Probing the unimaginable: The impact of aphantasia on distinct domains of visual mental imagery and visual perception

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Acknowledgments

This work was supported by funding from *Dassault Systèmes*. In addition, the work of PB is supported by the *Agence Nationale de la Recherche* through ANR-16-CE37-0005 and ANR-10-IAIHU-06, and by the *Fondation pour la Recherche sur les AVC* through FR-AVC-017. We would like to thank Dounia Hajhajate for her help in building the eBIP, Lei Zhang for statistical advice, and all the participants for their interest and the time they devoted to this study.

Keywords

Visual perception; visual mental imagery; aphantasia; phenomenal consciousness

Abstract

Different individuals experience varying degrees of vividness in their visual mental images. The distribution of these variations across different imagery domains, such as object shape, color, written words, faces, and spatial relationships, remains unknown. To address this issue, we conducted a study with 117 healthy participants who reported different levels of imagery vividness. Of these participants, 44 reported experiencing absent or nearly absent visual imagery, a condition known as "aphantasia". These individuals were compared to those with typical (N = 42) or unusually vivid (N = 31) imagery ability. We used an online version of the French-language Battérie Imagination-Perception (eBIP), which consists of tasks tapping each of the above-mentioned domains, both in visual imagery and in visual perception. We recorded the accuracy and response times (RTs) of participants' responses. Aphantasic participants reached similar levels of accuracy on all tasks compared to the other groups (Bayesian repeated measures ANOVA, BF = 0.02). However, their RTs were slower in both imagery and perceptual tasks (BF = 266), and they had lower confidence in their responses on perceptual tasks (BF = 7.78e5). A Bayesian regression analysis revealed that there was an inverse correlation between subjective vividness and RTs for the entire participant group: higher levels of vividness were associated with faster RTs. The pattern was similar in all the explored domains. The findings suggest that individuals with congenital aphantasia experience a slowing in processing visual information in both imagery and perception, but the precision of their processing remains unaffected. The observed performance pattern lends support to the hypotheses that congenital aphantasia is primarily a deficit of phenomenal consciousness, or that it employs alternative strategies other than visualization to access preserved visual information.

Introduction

Our "Mind's Eye" enables us to form mental images of objects, colors, and faces even when there is no physical visual input present. However, the level of detail and clarity of these mental images varies among individuals (Faw, 2009; Pearson, 2019). Some people may experience mental images as "quasi-visual" in nature, while others have less vivid images, down to the total absence of imagery experience in otherwise normal individuals (Galton, 1880). This condition was recently named “aphantasia” (Zeman et al., 2015), derived from the Greek word for "lack of images".

There is an ongoing debate about the nature of aphantasia. Some theories propose that it is a deficit in the ability to introspect (Nanay, 2021), while others suggest it is a result of a lack of ability to voluntarily generate mental images (Zeman et al., 2015), or a more general deficit in mental imagery capabilities (Keogh & Pearson, 2018; Wicken et al., 2021). In some cases, aphantasia is related to psychological or emotional factors, rather than any underlying physical or neurological condition (De Vito & Bartolomeo, 2016; Zago et al., 2011). In addition to lacking visual imagery, some individuals with aphantasia also report difficulty in recognizing faces, experience fewer qualitative details in their dreams, have an impaired autobiographical memory (Dawes et al., 2020; Zeman et al., 2020), reduced physiological responses (Kay et al., 2022; Wicken et al., 2021), and a lack of rivalry priming effect when using imagined primes (Keogh & Pearson, 2018).

However, despite their inability to voluntarily visualize mental images, individuals with congenital aphantasia may still be capable of successfully performing visual imagery tasks that are commonly used in research and clinical settings (Jacobs et al., 2018; Keogh et al., 2021; Milton et al., 2021; Pounder et al., 2022; Zeman et al., 2010). This is in sharp contrast to individuals with aphantasia resulting from brain damage, who typically have impaired performance on such tasks (Bartolomeo et al., 2002, 2020; Farah, 1988; Goldenberg, 1993; Liu et al., 2022; Moro et al., 2008). It's possible that individuals with congenital aphantasia may use alternative strategies to those who rely on visualization in order to successfully complete visual imagery tasks. These strategies may allow them to achieve similar levels of success as typical imagers (Jacobs et al., 2018; Keogh et al., 2021).

Another unresolved issue is the effect of aphantasia on specific domains of visual mental imagery. Case reports of post-stroke aphantasia indicate the existence of distinct domains of VMI, which can be selectively impaired by brain damage (Goldenberg, 1993): shapes of objects, colors of objects, faces, letters, and spatial relationships. For example, a patient with imaginal neglect had preserved general mental imagery capacities (Guariglia et al., 1993). Another patient had an association of alexia without agraphia and a selective imagery deficit for letters and words, with spared imagery of shapes, colors, and faces (Bartolomeo et al., 2002). Importantly, this patient was able to partially overcome his imagery deficit by using a non-visual, motor strategy of mimicking the movements of writing letters and words.

Given this evidence from neurological patients, it remains uncertain whether domain-specific information affects imagery or perceptual processing in aphantasia that is unrelated to brain damage. Previous studies investigating single domains resulted in piecemeal evidence, making it difficult to draw conclusions or establish a taxonomy of visual imagery capabilities. Further, response times (RTs) were not always recorded, despite their potential to disclose alternative strategies in aphantasia vs. typical imagery (Zeman et al., 2010). Another open issue concerns the mixed evidence on the relationship between aphantasia and perception, with some studies showing perceptual deficits, e.g. difficulty with face recognition (Zeman et al., 2020), and others indicating no perceptual impairment in aphantasia (Bainbridge et al., 2021). To systematically address these issues, we built upon our multi-domain French-language *Battérie Imagination Perception* (BIP) (Bourlon et al., 2009), and developed a computerized version of the BIP, which can be performed online (enhanced BIP, henceforth eBIP). Importantly, care was taken to exclude from the imagery tasks any questions that could be answered by relying on non-visual semantic memory (for example, questions about the color of snow or bananas). The eBIP allowed us to assess on a fine scale the relationships between performance in distinct domains of imagery and perception (shapes, colors, words, faces, and spatial relationships) in a sizable sample of neurotypical volunteers.

Our predictions were as follows:

1. If there is a relationship between the subjective vividness of mental images and efficient information processing, then individuals with typical or vivid imagery abilities should have better performance than those with aphantasia on imagery tasks and perhaps also on perception tasks, both in terms of accuracy and of RTs. This because imagery vividness might be considered as an imagery analog of sensory salience in perception, which reduces uncertainty by increasing the signal-to-noise ratio (Vincent, 2015).

2. If individuals with aphantasia can "just know" the correct response to imagery tasks without using visual mental images, their performance on these tasks might be faster than typical imagers as they may be able to access abstract semantic knowledge directly[1].

3. If individuals with aphantasia use non-visual, spatiomotor strategies (see, e.g., Bartolomeo et al., 2002), their performance should be especially impaired in domains that minimize the role of these strategies such as color and face imagery.

4. If aphantasia is mainly a deficit of introspection (Nanay, 2021), individuals with this condition should not show impaired accuracy on imagery tasks, as their underlying information processing abilities should be unaffected.

Methods

Ethical approval for this study was obtained from the IRB of Sorbonne University (ID-RCB: CER-2020-110).

[1] We thank Chris Summerfield for suggesting this possibility to us.

Participants

We recruited participants from the CNRS RISC volunteer database (https://www.risc.cnrs.fr/) and through French-language aphantasia groups on social media platforms such as Facebook, Twitter, and Instagram. Additionally, we also received some participants through spontaneous contact.

All participants were asked if they had a history of neurological or psychiatric conditions, and those who reported such a history were not included in the experiment. Included participants performed the online VVIQ and eBIP (https://visual-imagination.github.io/imagery/games/Games-ebip-fr/). A total of 176 participants completed a French translation (Santarpia et al., 2008) of the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973). Out of those 176 participants, 137 also completed the eBIP. After visual inspection, three participants were excluded from the analysis due to their random, fast responses and comments indicating that they had deliberately attempted to disturb the study. The remaining 134 participants were distributed in three imagery vividness groups according to their VVIQ score. In the French version of VVIQ (Santarpia et al., 2008) the total score ranges from 16 (“no images”) to 80 (“vivid and realistic images close to perception”). We used cut-off scores of 16-32 to identify individuals with aphantasia (Dance et al., 2022). Scores within the range of 48-64 were considered typical for imagery ability, corresponding to an average VVIQ score per question from 3 (Moderately clear and vivid) to 4 (Clear and reasonably vivid); scores above 67 indicated unusually vivid imagery ability (Santarpia et al., 2008). Seventeen participants with scores between 33-48 or 65-67 were excluded to reduce any potential overlapping between groups. Our final sample thus consisted of 117 participants who were divided into three subgroups: 44 individuals with aphantasia, 42 individuals with typical imagery ability, and 31 individuals with unusually vivid imagery ability.

Tasks

Participants completed three groups of tasks: VVIQ, visual imagery tasks, and visual perception tasks. As mentioned in the Introduction, the eBIP is based on a previous test battery (Bourlon et al., 2009), and assesses imagery of object shapes (Fig. 1A), object colors (Fig.1B), words (Fig. 1C), faces (Fig. 1D), and spatial relationships on an imaginary map of France (Fig. 1E) (Bourlon et al., 2011). On each trial of the imagery tasks, participants look at a blank screen and hear a word indicating a particular imagery domain (e.g., “shape”), followed by 2 words, designating the items the participant is required to imagine (e.g. “beaver”, “fox”). Participants are asked to form mental images of a typical instance of each item as vividly as possible. Afterward, they hear an attribute word (e.g. “long”). Once they have heard the attribute word, they press one of two buttons, indicating which of the items most closely corresponds to the attribute (e.g. which of the animals corresponds to the overall “long” shape in Figure 1A). Both speed and accuracy of response were emphasized. RTs for correct responses were recorded from the presentation of the attribute word to the response. Finally, participants report the overall vividness of their mental imagery for that trial on a 4-level Likert scale (four buttons, where button 1 represents “no image at all” and button 4 represents a “vivid and realistic image”). Each imagery domain block consisted of 15 trials, resulting in a total of 75 trials for the imagery tasks. Domain blocks were presented in a random order for each participant. The visual perception tasks (Fig. 1F) employed the same stimuli used for the imagery tasks, except that stimuli were presented in an audio-visual format: the same item names used for the imagery tasks were accompanied by the corresponding images, presented in color on the computer screen. In place of the vividness score used for the imagery tasks, participants were asked to rate their confidence in the accuracy of their response on a 4-point Likert scale. This scale ranged from 1, which represented "not sure," to 4, which represented "very confident." Each perceptual domain consisted of 6 trials, resulting in a total of 30 trials. The order of domain block presentation was randomized across participants. All voice recordings were digitized at a 44.1 kHz sampling rate. The image set in the perception task comprised color photographs on a white background. Letters in the word perception task were presented in “Monotype Corsiva” font. The experiment was coded in Psychopy (version 3.2.4, https://www.psychopy.org/) and presented on the Pavlovia online platform (https://pavlovia.org/). The eBIP takes around 30 min to complete.

Data analysis

We conducted a Bayesian repeated measures analysis of variance (ANOVA) with the factors of Group (Aphantasia, Typical imagers, Vivid imagers), Modality (Imagery, Perception), and Domain (Shape, Color, Word, Face, Space). The dependent variables were accuracy (arcsine-transformed proportions of correct responses) and response times (RTs). A Bayesian repeated measures ANOVA was conducted for each modality, with the factors of Group and Domain. The dependent variables were accuracy, RTs and trial-by-trial vividness scores (translated to a 0-1 scale and arcsine-transformed) for the imagery tasks, and accuracy, RTs, and trial-by-trial confidence scores (translated to a 0-1 scale and arcsine-transformed) for the perceptual tasks. For each participant, we excluded trials with response times (RT) faster than 150 ms or exceeding three SDs from the participant’s mean. To test prediction (3) (see Introduction), we performed a priori comparisons between groups for each imagery and perception domain. To see to what extent trial-by-trial vividness can predict imagery RTs, we fitted a Bayesian linear regression model with a uniform model prior, for the entire participant group.

Statistical tests were performed using JASP 0.16.2 (https://jasp-stats.org/), and used the JASP default priors. A commonly accepted convention is that Bayes factors (BF_{10} or BFs) between 3 and 10 indicate moderate evidence in favor of the model in the numerator (H1); BFs between 10 and 30 indicate strong evidence; BFs larger than 30 indicate very strong evidence. The inverse of these cut-offs values provides moderate (0.33-0.1), strong

(0.1-0.03), or very strong evidence (<0.03) for the model in the denominator (H0), i.e. the null hypothesis (Schmalz et al., 2021).

Data availability

The data used in the analysis were completely anonymized according to the ICM data protection policy. They are available upon reasonable request to the authors.

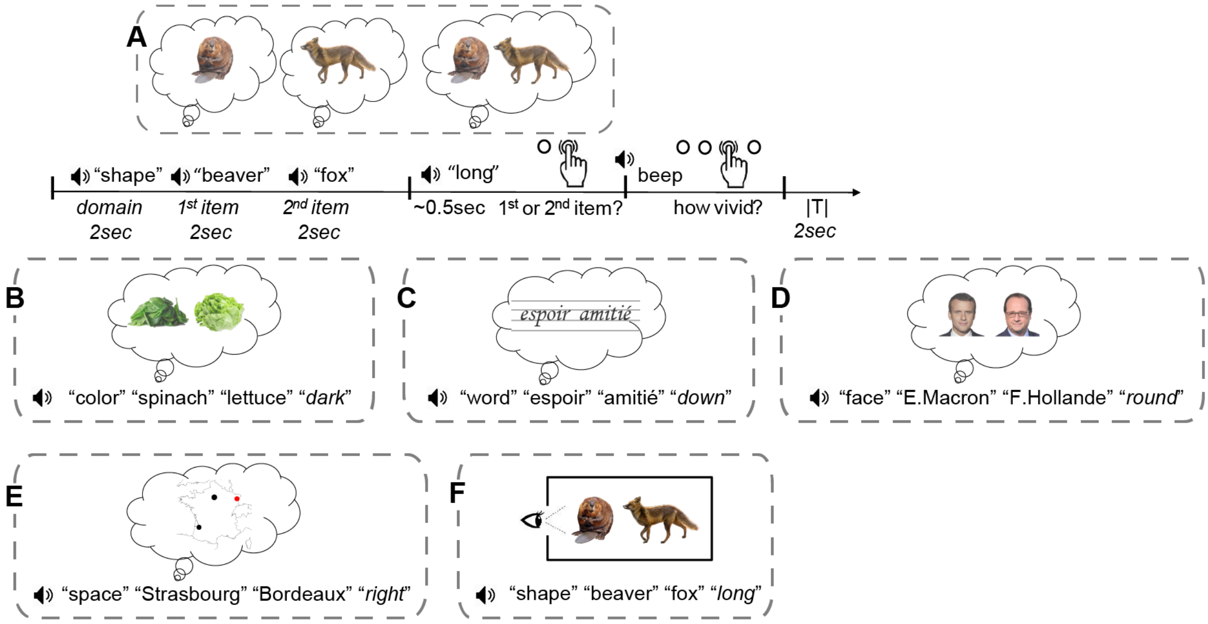

Figure 1. Examples of trials of the eBIP.

The eBIP includes five imagery tasks examining shapes, colors, words, faces, and spatial relationships (panels A-E), and five perceptual tasks using the same items as the imagery tasks (panel F), but with audio-visual stimulus presentation.

Results

Age and years of education were similar across the groups (Bayesian one-way ANOVAs, BFs = 0.13 and 0.10, respectively) (Table 1). As expected, there was a group difference in the VVIQ score (BF = 6.53e75), because aphantasic participants obtained lower VVIQ scores than the other groups did (pairwise comparisons, both BFs > 3.49e47), and typical imagers scored lower than vivid imagers (BF = 2.10e23).

Table 1. Demographic characteristics of participants. Means (SDs) are reported.

	Aphantasic individuals	Typical imagers	Vivid imagers
Gender	10M/34F	16M/26F	7M/24F
Age, years	35.43 (14.99)	37.02 (14.63)	34.74 (13.51)
Years of education	15.38 (1.93)	15.69 (2.35)	15.64 (2.18)
VVIQ score	20.70 (5.53)	57.38 (4.19)	73.03 (3.42)

Table 2 displays descriptive statistics for accuracy, RTs and trial-by-trial vividness scores in the imagery tasks. Table 3 describes statistics for accuracy, RTs, and trial-by-trial confidence scores in the perception tasks.

When comparing the accuracy of imagery and perception within groups, there was strong evidence of differences in accuracy, with main effects from Modality and Domain (BFs close to infinity). Importantly, there was also very strong evidence for the rejection of group differences (BF = 0.02), indicating that aphantasic individuals performed the imagery and perception tasks with the same accuracy as the other groups. Modality interacted with Domain (BF close to infinity), presumably because the accuracy difference between imagery and perception in color (0.23) was higher than in other domains (compare Fig.2A and Fig.3A). There was no other interaction (all BFs <0.01).

Concerning the RTs, BFs strongly supported the main effects of Group (BF = 266), Modality (BF = 1.369e10), and Domain (BF close to infinity). Aphantasic individuals performed the imagery and perception tasks slower than other groups (BFs > 2.75e9); typical imagers were slower than vivid imagers (BF = 3.23). Modality interacted with Domain (BF10 = 7.79e10), presumably because the slowing of RTs in imagery vs. perception for color (0.53s) was greater than for other domains (compare Fig.2B and Fig.3B). There was no evidence for other interactions (all BFs < 0.06).

The expected group effect for vividness was also observed for trial-by-trial vividness scores (BF = 5.00e14), because aphantasic participants had lower overall scores than the other groups (BFs > 1.82e79), and typical imagers obtained lower scores than vivid imagers (BF = 1.41e5). There was also an effect of Domain (BF = 1.43e7), which however did not interact with the group (BF = 8.43). Aphantasic participants had especially lower trial-by-trial vividness scores than the other groups in all domains (BFs > 1.67e10, Fig. 2C). Additionally, typical imagers had lower scores than vivid imagers in face imagery (BF = 27.93).

Within the imagery tasks, the overall accuracy showed a main Domain effect (BF = 1.11e14). There was no main Group effect (BF = 0.49), and no interaction between Group and Domain (BF = 0.01). Furthermore, there was moderate evidence for equivalence of accuracy across groups for face and space imagery (BFs < 0.17) and very strong evidence for equivalence across groups for color imagery (BF = 0.02). Also imagery of shapes and words elicited equivalent accuracy across groups (BF = 0.59 and 0.44, respectively).

Concerning the overall imagery RTs, there were main effects of Group (BF = 233) and Domain (BF = 187), because aphantasic participants responded 0.45 sec slower on average than the other groups (pariwise BFs > 11.91). Group and Domain did not interact (BF = 0.24), but aphantasic individuals responded slower than typical imagers did for shape and word imagery (BFs > 11.91), and had slower RTs than vivid imagers for imagery of shape, color, words, and faces (Fig. 2B; BFs > 11.36). There was insufficient evidence for group differences in RTs for imagery of spatial relationships (BF = 1.03).

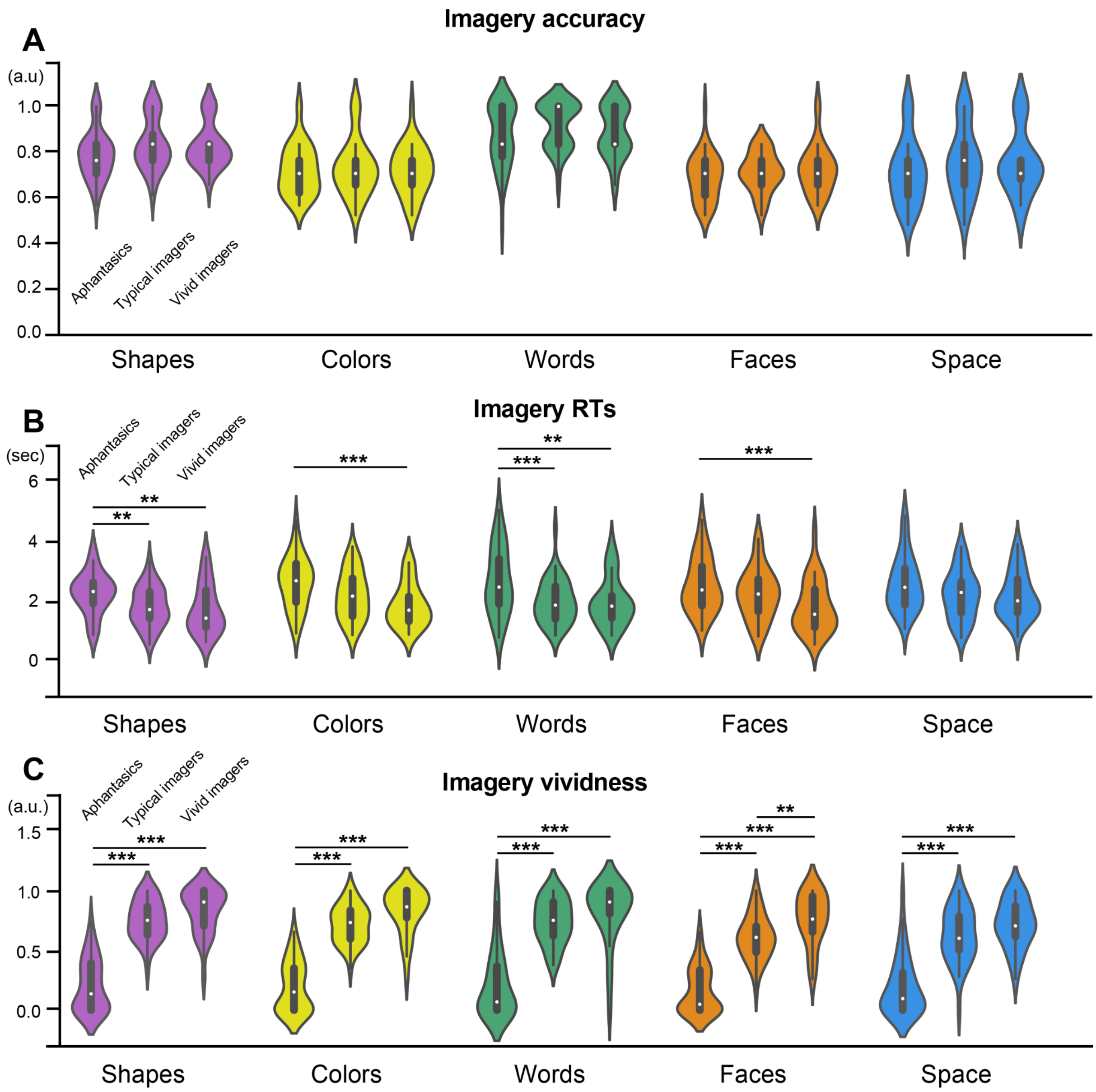

Figure 2. Visual imagery task performance across groups.

* BF 3-10; ** BF 10-30 ; *** BF > 30; a.u., arbitrary units.

Table 2. Performance of the three groups on the visual imagery tasks

	Aphantasic individuals mean (SD)	Typical imagers mean (SD)	Vivid Imagers mean (SD)
Imagery accuracy (proportion correct)			
Shapes	0.86 (0.11)	0.90 (0.09)	0.91 (0.06)
Colors	0.79 (0.13)	0.79 (0.13)	0.79 (0.12)
Words	0.91 (0.11)	0.96 (0.05)	0.94 (0.07)
Faces	0.74 (0.15)	0.79 (0.12)	0.80 (0.14)
Space	0.76 (0.16)	0.76 (0.20)	0.82 (0.13)
Imagery RTs (sec)			
Shapes	2.21 (0.69)	1.76 (0.65)	1.67 (0.81)
Colors	2.57 (0.85)	2.13 (0.79)	1.80 (0.71)
Words	2.62 (1.11)	1.92 (0.72)	1.91 (0.78)
Faces	2.48 (0.91)	2.19 (0.83)	1.75 (0.85)
Space	2.53 (0.91)	2.15 (0.80)	2.12 (0.76)
Imagery vividness (arbitrary units)			
Shapes	0.20 (0.22)	0.75 (0.16)	0.84 (0.18)
Colors	0.19 (0.21)	0.72 (0.16)	0.83 (0.19)
Words	0.21 (0.27)	0.74 (0.18)	0.82 (0.25)
Faces	0.16 (0.19)	0.61 (0.18)	0.77 (0.21)
Space	0.20 (0.24)	0.63 (0.22)	0.72 (0.20)

Table 3. Performance of the three groups on the visual perception tasks

	Aphantasia mean (SD)	Typical imagers mean (SD)	Vivid Imagers mean (SD)
Perceptual accuracy (proportion correct)			
Shapes	0.95 (0.10)	0.96 (0.09)	0.94 (0.11)
Colors	0.98 (0.07)	0.96 (0.08)	0.94 (0.11)
Words	0.87 (0.18)	0.86 (0.19)	0.92 (0.12)
Faces	0.78 (0.21)	0.78 (0.16)	0.80 (0.13)
Space	0.84 (0.19)	0.85 (0.22)	0.86 (0.19)
Perceptual RTs (sec)			
Shapes	2.66 (0.83)	2.06 (0.76)	2.04 (0.84)
Colors	1.96 (0.79)	1.59 (0.55)	1.39 (0.79)
Words	2.20 (0.87)	1.89 (0.72)	1.79 (0.85)
Faces	2.53 (1.00)	2.08 (0.75)	1.87 (0.73)
Space	2.78 (0.92)	2.54 (1.06)	2.29 (0.93)
Perceptual confidence (arbitrary units)			
Shapes	0.75 (0.27)	0.83 (0.21)	0.90 (0.14)
Colors	0.82 (0.25)	0.85 (0.22)	0.95 (0.12)
Words	0.75 (0.31)	0.77 (0.29)	0.87 (0.22)
Faces	0.61 (0.24)	0.68 (0.23)	0.80 (0.17)
Space	0.81 (0.25)	0.86 (0.18)	0.89 (0.16)

Table 3 displays descriptive statistics for the perception tasks. Concerning accuracy, there was a significant main domain effect (BF close to infinity), presumably because faces evoked more errors that the other domains. However, this was true for all groups (BF = 0.034), and there was no Domain x Group interaction (BF = 0.004). BFs supported group equivalence in accuracy in all perceptual domains (all BFs < 0.23, except color, BF = 0.36; Fig. 3A).

On the overall perceptual RTs, there was a main effect of Group (BF = 28.08) and a significant Domain effect (BF close to infinity). Similar to the imagery tasks, aphantasic participants had slower overall perceptual RTs than the other groups (BFs > 2,250). There was no interaction effect (BF = 0.04). Concerning specific domains, aphantasic participants had slower RTs than typical imagers in the perception of shape and color (BFs > 3.43) and slower RTs than vivid imagers in the perception of shape, color, and faces (BFs > 6.14; Fig. 3B). There was no evidence for group RT differences in the perception of words (BF = 0.71) or spatial relationships (BF = 0.51). Concerning perceptual confidence, there were main effects of Group (BF = 4.56) and Domain (BF = 5.807e12), which did not interact (BF = 0.054). Aphantasic participants and typical imagers were generally less confident about their responses than vivid imagers (BFs = 7.78e5 and BF = 61.06, respectively). Aphantasic participants were especially less confident than vivid imagers in the perception of shapes and faces (BFs > 6.57). However, their confidence level was the same as the other groups when it came to perceiving spatial relationships (BF = 0.24; Fig. 3C). Typical imagers showed less confidence than vivid imagers in face perception (BF = 3.79).

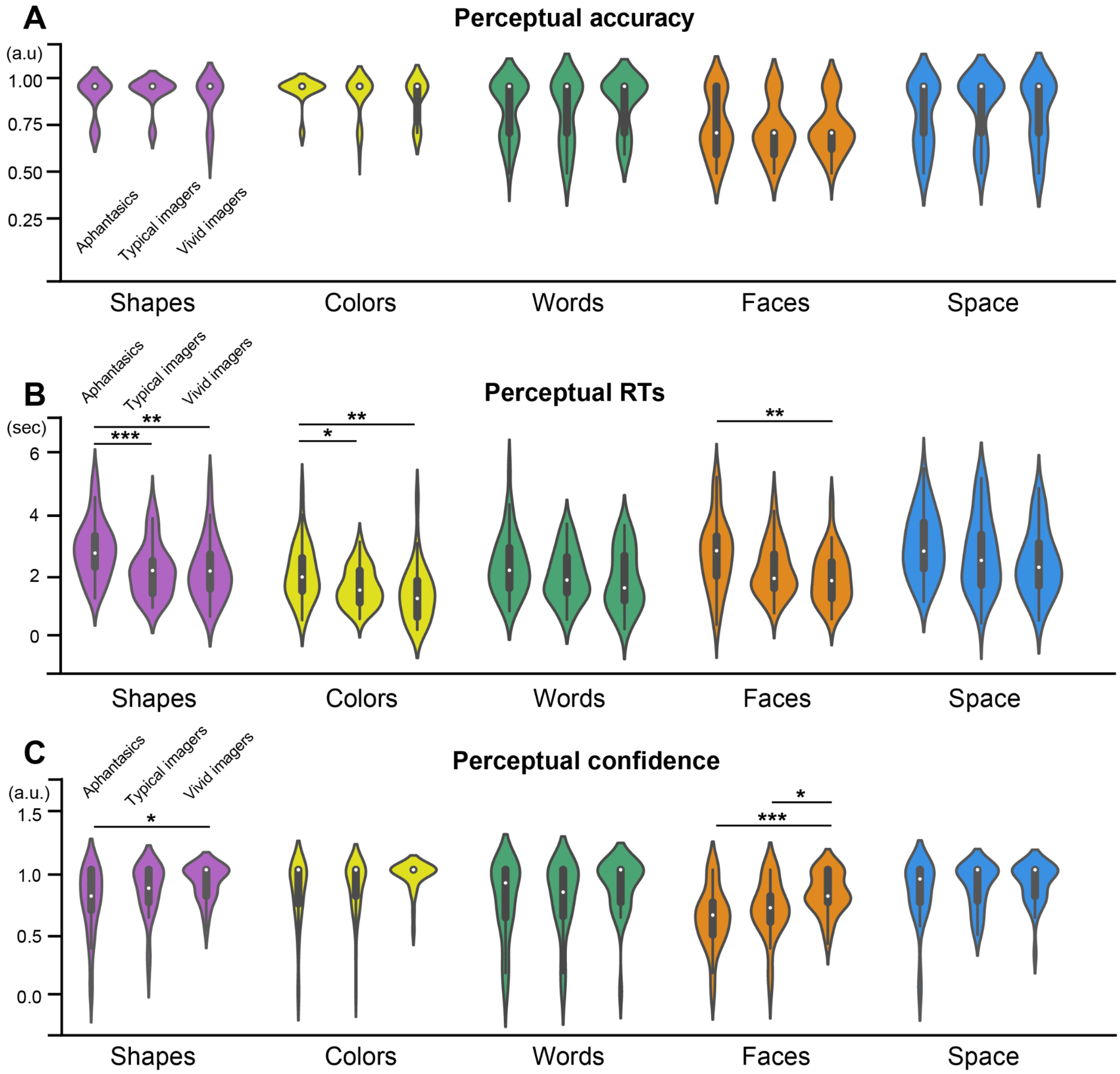

Figure 3. Performance on visual perception tasks.

* BF 3-10; ** BF 10-30 ; *** BF > 30; a.u., arbitrary units.

Across all the response time data there seems to be a general trend that aphantasic individuals took longer to respond both in the imagery condition and in the perception condition. Could it be the case that those with aphantasia were simply slower at everything they were tested for? Independent evidence from another study (Liu et al., 2023) suggests that this is not the case. Liu et al. had ten typical imagers and ten aphantasic individuals (distinct from the participants in the present study) perform the eBIP while their brain activity was measured using fMRI. Importantly, participants also performed an additional control task minimizing visual mental imagery, wherein they had to answer questions related to the meaning of abstract words. The behavioral results (Table 4) confirmed that individuals with aphantasia exhibited slower RTs compared to typical imagers in both imagery and perception tasks (BF = 30 and 85, respectively). Crucially, however, there was no significant difference in RTs between the two groups in the control task involving abstract words (BF = 0.41). This finding suggests that individuals with aphantasia tend to exhibit slower RTs when answering questions related to the visual characteristics of items (whether real or imagined), but overall, they are not generally slower compared to individuals with typical imagery abilities.

In the present participant group, we also performed a Bayesian linear regression analysis and found strong evidence that the trial-by-trial vividness predicted participants' RTs, as the odds in favor of the model including vividness were 28.81 times higher compared to the null model. The posterior mean and SD for the vividness factor were -0.60 (0.18) with a 95% credible interval from -0.96 to -0.23, indicating an inverse correlation between subjective vividness and RTs in the imagery tasks for the entire participant group. Such correlation was even stronger (BF = 332) after having excluded aphantasic individuals with normalized vividness scores close to 0 (Figure 4). We observed also an inverse relationship between accuracy scores and RTs in the imagery tasks (Pearson's $r = -0.26$, BF = 13.02). Importantly, this result excludes the possibility that participants traded speed for accuracy when performing the imagery tasks.

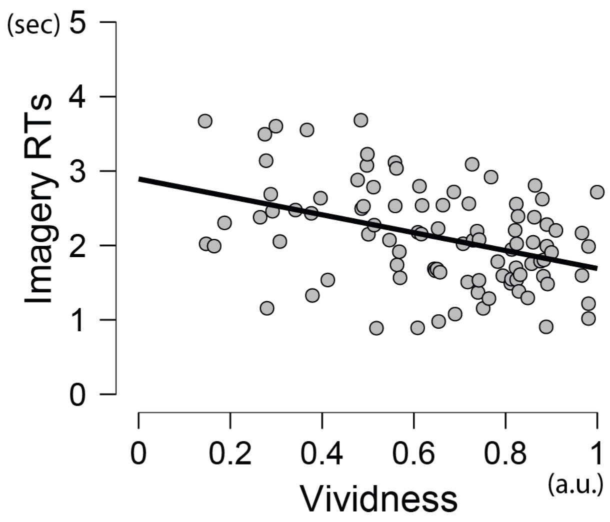

Figure 4. Scatterplot showing the negative correlation between subjective vividness and RTs in the imagery tasks, after the exclusion of individuals with vividness scores close to 0.

Table 4. RTs (in sec) for participants with aphantasia (N=10) or typical imagery (N=10) from the Liu et al's fMRI study (Liu et al., 2023)

	Shapes mean (SD)	Colors mean (SD)	Words mean (SD)	Faces mean (SD)	Maps mean (SD)
Imagery					
Typical imagers	1.57 (0.20)	1.60 (0.21)	1.47 (0.21)	1.65 (0.20)	1.71 (0.33)
Aphantasics	1.88 (0.55)	1.95 (0.58)	1.73 (0.69)	2.04 (0.67)	2.04 (0.62)
Perception					
Typical imagers	1.24 (0.28)	1.31 (0.27)	1.23 (0.19)	1.38 (0.26)	1.46 (0.33)
Aphantasics	1.69 (0.71)	1.79 (0.89)	1.70 (0.84)	1.83 (0.84)	1.70 (0.69)
	Abstract words				
Typical imagers	2.45 (0.55)				
Aphantasics	2.53 (0.52)				

Discussion

We examined the cognitive abilities of individuals with varying levels of vividness in visual mental imagery across five domains: object shape, object color, written words, faces, and spatial relationships. Our participants did not report any neurological or psychiatric history; thus, their lack of visual mental imagery may be considered as congenital aphantasia

(Zeman et al., 2015). This is an inference based on the fact that participants did not report events that could be associated with the usual causes of acquired aphantasia: stroke (e.g., Bartolomeo et al., 2002), head trauma (e.g., Moro et al., 2008), or psychiatric conditions (e.g., de Vito & Bartolomeo, 2016). Our study demonstrated, through Bayesian analysis, that aphantasic participants had comparable accuracy on all tasks compared to other groups, but had longer response times across all domains except spatial relationships, and had lower confidence in their responses on tasks involving perception of shapes and faces. These results suggest that congenital aphantasia affects the speed of information processing in both visual imagery and visual perception tasks, but not its precision.

Concerning the predictions outlined in the introduction, our results do not align with predictions (1) and (2) which suggest a deficit in information processing and fast, direct access to semantics respectively. Instead, the results partially confirm predictions (3) and (4), which suggest the use of non-visual, spatiomotor strategies and an introspection deficit respectively. Specifically, the preserved accuracy is inconsistent with prediction (1) and the slowed RTs are inconsistent with prediction (2). Prediction (3) would have expected poorer performance in aphantasic individuals on imagery tasks that do not involve spatiomotor abilities, such as color and face imagery. This prediction was partially supported by the increased RTs for shapes, colors, words, and faces, but relatively normal RTs for spatial relationships. However, accuracy across all domains was also preserved, contrary to this prediction.

Our findings seem to better align with prediction (4), of defective introspection. This is because the preserved accuracy suggests that access to visual information from semantic memory is maintained, despite the absence of phenomenal consciousness. If this is the case, then congenital aphantasia would serve as an illustration of access consciousness without phenomenal consciousness (Block, 1995). For instance, visual information could be processed to a level sufficient to produce a correct response, but not integrated enough or too noisy to reach a stable metacognitive level of processing. This form of impaired phenomenal consciousness might also explain the decreased confidence in responses requiring the perceptual processing of shapes and faces. Reduced ability for self-reflection in neurotypical participants is a common observation, e.g. in the domain of spatial attention (Bartolomeo et al., 2007; Decaix et al., 2002; Recht et al., 2021).

A possible objection to our conclusions is that, despite our efforts to exclude all non-visual questions from the eBIP, there may be instances where our questions may have measured non-visual semantic knowledge instead of visual mental imagery. Against this possibility, we note that, first, as mentioned in the introduction, patients with left temporal damage who report losing their visual mental images typically perform poorly on tests similar to the eBIP despite normal semantic memory (Bartolomeo, 2002; Beauvois & Saillant, 1985). Additionally, in our participant sample, there was an inverse correlation between RTs and vividness scores, which suggests that our participants were indeed attempting to construct visual mental images when performing the eBIP. The eBIP was developed from a previous clinical tool designed to assess neurological patients (Bourlon et al., 2009). Both in the previous and in the present version, we specifically chose trials where individuals with typical mental imagery capabilities reported generating mental images in response to imagery-based questions. In pilot testing, we excluded all trials that could be responded to by using nonvisual semantic memory. For example, we excluded trials where words were strongly associated with color names, such as "teeth/snow", "cane sugar/ice sugar", and "ashes/coal" (see Bartolomeo et al., 1997, for further discussion of this issue).

In our data, there seems to be a general trend for aphantasic individuals to take longer to respond both in the imagery condition and in the perception condition. This pattern may suggest that aphantasic individuals have a natural tendency to respond slower, unrelated to visual mental imagery, although we haven't found any independent evidence supporting this idea. Three lines of evidence contradict the possibility of an aspecific RT slowing in aphantasia. First, a previous study demonstrated that individuals with aphantasia were able to perform various cognitive and neuropsychological tasks with similar RTs compared to controls, with the exception of challenging versions of a visual working memory task (Pounder et al., 2022). Second, our participants' RTs exhibited an inverse correlation with imagery vividness, indicating that individuals with higher imagery vividness tended to have faster RTs. This suggests that the slower RTs observed in individuals with aphantasia are indeed associated with their lower levels of imagery vividness. Third, in a separate study involving individuals with aphantasia and individuals with typical imagery abilities, both groups performed the eBIP task along with an additional task involving abstract words (Liu et al., 2023). The results revealed that individuals with aphantasia exhibited slower RTs for both imagery and perceptual items, which is consistent with the findings of the present study. However, there was no significant difference in RTs between the two groups for the task involving abstract words. Future studies should incorporate an appropriate control condition to further investigate the reasons behind the slower RTs observed in individuals with aphantasia.

There are some limitations to consider in the current study. First, the participants were recruited online, which resulted in less control over the specific environment and behavior compared to a lab-based study, despite providing detailed instructions to the participants. Second, the study relied on self-report measures of VVIQ to identify participants with congenital aphantasia, which could have introduced bias due to individual differences in self-judgment, as some typical imagers may have thought they had dim or vague visual imagery. To address this issue, the study excluded participants with VVIQ scores between 33-48 and 65-67. Third, the retrieval of domain-specific visual imagery in the study relied on semantic knowledge, and there was no control over the knowledge level of the participants about the items used in the imagery tasks (e.g., names of celebrities and French cities). This may have led to reduced performance in some participants due to a lack of semantic knowledge. Future studies should consider the participant's familiarity with the items before the task session in the lab. Last, it is currently unclear whether congenital aphantasia is a uniform condition or if it comprises various subtypes that utilize different cognitive processes and result in different levels of efficiency. Future work should explore potential individual variations in aphantasia to gain a more comprehensive understanding of the underlying cognitive mechanisms.

To summarize, our study established that individuals with congenital aphantasia exhibit normal overall accuracy on imagery tasks, but have longer response times and less confidence in their responses on some visual perception tasks. These differences may be related to impaired introspection and the use of alternative strategies to complete the imagery tasks. Research efforts are in progress (Liu et al., 2023) to investigate the neural mechanisms underlying these behavioral observations.

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