуально выраженной способности обнаруживается, что она не едина: люди, у которых развито объектное воображение, не обязательно преуспевают в задачах, требующих пространственного воображения, и наоборот. В данной статье мы показываем, что, поскольку афантазия обычно выявляется на основе низких баллов по Опроснику живости зрительного воображения (Vividness of Visual Imagery Questionnaire, VVIQ), который диагностирует только объектное воображение, то можно заключить, что афантазия, как она обычно описывается сейчас, — это дефицит только объектного воображения, а не общее нарушение зрительного воображения. Мы предполагаем, что пространственная афантазия (неспособность представлять пространственные свойства и отношения) может быть отдельным типом нарушений зрительного воображения. У людей с пространственной афантазией не обязательно должны наблюдаться также и проблемы с объектным воображением. Мы обсуждаем возможные направления будущих исследований, которые позволили бы обратиться к изучению проявлений пространственной афантазии в поведении человека и в нейрофизиологическом плане, а также соотношение объектной и пространственной афантазии.

Контактная информация: Олеся Блаженкова, olesya@sabanciuniv.edu, Faculty of Arts and Social Sciences, Sabanci University, Orta Mahalle, Üniversite Caddesi No: 27 Tuzla, 34956 Istanbul, Turkey; Екатерина Печенкова, evp@virtualcoglab.org.

Ключевые слова: афантазия, гиперфантазия, индивидуальные различия в воображении, объектное воображение, пространственное воображение, зрительное воображение, способность к визуализации

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Статья поступила в редакцию 6 ноября 2019 г. Принята в печать 28 декабря 2019 г.

Литература

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