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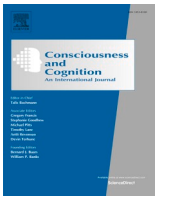

Review article

Aphantasia and involuntary imagery

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ABSTRACT

Aphantasia is a condition that is often characterized as the impaired ability to create *voluntary* mental images. Aphantasia is assumed to selectively affect voluntary imagery mainly because even though aphantasics report being unable to visualize something at will, many report having visual dreams. We argue that this common characterization of aphantasia is incorrect. Studies on aphantasia are often not clear about whether they are assessing voluntary or involuntary imagery, but some studies show that several forms of involuntary imagery are also affected in aphantasia (including imagery in dreams). We also raise problems for two attempts to show that involuntary images are preserved in aphantasia. In addition, we report the results of a study about afterimages in aphantasia, which suggest that these tend to be less intense in aphantasics than in controls. Involuntary imagery is often treated as a unitary kind that is either present or absent in aphantasia. We suggest that this approach is mistaken and that we should look at different types of involuntary imagery case by case. Doing so reveals no evidence of preserved involuntary imagery in aphantasia. We suggest that a broader characterization of aphantasia, as a deficit in forming mental imagery, whether voluntary or not, is more appropriate. Characterizing aphantasia as a volitional deficit is likely to lead researchers to give incorrect explanations for aphantasia, and to look for the wrong mechanisms underlying it.

1. Introduction

Aphantasia is a condition frequently characterized as the impaired ability to create *voluntary* mental images. Mental images are here understood as experiences that resemble perceptual experiences in any sensory modality, but which occur in the absence of the relevant stimuli. Thus Zeman et al. (2015), in the paper that coined the term "aphantasia", proposed "the use of the term 'aphantasia' to refer to a condition of reduced or absent voluntary imagery" (p. 379). Pearson (2019), similarly, characterizes individuals with aphantasia as lacking "the ability to voluntarily form mental images" (p. 624). Pounder et al. (2022) note that "[a]phantasia describes the experience of individuals who self-report a lack of voluntary visual imagery" (p. 180). Monzel, Keidel, & Reuter (2021) state that "[a]phantasia is the condition of reduced or absent voluntary imagery". Bainbridge et al. (2021) claim that aphantasia is "defined by an inability to create voluntary visual mental images" (p. 160). For similar characterizations, see Zhao et al. (2022), Palermo et al. (2022) and Jacobs et al. (2018). A few studies remain neutral about whether aphantasia affects voluntary images selectively, but they tend to characterize it as the lack of *visual* imagery, which is problematic (see discussion below) (cf. Keogh & Pearson, 2021; Wicken et al.,

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2021).

Aphantasia is often assumed to not affect involuntary imagery mainly because, even though aphantasics report being unable to visualize at will, many individuals with aphantasia report having visual dreams. In Zeman et al. (2015)'s initial study, 17 out of 21 participants who reported poor visual images said that they had visual dreams. In a more recent study, Zeman et al. (2020) confirmed that most aphantasics report having visual images in dreams (63.4 %, in a study with 2,000 aphantasics). Given that dreams are a paradigmatic example of an involuntary process, this observation is taken to suggest that involuntary images are generally preserved in aphantasia. Thus, Dijkstra et al. (2019) note that "this suggests a dissociation between the involuntary, automatic simulation underlying perception and dreaming and the deliberate, conscious simulation that underlies imagery" (p. 430). Whiteley (2021) notes that "[t]he aphantasia studies notably suggest a strong neurophysiological dissociation between voluntary and involuntary forms of mental imagery, with only the capacity for the former being lost by the majority of aphantasic subjects." (p. 2113). And Milton et al. (2021) also take it that the fact that many aphantasics can have visual dreams suggests "that they are capable of experiencing imagery when the requirement for voluntary imagery generation is removed" (Milton et al., 2021, p. 11).

The assumption that aphantasia selectively affects voluntary imagery is central to much of the literature on aphantasia. Cavedon-Taylor (2022), for instance, explicitly argues that aphantasia does not affect involuntary imagery and maintains that aphantasia should be characterized as a deficit in voluntary imagery. Whiteley (2021) relies on this assumption to argue against a conception of dreams that takes them to be imaginative agential experiences. Finally, this assumption is also important for Nanay's (2021b) recent account of aphantasia, as he claims that aphantasics may use unconscious involuntary images to solve working memory tasks.

Importantly, there is a general tendency in the literature to treat involuntary imagery as a unified kind, which, given the case of dreams, is said to be generally preserved in aphantasia. We here suggest that involuntary imagery may come in different forms (such as imagery triggered by reading, intrusive images, pseudo-hallucinations and afterimages) and from the presence of imagery in dreams in many aphantasics we cannot infer the presence of the entire class of involuntary images, as is usually done. Contrary to the current consensus, which treats aphantasia as a volitional deficit, we argue that the characterization of aphantasia as a deficit in voluntary images is incorrect. It does not take into account the results of studies of aphantasia that assess, though not always explicitly, other forms of involuntary images. These studies indicate that several forms of involuntary imagery, which have not been explicitly noticed in the literature, are also impaired in aphantasia.

Some researchers do recognize that involuntary imagery can be affected in aphantasia, but this is mainly because some aphantasics don't have visual dreams (Nanay, 2021b; Blomkvist, 2023). There is then an implicit assumption that we should infer the presence or absence of involuntary imagery from the presence or absence of dreams. This, we will argue, is problematic, for it ignores other forms of involuntary imagery. In addition, despite this occasional recognition, aphantasia continues to be explicitly characterized as a voluntary imagery deficit.

Even though the literature on aphantasia relies heavily on the distinction between "voluntary" and "involuntary" imagery, what actually distinguishes one from the other is not made explicit, and many studies are not clear about which form of imagery is being tested. The distinction is typically drawn by means of paradigmatic examples: forming an image of an apple after being asked to do so is taken to be an example of a voluntary process, whereas mental images formed in dreams, or in flashback, are taken to be involuntary (cf. Fazekas, Nanay, & Pearson, 2021; Zeman, 2015; Nanay, 2021a). Involuntary images are sometimes said to be automatic (Pearson & Westbrook, 2015), or spontaneous (Fazekas et al., 2021), and voluntary ones are said to be under one's control (Pearson & Westbrook, 2015), but these notions are also not clarified.

We do not propose to define these notions here. Instead, we propose a practical way of distinguishing voluntary and involuntary images in the context of psychological studies: a study that explicitly asks participants to form mental images, and investigates how that affects performance in a task, counts as one that investigates *voluntary* imagery. Subjects presumably intend to follow the instructions, and if able to, they form a mental image. In contrast, studies in which no explicit instructions to form images are given, but in which we have reason to believe that images are formed without the subject intending to, can be said to assess involuntary imagery. With this clarification in mind, we will see that aphantasics differed from controls in a number of studies that investigated, albeit not explicitly, involuntary imagery. Given the differences between aphantasics and controls, we will argue that these forms of involuntary imagery (such as imagery triggered by reading and pseudo-hallucinations) are also impaired in aphantasia.

It is not only in regard to the voluntary/involuntary aspects of mental imagery that the current literature on aphantasia has been led astray. There are two other respects in which common characterizations of aphantasia are problematic. First, there is no agreement as to the extent to which imagery formation is said to be affected in aphantasia. While some consider aphantasics to be those with reduced or absent mental imagery (Zeman et al., 2015), others take them to lack mental imagery entirely (Pounder et al., 2022). Frequently, within the same study, aphantasia is explicitly characterized as a condition in which subjects completely lack imagery, while the participants recruited include both those who report reduced visual imagery and those who report absent visual imagery (as measured by the VVIQ; cf. Keogh & Pearson, 2018). Lumping together individuals with reduced and absent voluntary mental imagery can be problematic, though, as some studies suggest that significant differences in task performance, e.g. mental rotation and susceptibility for pseudo-hallucinations, can be found between these two groups (cf. Pounder et al., 2022; Reeder, 2022; Zeman et al., 2020).

A second issue concerning common characterizations of aphantasia is that it is often considered a deficit in *visual* mental images (cf. Milton et al., 2021; Bainbridge et al., 2021). However, studies indicate that other modalities of mental imagery can also be affected in aphantasia (Dance et al., 2021; Dawes et al., 2020). Hinwar & Lambert (2021) suggested the coinage of a new term, "anauralia", for the lack of auditory imagery. But Monzel, Mitchell et al. (2022) argue for a more inclusive definition of aphantasia, which remains neutral about which modality is affected.

Our claim in this paper is that something similar holds for the voluntary/involuntary distinction. Given the studies that will be reviewed in what follows, and the recognition that involuntary imagery may come in different forms, it is better to characterize

aphantasia as being neutral about whether voluntary or involuntary imagery is affected. To be sure, the inclusion of the qualification of "voluntary" in the characterization of aphantasia is not universal, and some omit it (cf. Keogh & Pearson, 2021; Wicken et al., 2021). But the reasons for the omission are not made clear, and the fact that other forms of involuntary images, aside from dreams, can be affected in aphantasia is often overlooked. Watkins (2018), for instance, suggests a distinction between total aphantasia, which affects both voluntary and involuntary imagery, and voluntary aphantasia, which affects only voluntary forms. However, his terminology has the problem of assuming that involuntary imagery forms a unified category that is either present or absent in aphantasia. And at present, it is unclear whether there really are forms of aphantasia that only affect voluntary imagery, leaving all forms of involuntary imagery intact. For even if some aphantasics have, for instance, visual dreams, it could be that they have other forms of involuntary imagery that are impaired.

In what follows, in section 2, we start by reviewing two of the most influential studies that assess the lack of voluntary imagery in aphantasics without relying solely on self-report. We then review, in section 3, four studies that, in our view, implicitly investigated involuntary images in aphantasia, and found differences between aphantasics and controls. But involuntary images may come in different forms, and some studies explicitly claim that certain forms of involuntary images are preserved in aphantasia. We consider these in sections 4 and 5. In section 4, we critically assess a recent study that claims to show that associative involuntary visual images are preserved in aphantasia. The evidence available is insufficient to establish the presence of this form of involuntary imagery in aphantasia. In section 5, we consider and criticize Cavedon-Taylor's claim that aphantasics have intrusive involuntary images. In section 6, we report the results of a new study about afterimages in aphantasia, which suggest that these tend to be less intense in aphantasics than in controls. In section 7, we revisit the case of dreams in aphantasia, in order to argue that it does not support the volitional account of aphantasia. In section 8, we consider flashes of imagery in aphantasia. We end, in section 9, by considering some implications of the claim that aphantasia also affects involuntary images, and by suggesting that aphantasia should be viewed as a deficit in mental imagery, whether voluntary or not.

2. Aphantasia and voluntary images

Aphantasia is typically identified, and operationally defined, by means of the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973).[1] In the VVIQ, subjects are instructed to think about different things or scenarios (e.g., a relative or friend, or a country scene), and "to consider carefully the picture that comes before your mind's eye", rating different aspects of the picture from 1 ("No image at all, you only 'know' that you are thinking of the object") to 5 ("Perfectly clear and vivid as real seeing"). An individual counts as an aphantasic, for the purposes of various studies, if they score extremely low on the VVIQ. The VVIQ assesses voluntary imagery, given that subjects form the intention to imagine and do so if able to.[2] There is, however, no consensus on how low one needs to score to count as an aphantasic. Scoring on the VVIQ ranges from 16 to 80. In Keogh et al. (2021), aphantasics were those who scored lower than 32. In Zeman et al. (2020), aphantasics were "defined as VVIQ scores of 16-23/80" (p. 428). Zeman et al. (2020) also distinguish between extreme aphantasia (minimum score on the VVIQ) and moderate aphantasia (score between 17 and 23), and some differences were found between the two groups (Zeman et al., 2020 supplementary materials; see also Pounder et al., 2022, where considering extreme vs. moderate aphantasia revealed a difference in reaction time in a mental rotation task).

There are by now a number of studies that revealed behavioral differences between aphantasics and imagers (i.e., people who can form mental images). They support the idea that there is a genuine difference in the imagery experiences of aphantasics and imagers, and not merely in the way they describe their experiences (as Schwitzgebel (2008) suggests). The main studies assessed voluntary imagery, as they involved explicit instructions for participants to form mental images. Let's consider two of the most influential studies.

The first is Keogh and Pearson (2018; replicated in Keogh and Pearson, 2024), which was one of the first studies to provide validation for aphantasics' reports in an objective way. They investigated whether forming a visual image could prime perception in aphantasics, as it does in controls. In the task, subjects were instructed to form a mental image either of a red horizontal patch or of a green vertical patch. After that, they were presented with a green vertical patch in one eye and a red horizontal patch in the other eye (see Fig. 1a). When different images are presented to different eyes, instead of overlapping, one image dominates perception, while the other is suppressed (a phenomenon known as binocular rivalry). In individuals who can form visual images, what they were asked to imagine tended to influence which image dominated perception. If they were asked to imagine a red horizontal patch, for example, that is what they were most likely to see when different images were presented to each eye. They found, however, that significantly fewer individuals from the aphantasia sample showed priming effects, and the group mean priming effect was no different from chance. Mental images did not prime perception in most aphantasics.

In another study, Kay et al. (2022) investigated whether imagining a bright or a dark triangle can affect the size of the pupils in imagers and in aphantasics. They found that in people who can imagine, pupils were larger when they imagined a dark triangle than when they imagined a bright triangle, similar to what happens in perception. Aphantasics, however, showed the same pattern of pupil

[1] Although aphantasia is often understood as a deficit in visual imagery, it can, as noted above, affect imagery across multiple domains (Dance et al., 2021; Dawes et al., 2020).

[2] Thus, one issue with using the VVIQ to characterize aphantasic individuals is that it only looks at voluntary visual imagery. Given that the VVIQ does not assess involuntary imagery, it does not give us a full picture of the imagery deficits involved in aphantasia, and, as Blomkvist (2023) notes, it leaves individuals with other deficits in mental imagery out of the sample of several studies. For the purposes of assessing involuntary imagery in aphantasia, a better classification tool should be developed.

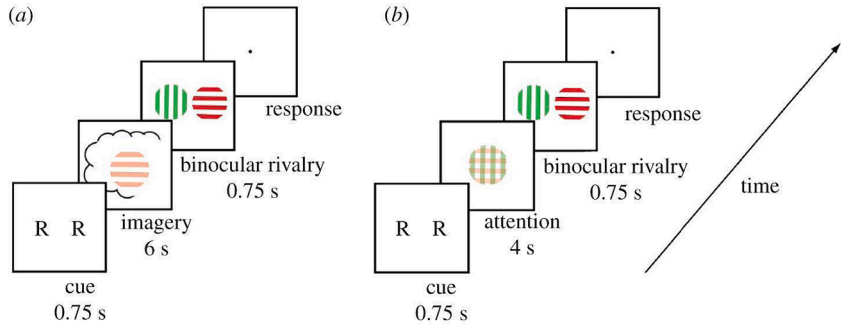

Fig. 1. (a) imagery task; (b) attention task (from Keogh and Pearson, 2021).

dilation in perception, but not when they were asked to imagine a bright and a dark triangle.

These are studies that are taken to validate aphantasics' report of lack of visual images in a more objective way (Krempel, 2023). And both involved tasks in which participants were explicitly instructed to form visual mental images. This suggests that what is being assessed is voluntary visual images. To the extent that they found significant differences between aphantasics and controls, they can be said to validate the self-reports of a deficit in voluntary visual images.

3. Aphantasia and involuntary images

Not all studies that investigate aphantasia involve explicitly asking participants to form visual mental images. In fact, many do not. In our view, at least four of these studies can be interpreted as having implicitly assessed *involuntary* imagery.

Keogh and Pearson (2021) found differences in perceptual priming between aphantasics and controls not only in a task that involved explicit instructions for subjects to form mental images (which replicated their 2018 study, mentioned in section 2), but also in an attention task that did not involve explicit instructions to imagine. They presented participants with a plaid stimulus, made of red horizontal and green vertical lines, and instructed them to attend either to the red horizontal or green vertical lines in it. The plaid stimulus could be very bright or very weak and, in some trials, no plaid stimulus was actually presented. Participants, however, were told that the plaid stimulus was always there, however "sometimes they might find it hard to see, but should try to attend to the cued image even if they were unable to see it" (p. 2). After attending to the cued image for 4 s, participants were immediately presented binocularly with a red horizontal image to one eye and a green vertical image to the other (see Fig. 1b). They found that, for imagers, attention to a feature of a stimulus primed dominance in subsequent binocular rivalry, including in the trials where no image was actually present, which they referred to as trials involving attentional templates. Aphantasics, on the contrary, only exhibited priming significantly greater than chance when the stimulus was very bright.[3]

A natural interpretation of these results, contemplated by the authors, is that mental images were driving the effect in the attentional templates trials in imagers, priming perception when no stimulus was actually present. Support for this interpretation comes from one of their experiments, in which they made the background screen luminous (instead of black) in the attention task. This significantly reduced priming in the binocular rivalry in imagers in the attentional template trials, but not in the trials in which the stimulus was present. Importantly, a luminous background also disrupts priming in the imagery task, where participants are instructed to imagine (Pearson et al., 2008). This suggests that there is likely a common cause that drives the effect of perceptual priming in the attentional templates trials and in the imagery trials, and a good candidate here is that mental images are involved in both cases.

But importantly, though the authors say nothing about this, the images formed in the attentional template trials are likely involuntary.[4] After all, participants were not instructed to form an image in the attention task, but were instead instructed to attend to the cued image. If participants intentionally imagined the plaid stimulus, they would have gone against the instructions they received. If anything, they were likely making an effort to *see* the stimulus, which they were told was present but was hard to see. In so doing, they likely involuntarily imagined the stimulus. These involuntary visual mental images then primed perception in subsequent binocular rivalry.

Now, if aphantasia were a deficit that affected voluntary imagery exclusively, leaving involuntary images intact, we would have expected aphantasics to have shown the same kind of priming that controls did in the attentional templates trials. In trying to see the

[3] Interestingly, controls showed significantly stronger priming than aphantasics also when the stimulus was very bright (though only in their experiment 3, but not in experiment 2). It could be suggested that the difference in priming between aphantasics and controls is due to aphantasics having a deficit in attentional processes. However, if aphantasics had a general attentional deficit, they shouldn't have shown priming with the bright stimulus. In addition, it is possible that the explanation for the fact that aphantasics showed lower priming than controls with the very bright stimuli, and no significant priming in the weak and absent stimuli, has to do not with attention, but rather with imagery playing some role in perception.

[4] This goes against Blomkvist, who, in interpreting this study, says that "aphantasics showed no evidence of being able to form attentional templates, confirming their inability to form *voluntary* visual imagery." (2023, p. 4, our emphasis).

stimulus, they should have been able to form an involuntary visual image, and that should have influenced what they saw in the subsequent binocular presentation. Given that no such influence occurred, this suggests that at least this form of involuntary image is impaired in aphantasia.[5]

Another study that arguably investigated involuntary images in aphantasia is Wicken et al., 2021. They measured participants' physiological responses associated with fear in two experiments, one in which participants read fear-inducing fictitious scenarios and another in which they showed participants frightening photographs (e.g. of a snake's mouth). Aphantasics did not differ from controls in their physiological reactions when perceiving fearful pictures, but they showed significantly reduced fear responses when reading fearful stories, when compared to controls. The authors' interpretation of the results is that mental images amplified emotional responses in the individuals who can imagine, when reading the fearful stories, but not in aphantasics. But note that participants were not instructed to form visual mental images when reading the story, and forming an image was not required to perform the task. What likely happened is that mental images were involuntarily generated, simply induced by the reading of the stories in imagers, and not as a consequence of an intention to form them. This is in fact how mental images evoked by reading are commonly understood. As Nanay, 2021a notes, "reading a novel tends to lead to mental imagery in a variety of sense modalities. This triggering of mental imagery is typically involuntary: you do not need to count to three and voluntarily conjure up the mental imagery of the protagonist's face, instead, you have involuntary mental imagery episodes somewhat reminiscent of flashbacks." The idea that language processing can automatically trigger mental images is also supported by some empirical studies (cf. Dils & Boroditsky, 2010, Bergen et al., 2007). Thus, to the extent that aphantasics did not show the same physiological reactions when reading fearful stories as controls, this suggests that they did not form *involuntary* images. If so, then aphantasia does not affect voluntary images selectively; involuntary images, in this case images evoked by reading, also appear to be impaired.

In a similar study, Monzel, Keidel, & Reuter (2023) measured participants' empathy, by means of a questionnaire, when viewing photos of individuals in vulnerable states and when hearing verbal descriptions of the photos. While aphantasics and controls did not differ in their empathy responses when viewing the photos, controls showed higher empathy than aphantasics in the verbal description condition. The explanation suggested is that visual mental images may play a role in empathy responses when visual stimuli are not present. But here again, participants where not instructed to form a mental image while hearing the description. They only had to hear it, and rate how emotionally moving it was . It is possible, then, that controls formed involuntary images while hearing the description, while aphantasics didn't, indicating thus that involuntary imagery is also impaired in aphantasia.

Finally, Königsmark et al. (2021) investigated the relationship between visual imagery vividness and what they call "pseudo--hallucinations", i.e. anomalous visual experiences induced by a certain visual stimulus. Participants were asked to view a full-screen visual flicker that rapidly alternated between the colors black and red, for 10 min. Viewing the flicker can induce visual experiences of features that are not present in the stimulus, such as experiences of colors and/or geometrical patterns, and even of complex objects and/or environments. These pseudo-hallucinations can be considered a form of mental imagery, given that they are similar to visual experiences, but they are not triggered by the relevant external stimuli. They found that imagers were much more likely to report experiencing these pseudo-hallucinations than aphantasics, and, among those who had pseudo-hallucinations, aphantasics reported less vivid and less complex experiences than the ones experienced by imagers, mostly of geometric shapes. Here again, participants were not instructed to form these visual mental images while viewing the flicker, and we have no reason to attribute to them the intention to imagine (in particular meaningless shapes and colors). These images seem to have occurred involuntarily, so much so that they are called "pseudo-hallucinations" by the authors. Importantly, these results were replicated in a much larger sample in Reeder (2022) and are consistent with data from Dance et al. (2021), which, in a pattern glare task, found that aphantasics reported fewer visual distortions than controls when staring at achromatic gratings (with medium and high spatial frequencies).

The differences observed between aphantasics and imagers suggest that involuntary images, in this case ones that occur in interaction with perception, can also be impaired in aphantasia. This interaction likely occurs due to shared (though not entirely overlapping) neural representations between imagery and perception (Cichy et al., 2012; Xie et al., 2020; Spagna et al., 2024), also leading to effects of aphantasia on perceptual processes (Liu & Bartolomeo, 2023), such as visual search (Monzel, Keidel, & Reuter, 2021; Monzel & Reuter, 2023) and sensory sensitivity (Dance et al., 2021).

Now, aphantasics were still about twice as likely to experience pseudo-hallucinations than not, when viewing the flicker, suggesting that this kind of involuntary image may be preserved in aphantasia. But given that imagers were much more likely to report experiencing pseudo-hallucinations than aphantasics, and that their experiences involved more complex and vivid objects than aphantasics, this too suggests that there is a difference in the experience of involuntary images in imagers and aphantasics, taken as a group. The claim that aphantasia is a volitional deficit, then, conflicts with this result.

Although the studies reviewed here are not described by their authors as assessing involuntary images, none of them involved instructions for participants to form mental images. And nothing in these experiments suggests that subjects should have any reason to form an intention to imagine something; images were not required to perform the tasks. In the first study mentioned (Keogh and

[5] As mentioned by a reviewer, Cabbai et al. (2023) found that aphantasics' "guidance by visual attentional templates is not impaired" (p. 272), which might appear to challenge Keogh and Pearson's (2021) result. However, it is important to note that they used a very different task involving visual search – which was not the case in Keogh and Pearson (2021). In addition, Cabbai et al. asked participants about the strategies they used to solve their search task, and found that the majority of aphantasics reported using a verbal strategy, while non-aphantasics tended to visualize the stimulus. In this case, then, it seems that similar performance was achieved by very different means. Cabbai et al.'s result does not suggest, then, preserved involuntary imagery in aphantasia, but rather that aphantasics have other forms of representation (e.g. verbal) available to improve search tasks. We thank the reviewer for raising this issue.

Pearson, 2021), in particular, such an intention would actually go against the instructions given, which were to *attend* to the stimulus – and not to imagine it. It is reasonable to assume, then, that mental images that affected responses in those studies were involuntary. Given the differences between aphantasics and controls, at least these forms of involuntary image are also affected in aphantasia. All of this suggests that characterizing aphantasia as a deficit in voluntary images, and claiming that involuntary images are preserved in aphantasia, as many do, is inappropriate.[6]

4. Involuntary associative images in aphantasia

The studies reviewed above suggest that some forms of involuntary images are affected in aphantasia. As such, they are sufficient to challenge the common characterization of aphantasia as a volitional deficit. But it could still be the case that other forms of involuntary imagery, not assessed in these studies, are preserved in aphantasia, for involuntary imagery should not be assumed from the outset to form a unitary kind. Our investigation should then proceed case by case. It is therefore worth looking at other forms of involuntary images that have been explicitly assessed in aphantasia.

Most studies on aphantasia are officially silent about involuntary images, such as the ones reviewed in section 3. But some studies explicitly claim that certain forms of involuntary images are preserved in aphantasia, such as Palermo et al. (2022). They investigated whether associative involuntary images can be preserved in aphantasia. To do that, they showed both aphantasics and non-aphantasics two drawings of black and white fruits or vegetables (e.g. a tomato and an eggplant), and asked which type of object has the darkest color. Their reasoning was that, after frequent exposure to the co-occurrence of a shape and a color (such as the shape of a tomato and the color red), the mere presence of the shape alone (e.g. of a tomato) triggers the involuntary image of a color (e.g. red), an effect of associative learning. In order to solve the task, then, participants would presumably compare the two involuntary images of color that were triggered by the shapes, and then decide which one was darker. They found that aphantasics were as accurate and as fast as controls in this task, which they take to suggest that both groups used the same cognitive processes to solve it (p. 10). Given that, in their view, the task involves the use of involuntary images, the authors conclude that "this kind of involuntary object imagery is intact in all groups".

If this conclusion is correct, then at least this form of involuntary imagery can be dissociated from the voluntary kind, and be preserved in aphantasia. But the reasoning involved here is questionable. One reason is that the empirical basis for claiming that involuntary color images occur given the shape of an object that has a canonical color is not as strong as the authors assume, since studies that claim to show that color memory affects color experience have been criticized. In a typical experiment (cf. Hansen et al., 2006), subjects are instructed to adjust the color of objects that do and do not have a typical color, e.g., a banana and a disc, to make them gray. But in so doing, what they find is that subjects make different color adjustments depending on whether the object has a canonical color or not. Subjects tend to make the banana bluish-gray, but not the disc, for which they choose an achromatic gray. The traditional interpretation here is that the knowledge of the banana's typical color affects color experience and makes the achromatically gray banana still look yellow. In order for the banana to really look gray, subjects have to make it bluish, which is yellow's opponent color.

But the problem here is that it could well be that subjects respond this way not because the achromatic banana looks yellow, but because they adopt the strategy of moving its color a safe distance away from its canonical color, while still complying with the experimental instructions of making the object gray (Zeimbekis, 2013; Krempel, 2021). In support of this interpretation, Valenti & Firestone (2019) show that subjects have no problem finding the odd color out when presented with three objects side by side. For example, if presented with a gray banana, a bluish-gray banana and a gray disc, subjects can tell that the bluish gray banana is the odd color out. This goes against the prediction of the memory color effect view, which says that subjects should select the gray banana as the odd one, given that it is supposed to look yellow. This challenges, then, Palermo et al.'s assumption that seeing the shape of an object that has a canonical color will trigger the experience of that color even when the color is absent. It is, then, not clear that, to solve their task, subjects compare the colors of involuntary color imagery.

Another issue is that, even if the black and white shapes in fact triggered involuntary color images in the control participants, it is possible that aphantasics simply used a different strategy to solve the task, appealing, for instance, to their semantic knowledge of the colors of the objects. This is in fact what some authors suggest aphantasics do when it comes to tasks that are believed to require images, but which they have no problem solving (cf. Keogh et al., 2021; Zeman et al., 2020). An example is Zeman et al. (2010), who studied MX, an individual who had lost the ability to form visual mental images following a heart procedure, but who was still capable of performing several "imagery tasks", being able, for instance, to answer "high imagery questions" (such as "Is the green of grass darker than the green of a pine tree?"; Zeman et al., 2010,p. 147). They take this as an indication that MX used a non-visual strategy to solve these tasks.

Palermo et al. assume that it is less likely that aphantasics used semantic knowledge than that they used involuntary visual images, because there was no difference between groups in response time. But participants were not instructed to perform the task as fast as possible, and the study was conducted online, which allowed for a wide variation across subjects in response times (which were on

[6] There are other studies that found behavioral differences between aphantasics and controls that did not involve instructions to form mental images. But these were studies that assessed memory (cf. Bainbridge et al., 2021; Dawes et al., 2022; Monzel, Vetterlein, & Reuter, 2021), and where subjects may have had a reason to form an image, in order to better perform the task. They may have assessed voluntary imagery, even if not explicitly.

average 7.8 sec. (SD = 5.2) for aphantasics and 7.2 sec. (SD = 4.0) for controls[7]). It is unclear, then, that much can be concluded about the cognitive strategies used on the basis of response times obtained in this study. Palermo et al. do not, therefore, succeed in showing that this form of associative involuntary image is intact in aphantasia.

5. Intrusive images

Another natural place to look, when trying to investigate involuntary images in aphantasia, is the intrusive, involuntary images often present in psychopathologies. In a recent paper, Cavedon-Taylor (2022) looks at this issue and argues, contrary to what we are suggesting, that the best characterization of aphantasia is in fact in terms of a deficit in generating voluntary mental images (as opposed to as a deficit in metacognition or as a lack of mental images altogether). According to him, what he calls "the volitional definition" is the one that best explains the occurrence of psychopathology among aphantasics. He invokes data from Dawes et al. (2020), that investigated self-report responses to stressful events by using The Post-Traumatic Stress Disorder (PTSD) Checklist for DSM-5 (PCL-5; Weathers et al., 2013), a 20-item questionnaire that asks subjects how much they have been bothered by, e.g. "Repeated, disturbing, and unwanted memories of the stressful experience", or "Avoiding memories, thoughts, or feelings related to the stressful experience". He notes that they found no significant differences between controls and aphantasics.

As Cavedon-Taylor (2022) notes, there is a connection between several psychopathologies and the presence of intrusive, involuntary mental images. PTSD, for instance, is often associated with the presence of flashbacks or intrusive images. He then argues that if aphantasia is a deficit in voluntary images, we can explain the similarity between aphantasics and controls in responding to stressful events by the assumption that aphantasics have intrusive, *involuntary* images. If, however, aphantasia impacted imagery more generally, we couldn't explain why aphantasics did not differ from controls in their responses to the PCL-5.

The problem is that Dawes et al. (2020)'s data is insufficient to establish the presence of intrusive involuntary images and flashbacks in aphantasia. This is because none of the items in the PCL-5 is explicit about the presence of intrusive *images* – they mention instead memories, thoughts and feelings associated with the stressful experience. One item does mention "Suddenly feeling or acting as if the stressful experience were actually happening again (as if you were actually back there reliving it)?". But aphantasics might experience something like "reliving" a past event because they have negative emotions when thinking about it, perhaps similar to the emotions that they had when the event happened. Given that aphantasia doesn't render one incapable of thinking about or remembering past events (even if some studies indicate that aphantasics' memories are less phenomenologically rich than those of controls – see Dawes et al. 2022 and Milton et al. 2021) it could be that bringing a stressful past event to mind is disturbing for them even in the absence of imagery. Aphantasics might, for instance, have intrusive thoughts in inner speech without having intrusive involuntary visual images of a past event. The experience of inner speech might then trigger negative emotions.

In addition, Dawes et al. data already indicated that aphantasics scored lower than controls in the intrusion sub-component of the PCL-5, reporting fewer memory intrusions. This is supported by recent data from Keogh et al. (2023). They used the trauma film paradigm, where participants (aphantasics and controls) had to watch a 10-minute traumatic film that depicted the outcome of a fatal car accident. Participants were then questioned about intrusions related to the film, immediately after watching it, and over the course of a week. Aphantasics reported fewer intrusions both immediately after watching the film and over the course of a week. Aphantasics also reported that their intrusions were mostly verbal, while controls reported that their intrusions were mostly visual. Contrary to what Cavedon-Taylor (2022) claims, the case of psychopathology does not support the volitional definition of aphantasia. Given that aphantasics appear to have fewer intrusions than controls, and that they report experiencing intrusions in a verbal format, it seems that they are less subjected to involuntary intrusive mental images.

6. Afterimages

Afterimages are visual perseverations that often occur after intense light stimulation has ceased. Although afterimages are widely recognized as a perceptual phenomenon that is caused by local retinal adaptation (Brindley, 1962; MacLeod & Hayhoe, 1974; Rushton & Henry, 1968), afterimage signals can be modified by cortical processes (Zaidi et al., 2012). Afterimages can be considered a special kind of mental imagery themselves - even though they are driven by a perceived stimulus - since they continue to occur when the relevant stimuli are no longer present. They are also clearly involuntary, given that they occur independently of the agent's intention. Thus, to investigate the occurrence of afterimages in aphantasia, we performed a short online experiment.

6.1. Method

6.1.1. Participants

Participants were recruited from the Aphantasia Research Project Bonn (see also Monzel, Vetterlein, et al., 2023; Monzel, Vetterlein, & Reuter, 2022) as well as from the student body of the University of Bonn. In total, 75 aphantasics (VVIQ <= 32) and 151 controls (VVIQ > 32) took part in the experiment. Participants were predominantly female (63.7 % female, 30.5 % male, 0.9 % others) and on average 29.25 years old (SD = 12.27).

[7] Palermo, personal communication.

6.1.2. Materials

For the assessment of visual imagery vividness, the VVIQ was used (Marks, 1973). For the assessment of afterimage intensity, participants were instructed to fixate the center of three different stimuli (see Fig. 2), presented one at a time, and to blink as little as possible. Each stimulus was presented once for 15 s and once for 30 s, resulting in a total of six trials. After each observation phase, a white screen was shown for 10 s and participants were asked to look at the white screen to potentially experience something called an "afterimage". Participants were informed that the colors of the afterimage would be inverted in comparison to the original stimulus (i.e., "the dark areas of the afterimage will be the light areas of the original shape and vice versa"). After the 10 s period, participants were asked to rate the intensity of the afterimage on a scale from 1 ('no after image at all') to 7 ('the black areas of the after image were just as dark as the black areas of the original shape'). All trials were presented at random.

6.1.3. Procedure

The software PsyToolkit was used for online data collection (Stoet, 2010, 2017). The VVIQ was administered before the experiment started. There was also the possibility to skip the VVIQ when the VVIQ score was already deposited in the Aphantasia Research Database.

6.1.4. Data analysis

The intensity ratings of all six trials were averaged. A mixed 2x2 ANOVA with group as between-subject factor (aphantasics vs. controls), observation time as within-subject factor (15 s vs. 30 s) and mean intensity rating as dependent variable was calculated. Afterwards, two correlations were calculated between VVIQ score and mean intensity ratings in trials with short and long observation times to check whether the effects of the group analysis could be transferred to the entire vividness spectrum. Importantly, there were 20 missing values in the long observation time condition due to a technical error. Last, a mixed 2x3 ANOVA with post-hoc comparisons was calculated with group as between-subject factor (controls vs. moderate aphantasia vs. extreme aphantasia) and observation time as within-subject factor (15 s vs. 30 s) to check for intensity rating differences between between moderate aphantasia ($n = 31$, $16 < VVIQ <= 32$) and extreme aphantasia ($n = 44$, $VVIQ = 16$).

6.2. Results

The 2x2 mixed ANOVA revealed a main effect of observation time, $F(1, 204) = 11.32$, $p < .001$, $\eta 2 = 0.05$, as well as a main effect of group, $F(1, 204) = 104.73$, $p < .001$, $\eta 2 = 0.16$, indicating higher intensities after long observation times ($M = 4.51$, $SD = 1.38$) compared to short observation times ($M = 4.28$, $SD = 1.31$) and higher intensities for controls ($M = 4.71$, $SD = 1.22$) compared to aphantasics ($M = 3.53$, $SD = 1.04$) (see Fig. 3). No interaction effect was found, $F(1, 204) = 0.60$, $p < .441$, $\eta 2 < 0.01$. The same results were found when the VVIQ scores were correlated with the intensity ratings for short, $r(224) = 0.43$, $p < .001$, and long, $r(204) = 0.41$, $p < .001$, observation times. When reanalyzing the data differentiating between controls, moderate aphantasia and extreme aphantasia, no significant differences were found between extreme and moderate aphantasia, $\Delta M = -0.39$, $p = .687$.

6.3. Discussion

According to our analyses, aphantasics were able to perceive afterimages, which is in line with afterimages being an at least partially perceptual phenomenon (Brindley, 1962; MacLeod & Hayhoe, 1974; Rushton & Henry, 1968). However, they perceived the afterimages less intensely, suggesting that vivid mental imagery can modify the experience of afterimages. Moreover, the main effect of observation time validates our results, as it has already been found in the past that the afterimage intensity increases as a function of observation time (Georgeson & Turner, 1985). In contrast, the alternative explanation of a *generally* more conservative answer pattern in aphantasics is weakened (cf. confidence gap in aphantasics, Monzel, Dance, Azañón & Simner, 2023), since this would have led to an interaction effect between group and observation time. Another alternative explanation could be that the perceived intensity of the original stimuli was already reduced in aphantasics when compared to controls. In this case, however, the observation time should not have played a role either, which would also have led to an interaction effect between group and observation time. Overall, as neither controls nor aphantasics were instructed to form an afterimage of the observed stimuli, and afterimages are generally not formed intentionally, afterimages are another form of involuntary mental imagery whose intensity is affected in aphantasia.

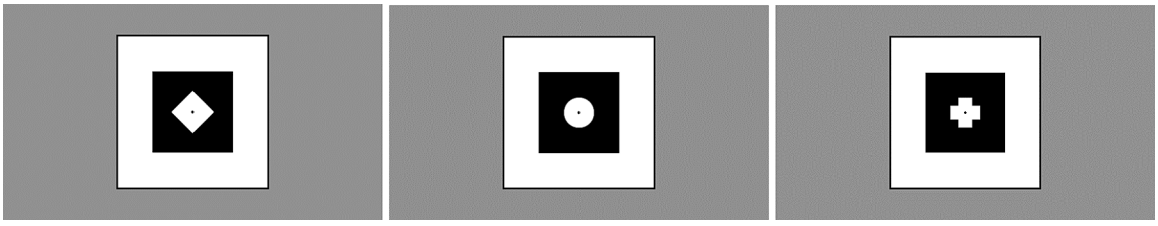

Fig. 2. Stimuli of the afterimage experiment.

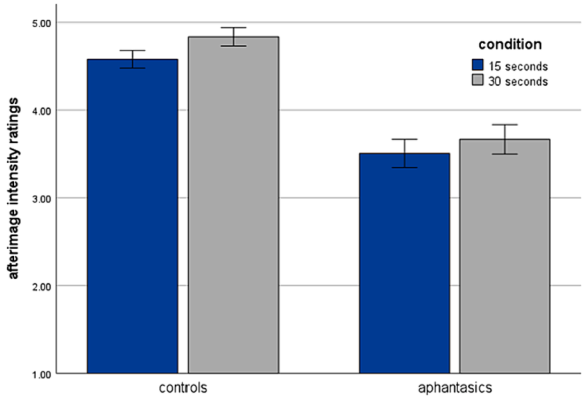

Fig. 3. Afterimage intensity ratings as a function of group and condition (N = 226).

7. Dreams revisited

It seems, then, that the case to be made for the claim that aphantasics have preserved involuntary imagery must be based mostly on dreams. As we've seen, most aphantasics report having visual dreams, and given that these images are involuntary (with the possible exception of lucid dreams), it is said that involuntary images are preserved in aphantasia. Now, even if the experience of imagistic dreams were fully preserved in aphantasia, that would not be enough to conclude that involuntary imagery as a whole is unaffected in aphantasia, as many claim. For as we've seen, there are multiple forms of involuntary images that do seem to be affected in aphantasia. Thus, the most that we would be able to conclude, if imagistic dreams were intact in aphantasia, is that *this particular form* of involuntary imagery remains intact in aphantasia – a much more modest claim than the one that is made in the literature.

But even this more modest claim is questionable. In Dawes et al. (2020), aphantasics reported experiencing significantly fewer dreams than controls, and their dreams were reported to be less vivid. Similarly, in Zeman et al. (2020), aphantasics were more likely to report experiencing absence of dreams or non-visual dreams than controls and hyperphantasics (individuals who report extremely vivid images). This indicates that aphantasia impacts the involuntary images that occur in dreams as well. Dawes et al. conclude that their data "suggest that any cognitive function (*voluntary or involuntary*) involving a sensory visual component is likely to be reduced in aphantasic individuals, and it is this generalized reduction in the sensory simulation of complex events and scenes that is most striking in aphantasia" (Dawes et al., 2020,p. 4, our emphasis).

In addition, in cases of acquired visual aphantasia, where the ability to visualize is for some reason lost, the ability to have visual dreams also tends to be impaired. Knowles et al. (2021) report that of 28 cases of acquired aphantasia, "around half had lost visual dreaming, a third had preserved visual dreaming and the remainder had visual dreaming of reduced intensity". MX, the subject with acquired aphantasia studied in Zeman et al. (2010), initially lost both the ability to voluntarily form visual images and to dream visually (although he subsequently recovered the ability to have visual dreams, but not the ability to form voluntary visual images in waking life). This finding suggests that the two forms of imagery, though they can come apart, are not completely unrelated, and they might have shared mechanisms. As Zeman et al. note, "these two forms of imagery involve partially but incompletely overlapping neural networks, which is plausible in both neurological and cognitive terms" (2010, p. 154).

Thus even though many individuals with aphantasia have imagistic dreams, aphantasia tends to affect imagery in dreams as well (both its occurrence and its phenomenological richness). The case of dreams in aphantasia, which was supposed to motivate the idea that aphantasia selectively affects *voluntary* images, is then more complicated than usually described, and the experience of involuntary images in dreams appears to have some connection with experiences of voluntary images in waking life.

Moreover, given that we have reasons to accept that several forms of involuntary imagery may be affected in aphantasia, the preservation of imagistic dreams in some aphantasics might have more to do with the brain being in a very different state when we are asleep, than with the involuntariness of images in dreams. Mental images in dreams might form their own category, and some might even count as voluntary, such as those in lucid dreams (Holzinger and Mayer, 2020). Future research should investigate whether aphantasics can have both regular and lucid dreams. If aphantasics can have lucid dreams, that would suggest that some forms of voluntary imagery can be preserved in aphantasia. This would suggest that voluntary imagery too may come in many different forms, and that aphantasia should not be viewed as a general deficit in voluntary imagery.

Another topic for future research when looking at involuntary imagery in aphantasia concerns the hypnagogic state. The hypnagogic state is a "transitional stage between wakefulness and sleep, in which sensory perceptions can be experienced" (Ghibellini and Meier, 2023). It can involve "spontaneously appearing visual, auditory and kinaesthetic images" (Schacter, 1976, p. 453). Ghibellini & Meier (2023) note that imagery in dreams and hypnagogic state can differ in many ways. According to them, the most common experiences in the hypnagogic state are "kinaesthetic experiences, such as the feeling of a presence in the room and the feeling of falling, as well as visual experiences (…), followed by experiences in the auditory modality". Future research should investigate whether aphantasics have similar experiences in the hypnagogic state than imagers, or whether they tend to have fewer visual experiences.

In sum, given the other forms of involuntary imagery deficits reviewed, as well as the impact of aphantasia on dreams, we should be cautious and not infer that a general category of images is preserved in aphantasia (i.e. involuntary images) simply because one of its

instances (i.e. images in dreams) can be.

8. Flashes of imagery

In the Zeman et al. (2015) original paper, where the term "aphantasia" was coined and the condition was characterized as a deficit in voluntary imagery, they based their claim that there is "a significant dissociation between voluntary and involuntary imagery" (p. 379) not only on the fact that many aphantasics dream, but also on the fact that 10 out of 21 aphantasics reported having "flashes of imagery". These flashes were interpreted as being involuntary forms of imagery that were preserved in aphantasia. It is hard, however, to determine whether these flashes were truly involuntary, as the question they asked was: "Is your lack of visual imagery total, or do you sometimes experience brief flashes of imagery?". The question is underspecified. It could be that some aphantasics experience flashes of images when they are voluntarily trying to form an image, but are unable to sustain it in mind. If so, this would indicate a deficit in the maintenance of an image, rather than preserved involuntary imagery.

Another possibility is that these flashes of imagery are involuntary, as Zeman et al. assume they are, but only experienced in some circumstances, such as hypnagogic states. The problem, however, is that the study did not assess the presence of flashes of images in controls. It is then unclear whether aphantasics' experience of flashes of images is unaffected, for it could be that they experience fewer of those than imagers. And in fact, a substantial portion of aphantasics reports lacking even flashes of images. In Zeman et al. (2020), about 60 % of extreme aphantasics (who scored at floor on the VVIQ) reported that they had a total lack of visual imagery, including flashes. So even though aphantasia is not incompatible with the experience of flashes of imagery, aphantasia might affect them to a greater extent than in controls (much like in the case of dreams). In any case, even if we accept that flashes of imagery are involuntary and not affected in aphantasia, we have seen that other forms of involuntary imagery appear to be impaired in aphantasia, and so the volitional characterization of aphantasia should be avoided.

9. Conclusion

We have argued that, contrary to a common view, aphantasia is not a deficit that selectively affects voluntary images. As suggested in section 3, some forms of involuntary imagery, such as imagery formed while reading or hearing a verbal description of something, as well as images formed in interaction with perception, appear to be affected in aphantasia. Intrusive memories also appear to be less frequent in aphantasics, and to take a verbal, instead of visual format, which again suggests that involuntary imagery is also affected in aphantasia (section 5). Even imagery in dreams tends to be affected in aphantasia (section 7). As for associative imagery (section 4), the evidence available is insufficient to determine whether it is preserved in aphantasia or not.

Aside from suggesting the reinterpretation of several studies, in which we see involuntary imagery being affected in aphantasia, we also reported (in section 6) the results of a new study on the experience of afterimages in aphantasics, indicating that afterimage intensity is amplified by visual imagery vividness. That aphantasics reported less intense afterimages than controls suggests that this form of involuntary imagery (one that is closely tied to perception) is also affected in aphantasia, once again confirming that voluntary mental imagery is not the only form of imagery affected in aphantasia.

Perhaps the fact that aphantasia affects involuntary as well as voluntary imagery is unsurprising, for as research independent of aphantasia indicates, individuals who report more vivid and frequent visual involuntary images, such as images in memory intrusions or hallucinations, also tend to report more vivid voluntary images (Shine et al., 2015, Morina et al., 2013). Salge et al. (2021), also report that subjects with more vivid visual images are more prone to experiencing faces in noise (a case of pareidolia), which might be a case of anomalous (involuntary) visual experience that recruits visual images. Data such as these led Pearson and Westbrook (2015) to argue that there are overlapping mechanisms between voluntary and involuntary images. If that is right, then it would be natural to expect that, in a population that reports a deficit in voluntary visual images, namely aphantasics, involuntary visual images would also be affected. And this is what the data so far suggests.

As we suggested, involuntary images may come in many different forms. Dreams are just one form of involuntary imagery, and even if they are preserved in some aphantasics, other forms of involuntary imagery may be affected (such as imagery formed while reading). Pearson and Westbrook (2015) also count cases of visual illusion as cases of involuntary mental images, for instance, the neon color spreading illusion, given that in visual illusions one experiences a certain feature that is not actually present in the stimulus. One hypothesis is that cases of illusory experience are more perceptual than imagistic, in that the features involved in visual illusions, such as colors or motions, are experienced as being out there, unlike what typically occurs in cases of voluntary or other forms of involuntary images. The experience of color in the neon spreading illusion and the image of a colored circle triggered by reading seem phenomenologically different, even if they are both involuntary. It could then be that aphantasics would be equally subject to visual illusions, even if they have no involuntary images triggered by reading, for example. However, preliminary results suggest that, even though aphantasics can experience the neon color spreading illusion, they experience it in a less intense way than controls (Pearson, 2022), similarly to what we found in regard to afterimages. This suggests that mental imagery can interfere with perceptual processes. We shouldn't, however, assume that involuntary images form a single kind that is either present or absent in aphantasia. Some types of involuntary imagery might be present in some individuals, while affected in others. For example, Dance et al. (2021) showed that aphantasics also can experience grapheme-color synesthesia, albeit more 'associative' than 'projective'. Further research should investigate individual differences within aphantasia, looking at how it affects different forms of involuntary and voluntary imagery.

Clarity about the impairment of involuntary imagery in aphantasia is important if we are interested in understanding what aphantasia really is and the mechanisms behind it – things that are not yet understood. If aphantasia affects at least some forms of involuntary images as well as voluntary ones, then the characterization of aphantasia as a deficit in voluntary imagery is not correct.

Characterizing aphantasia as a volitional deficit is likely to lead researchers to give incorrect explanations for aphantasia, and to look for the wrong mechanisms underlying it.

Following Monzel, Mitchell et al. (2022), which suggests that aphantasia should not be characterized as a deficit in *visual* imagery exclusively, but in mental imagery more broadly, we suggest that something analogous applies to another dimension: that of voluntary/involuntary imagery. Aphantasia is better characterized as a deficit in forming mental imagery, whether voluntary or not. This characterization does not imply that all forms of involuntary imagery will be affected in all individuals with aphantasia. Some aphantasics have unaffected visual dreams, for example. Characterizing aphantasia more generally allows us to accept that involuntary images may or may not be affected. Similarly for voluntary images, for as Blomkvist (2023) points out, there might be a double dissociation between voluntary and involuntary imagery, such that some individuals may have voluntary imagery but lack involuntary imagery. But the data so far suggests that there is at least a tendency for involuntary images of multiple forms to be affected in aphantasia, something that has not yet been recognized, and that is left unexplained if aphantasia is characterized as a deficit in voluntary imagery exclusively.

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CRediT authorship contribution statement

Raquel Krempel: Writing – review & editing, Writing – original draft, Project administration, Investigation, Funding acquisition, Conceptualization. **Merlin Monzel:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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