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Review article

"*The Giant Black Elephant with white Tusks stood in a field of Green Grass*": Cognitive and brain mechanisms underlying aphantasia

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A R T I C L E I N F O

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A B S T R A C T

Aphantasia, a spectrum of inabilities creating and perceiving mental images, is becoming more of a focus in continued research to better understand functions of sensory perception and imagination. Current research on aphantasia is still in an era of exploration to find its underlying neural mechanisms, comorbidities and comparing levels of visual imagery to other cognitive functions. Through a systematic review, this article explores the most influential developments in aphantasia research. The search included 3 databases-*PsycINFO, PubMed, and Web of Science.* After a rigorous selection process, 52 studies are included in this review. The findings include new research themes across different studies such as relationships between aphantasia and diminished episodic and autobiographical memory, comorbidities including autism, attention, emotions, and neurobiological differences. By integrating diverse perspectives, this review aims to contribute to a deeper understanding of the cognitive processes underlying mental imagery and offers implications for further development in aphantasia research.

1. Introduction

The ability to form visual imagery underlies an array of cognitive functions, such as executive processes in selecting and maintaining visualization, memorizing to remember the content to be imagined, and perceptual processes involving visual qualities (Daselaar et al., 2010; Zvyagintsev et al., 2013). While imagination and forming visual imagery of items and events may be implicit and variable across most people, there are conditions where such abilities may be compromised. Aphantasia is generally known as the inability or relative deficiency in the ability to voluntarily create visual mental images (Zeman et al., 2015), although the exact definition and the experience of it across individuals are debatable. While this cognitive variation is not newly identified (Galton, 1880), it has recently seen a surge in research interest, especially the impact of aphantasia on other aspects of human cognition, including but not limited to memory, attention, mood, and dreams. Thus, emerging evidence from aphantasia research confirms, along with many years of previous research, that visual imagery is central to many cognitive abilities used in everyday life.

Although the reported prevalence rates of aphantasia varies, recent literature (Beran et al., 2023) indicates an 8.9 % rate among an adult population with self-report measures, which was much more than 1.5 % that was collected using questionnaires from the same

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population. A recent study reported a 3.9 % prevalence of aphantasia in the general population (Dance et al., 2022). Online social support groups among various media sites are common with the presence of self-reported aphantasics. For example, the Aphantasia group on Reddit, a social network site, currently consists of around 67,000 members.

Notwithstanding the historical scientific documentation on the complexity of mental imagery generation, the specific causes of aphantasia are generally unknown. There are instances in which the condition can follow a neurological injury-specifically to the left temporal lobe (Bartolomeo, 2002). However, the specificity of such injuries and its resultant manifestation of aphantasia may be debatable. Neuroimaging studies have identified the neural correlates of visual imagery, and recent studies have hypothesized distinguishable neurological characteristics in aphantasic versus control participants. For example, positron-emission tomography (PET) studies have reported the primary visual cortex (V1 or Brodmann Area 17) to be central to creating visual mental imagery (Kosslyn & Thompson, 2003). Visual imagery has also been found to be associated with activation of supramodal and frontoparietal areas, (Ishai et al., 2000), higher order visual cortices, posterior cingulate cortex (PCC), medial temporal lobes, and the precuneus (Fulford et al., 2018). Furthermore, hippocampal activity has been shown to correlate with the vividness of autobiographical memory (Addis et al., 2004; Sheldon & Levine, 2013).

Previous studies have assessed aphantasia largely through questionnaires and psychometric tests. Most used across recent research is the *Vividness of Visual Imagery Questionnaire* (VVIQ; Marks, 1973) which allows for a scaled response of visual imagery across different imagined scenarios. The VVIQ asks participants to conjure various mental images (e.g., visualize the rising sun) and rate their clarity and vividness relative to normal vision. Additionally, psychophysical methods like the binocular-rivalry paradigm have been used to assess aphantasia by presenting different images to each eye and participants are asked if they saw one image, two images, or a blend of the two after being primed with a stimulus to imagine. Previous work has demonstrated that imagery strength measured by the binocular rivalry paradigm predicts subjective reports of imagery vividness (Pearson et al., 2011; Pearson, 2014).

The main goal of the current study is to review the existing empirical studies and case studies solely on aphantasia to identify emerging consensus across the current findings, discuss any discrepancies, and to discuss future research directions. The purpose of this systematic review is to examine the empirical evidence of aphantasia and report it for the purpose of understanding and for reference for future and current researchers. This is not the first review of aphantasia research as Zeman (2024) recently published a review article on the extremes of visual imagery including both aphantasia and hyperphantasia (Zeman, 2024). However, our study is a systematic review that focuses specifically on current findings and emerging themes in aphantasia research. The literature surrounding aphantasia per se is relatively limited and is gaining interest from researchers only recently. Additionally, there are even fewer studies that examine the underlying mechanisms of aphantasia, and how it impacts different skills. In this review, we plan to uncover possible underlying cognitive and neural mechanisms of aphantasia and their effects on different day-to-day activities. Better understanding of the findings will shed light on the mechanisms behind aphantasia and ways to metacognitively enhance mental imagery and/or address potential compensatory mechanisms to overcome limited or lack of imagery.

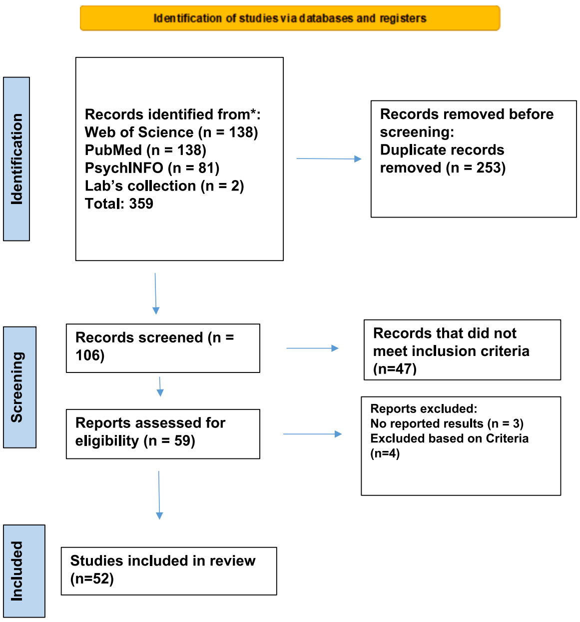

Fig. 1. Identification of Studies Fig. 1. Flow diagram of study identification via databases. Records were identified from three databases, and records that passed a screening were assessed by full text analysis for eligibility. 52 studies were included in the present review. The diagram was adapted from the PRISMA 2020 guidelines http://www.prisma-statement.org/ *Note*: Our research group has collected research articles on imagery over the years obtained at different times and not through search engines. Of our collection, two articles were used in this literature review.

2. Methods

Initial literature searches were conducted in October and November 2023, and updated in February and September 2024 using online databases *PsycINFO, PubMed*, and *Web of Science*. The search terms were "aphantasia;" "aphantasia" AND "memory;" "aphantasia" AND "reading;" "aphantasia" AND "autism;" "aphantasia" AND "fMRI"; ""aphantasia" and "individual differences." The term "aphantasia" was coined in 2015, and since then there has been a resurgence in general interest and empirical research on the phenomenon. Therefore, the search included publications within the past 9 years focusing specifically on publications using a clear aphantasic group (not other diagnoses or simple visual imagery differences). The studies included in this review met the following criteria: 1) reported as an empirical study 2) case report 3) published in a peer reviewed journal 4) written in English; and 5) the participants had aphantasia. Literature searches and screening procedures were repeated by multiple raters to ensure reliability. First, all search terms and combinations were searched across three search engines to identify articles for inclusion. The titles and abstracts were screened using the established eligibility criteria to determine inclusion. The abstracts that passed the reviewer's initial screening were included for full text review to determine eligibility. Opinion and commentary pieces were excluded from this review in order to solely present the empirical findings on aphantasia. 52 published articles met eligibility criteria (see Fig. 1 and Table 1). Eligibility was confirmed by all raters using the established eligibility criteria. Any differences across raters were discussed further to arrive at a consensus.

3. Results

3.1. Visual deficit or metacognitive deficit?

There has been extensive debate on the conceptualization of aphantasia as a visual deficit or a metacognitive deficit in imagery generation. Most evidence points to the former, with evidence in fear responses and compensatory cognitive mechanisms supporting aphantasia as a deficit in creating visual imagery (Keogh & Pearson, 2018; Keogh & Pearson, 2024; Wicken et al., 2021). Keogh and Pearson, (2018) found that 15 aphantasics, who demonstrated a lack of sensory imagery, scored in the above average range on spatial cognition suggesting the lack of visual imagery is not due to a lack of metacognition or introspection. The same researchers revisited this study with over 50 aphantasics subjectively extending evidence that aphantasics show a lack of sensory imagery. Interestingly, 12 % of aphantasics scored above 60 % on a priming paradigm, suggesting individuals have some form of "unconscious visual imagery" (Keogh & Pearson, 2024). One study found that individuals with aphantasia are less likely to use visual imagery strategies when asked to visualize and count the number of windows in their home. Instead, they more often used strategies such as avisual spatial imagery, kinesthetic imagery, and amodal "knowledge" to complete the task (Zeman et al., 2020). Another study found that aphantasic individuals scored higher on the cognitive domain of the Subjective Experiences Rating Scale (SERS) compared to control participants (Dawes et al., 2020). Furthermore, Liu and Bartolomeo (2023) suggest that congenital aphantasics experience a slowing in visual processing, but not any diminishment in accuracy, supporting their hypothesis of aphantasia as a deficit of phenomenal consciousness, or it uses different networks to access visual information other than visualization.

3.2. Subtypes of Aphantasia

Aphantasia is consistently reported as a lack of visual imagery. However, there are questions whether subtypes of aphantasia exist. There have been noted differences in performance for spatial and object visual imagery as distinguished by the Object and Spatial Imagery Questionnaire (OSIQ). Three studies found individuals with aphantasia to have deficits in object imagery only, highlighted by lower score in the object imagery subscale of OSIQ (Dawes et al., 2020; Dawes et al., 2022; Wittmann and Satirer, 2022), and a recent study found no reports of spatial orientation difficulty in a sample of 14 aphantasics (Monzel et al., 2024). However, one study (Palermo et al., 2022) found a distinction between spatial and object aphantasia deficits, suggesting subtypes of aphantasia in which object and spatial imagery are impaired. It should be noted that this is the sole result in this object and spatial imagery distinction. A case study example assessed the object and spatial imagery of a 24-year-old woman with congenital aphantasia using the OSIQ (Ganczarek et al., 2020). She scored very low on the object subscale and scored high on the spatial imagery subscale (a score of 22 compared to a score of 51). Moreover, on intelligence testing subscales the patient reported a preference in using spatial and verbal related information over object related ones in solving problems on an intelligence test (Ganczarek et al., 2020). Taken together, these results show an example of how differences in object and spatial imagery can impact individuals with aphantasia.

In a recent study, Dawes, Keogh, and Pearson (2024) proposed another way of subtyping aphantasia. They propose a modality-based subtype of aphantasia. Visual aphantasia was identified as the impairment of visual imagery, but an otherwise intact sensory imagery. Multisensory aphantasia was identified as both the impairment of visual and other sensory modality imagery (Dawes et al., 2024).

3.3. Aphantasia comorbidities

The inability to create visual imagery can accompany other diminished sensory experiences, such as anauralia, the lack of auditory imagery. In one study, individuals with aphantasia reported lower scores within auditory imagery (Hinwar & Lambert, 2021). In another study, Aryadoust (2019) examined the association between listening comprehension and visual imagery using an objective measure. Participants listened to oral excerpts and afterwards verbally described what they had seen in their mind's eye. The single

Table 1
Methodology of Articles Included.

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
Visual Deficit or Metacognitive Deficit?							
	Dawes et al. (2022)	Empirical	30	30	18–68	Self-identified	Aphantasic individuals scored higher on the cognitive domain of the Subjective Experiences Rating Scale (SERS) compared to control participants
	Keogh & Pearson (2018)	Empirical	224	15	Aphantasic (21–68), Control (18–80)	Self-identified; VVIQ	Results suggest aphantasia is not a metacognitive deficit or inability to introspect but rather lack of low-level sensory visual imagery. Aphantasics were impaired on all visual object imagery measures, but not spatial imagery.
	Keogh & Pearson (2024)	Commentary & Empirical	0	51	?	VVIQ; self-identification	Aphantasics do not show evidence of sensory visual imagery in binocular rivalry
	Liu & Bartolomeo (2023)	Empirical	42	44	Aphantasic (M = 35.43), Control (M = 34.74)	VVIQ	Aphantasic participants had comparable accuracy on imagery and visual perception tasks. Aphantasics performed the tasks slower than other groups, with slower reaction times overall compared to other groups.
	Wicken et al. (2021)	Empirical	E1: 24, E2: 15	E1: 22, E2: 16	Aphantasic (M = 33), Control (M = 23)	Self-identified, VVIQ, Binocular Rivalry Task	E1: Aphantasics had lower skin conductance level during imagery trials compared to controls. E2: this difference was not observed in perception trials.
	Zeman et al. (2020)	Empirical	400	2200	Aphantasia (M = 41.31), Control (M = 56.80)	VVIQ	Aphantasia is associated with difficulty in face recognition and impoverished autobiographical memories. Aphantasics were more likely to report absence of dreams, but a majority report they dream visually. About half of aphantasics report no imagery in any sensory modality, but many have imagery in one or more, often auditory.
Subtypes of Aphantasia							
	Dawes et al. (2020)	Empirical	control group 1 = 203; control group 2 = 197	267	17–75	Self-identified; VVIQ	Aphantasics scored lower on object imagery, report lower audio, tactile, kinesthetic, taste, olfactory, and emotion imagery. 26.22 % of aphantasics reported a complete lack of multi-sensory imagery. 73.78 % of aphantasics report imagery in non-visual sensory modalities. Aphantasics report lower ability to remember specific life events, factual memory, and almost no ability to generate visual sensory imagery when remembering past and future events. They report significant fewer night dreams, lower awareness and control during dreams, less vivid emotions in dreams – no differences in dream

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							cognitions or details of spatial features. No spatial abilities differences between the groups. No evidence for protections against trauma symptomology
	Dawes et al. (2022)	Empirical	30	30	18–68	Self-identified	Aphantasic individuals scored higher on the cognitive domain of the Subjective Experiences Rating Scale (SERS) compared to control participants
	Dawes et al. (2024)	Empirical	N/A	Sample 1: 962, Sample 2: 1148	Sample 1 (M = 39.24), Sample 2 (M = 40)	Self-identified; VVIQ	2 subgroups of aphantasia identified: visual aphantasia (impaired visual imagery, intact other sensory modality imagery) and multi-sensory aphantasia (impaired imagery in all sensory modalities)
	Ganczarek et al. (2020)	Case Study	N/A	1	24	VVIQ & Spontaneous Use of Imagery Scale; SUIS	Subject became aware of lack to visualize in college; however, did not prevent the achievement of good grades. She cannot use the benefits of imaginations when reading books or relaxing with a nice image in mind. No imagery in dreams and no experience of involuntary imagery. Does not remember the color of her mother's hair and forgets many things. When describing events from her biography, she sporadically used image characteristics such as adjectives – few references to emotions or sensations. She scored low on object imagery, but high in spatial imagery and verbal reasoning. She tested within normal range in working memory tasks. High general intelligence- testing higher on verbal scales versus spatial and visual processing scales. Aphantasia did not seem to affect general cognitive processing
	Monzel et al. (2024)	Empirical	16	14	Aphantasic (M = 31.47, SD = 10.45); Control (M = 28.19, SD = 12.27)	VVIQ, Binocular Rivalry Task	Poor autobiographical retrieval can lead to an episodic memory deficit which can be reflected through neural altered activation and connectivity between the hippocampus and visual-perceptual cortices
	Palermo et al. (2022)	Empirical	434	32	18–78	Object and Spatial Imagery Questionnaire (OSIQ)	They found a distinction between spatial and object aphantasia deficits, suggesting subtypes of aphantasia in which object and spatial imagery are impaired. Both groups were found to have intact involuntary object imagery. All object aphantasics reported mental imagery in their dreams, one spatial aphantasic reported no mental imagery during dreams. There were no significant differences between both aphantasic group and controls on retrospective and prospective memory tasks. Regarding face recognition, object aphantasics reported significantly lower face recognition skills than

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							spatial aphantasics. Concerning navigational skills, both OAph and SAph groups reported significantly lower navigational skills than Controls. Developmental topographical disorientation was found in 5 out of 15 in the OAph group (33.3 %) and 2 out of 17 in the SAph group (11.8 %).
	Wittmann & Satirer (2022)	Empirical	41	55	Aphantasic (M = 37.6, SD = 14.6); Control (M = 33.4, SD = 12.2)	VVIQ	Aphantasics when compared to controls showed lower rates of high confidence hits in associative memory tests; Aphantasics scored lower on the object scale of the OSIQ but not on the spatial scale; there was also a report of lower auditory imagery.
Aphantasia Comorbidities							
	Aryadoust (2019)	Empirical	30	1	18–24	N/A	The one aphantasic participant did not report any conspicuous difficulty in his listening comprehension, and his score was just above the mean score.
	Dance et al. (2021)	Empirical	E1a: 1073; E1b: 16,050; E2: 118	E1a: 212; E1b: 196; E2: 118	E1a: 18+; E1b: M = 29.11 (SD = 11.76); E2: aphantasic (M = 38.47, SD = 14.14) controls (M = 37.87; SD = 15.22)	VVIQ	E1a: grapheme-color synesthesia can exist within people with aphantasia and is no less prevalent compared to non-aphantasics. E1b: replication of findings from E1a. E2: People with aphantasia report higher AQ scores, specifically social skills and imagination subscales.
	Dance et al. (2021b)	Empirical	E1: 138; E2: 77; E3: 56	E1: 164; E2: 6; E3: 56	E1: aphantasic (M = 42.35); control (M = 37.39). E2: (M = 19.87). E3: aphantasic (M = 33.66); control (M = 29.84)	VVIQ	E1: aphantasics have weaker imagery compared to controls. They also had imagery deficits in at least one other domain (olfactory, gustatory). Aphantasics also report lower sensory sensitivity E2: imagery and sensory sensitivity is positively correlated in the general population. E3: people with aphantasia report significantly less pattern glare than controls, showing they experience lower levels of sensory sensitivity. During the Pattern Glare Task, aphantasics experienced less sensory sensitivity.
	Dance et al. (2023)	Empirical	40	52	Aphantasic (M = 42.25, SD = 16.29); Control (M = = 41.23, SD = 16.66)	VVIQ	Aphantasics compared to controls showed weaker face recognition in both self-report and behavioral measures. However, aphantasics can construct facial composites from memory. There were no differences in the ability to remember and recognize target faces from distractor faces. Aphantasia reported more traits associated with prosopagnosia, less accuracy at recognizing series of target faces, and poor face-matching. Aphantasics had significantly higher AQ scores than controls. However, AQ scores did not significantly correlate with any behavioral face

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							processing measures, before or after correcting for multiple comparisons
	Dupont et al. (2024a)	Empirical	14	14	18–26	VVIQ; Vividness of Movement Imagery Questionnaire (VMIQ-2)	Aphantasics do not explicitly generate motor images when prompted to explicitly imagine a maximal pinch movement in visual and kinesthetic modalities, nor present an increase in corticospinal excitability during explicit motor imagery. The same effect was observed during an implicit form of motor stimulation (observation of a video showing a pinching movement). Using transcranial magnetic stimulation, researchers triggered motor-evoked potentials in the target right index finger. This did not increase amplitude in aphantasics. It was also found that aphantasics present limited abilities in kinesthetic modalities but not a complete impairment. AQ scores did not differ between the two groups
	Hinwar & Lambert (2021)	Empirical	94	34	18–70	VVIQ	82 % of aphantasics were categorized as anauralic (lack of auditory imagery).
	Milton et al. (2021)	Empirical	Hyperphantasia = 25; Phantasics = 20	24	Aphantasic (M = 33.71; SD = 11.25); Control (M = 34.6; SD = 12.78); Hyperphantasics (M = 35.36; SD = 11.10)	VVIQ	During resting state fMRI, hyperphantasics revealed stronger connectivity between prefrontal cortices and the visual network than aphantasic participants. During task-based fMRI, there was greater anterior parietal activation among hyperphantasic and controls than aphantasics when comparing visualization of famous faces and places
	Monzel et al. (2024)	Empirical	16	14	Aphantasic (M = 31.47, SD = 10.45); Control (M = 28.19, SD = 12.27)	VVIQ, Binocular Rivalry Task	Poor autobiographical retrieval can lead to an episodic memory deficit which can be reflected through neural altered activation and connectivity between the hippocampus and visual-perceptual cortices
	Palermo et al. (2022)	Empirical	434	32	18–78	Object and Spatial Imagery Questionnaire (OSIQ)	*See results in subtypes of aphantasia*
	Pounder et al. (2024)	Empirical	30	29	Aphantasics (M = 38.1), Control (M = 39.1)	VVIQ	Aphantasics participants reported deficits in auditory and visual imagery, recorded by Buckness Auditory Imagery Scale. No evidence for subtypes of aphantasia
	Takahashi et al. (2023)	Empirical	2,465	105	Aphantasic, Self-identified(M = 35.29, SD = 9.38); Aphantasic, not self-identified (M = 40.67, SD = 9.53); Control (M = 38.20, SD = 11.65)	VVIQ	There is a discrepancy in the sample of those who identify as aphantasic and those who qualify as aphantasic, according to the VVIQ. 3.7 % fulfilled VVIQ criterion and 12.1 % fulfilled self-identification criterion. Self identification criterion contains questions related to face recognition, but not the VVIQ. There was no correlation of face recognition

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							ability and the low VVIQ (not self-identified aphantasics) group. In an additional analysis revealed that some aphantasics lacked all types of sensory imagery where others showed only low visual imagery. Aphantasics revealed no specific learning cognitive style (verbalizer or visualizer).
	Zeman et al. (2020)	Empirical	400	2200	Aphantasia (M = 41.31), Control (M = 56.80)	VVIQ	*See results in Visual Deficit or Metacognitive Deficit?*
Aphantasia and Attention	Cabbai et al. (2023)	Empirical	E1: 215, E3:242	E1: 11, E3:97	18–35	Self-identified	In E1, a dissociation between mechanism underlying attentional templates and mental imagery was found. In E3, aphantasics were slower than non-aphantasics during responses. However, mean contingent capture effect was very similar between the two groups. Aphantasics' contingent capture effect was not reduced compared to non-aphantasics.
	Keogh & Pearson (2021)	Empirical	Experiment 2: 10; Experiment 3: 15	Experiment 2: 10; Experiment 3: 15	18–50	Self-identified	Aphantasics experience feature-based attention through priming of the binocular rivalry paradigm. However, there was evidence that they have no attentional templates.
	Monzel et al. (2021)	Empirical	E1: 1324, E2:742	E1: 568, E2: 355	18–69	Self-identified	E1: aphantasics can be primed the same way controls can. E2: interaction effect between groups suggest aphantasics cannot be primed by their own imagery compared to controls. Aphantasics must rely on solely nonvisual search strategies. Researchers examined if attentional guidance in aphantasics is impaired. Amongst aphantasics, there is a lack of attentional guidance through visual imagery as there is no priming of visualization of whole objects by their own imagery. After subjects were primed by words or images, they were shown two stimuli and asked to indicate which corresponded to the mental representation cue. Aphantasics reacted slower to images than controls, relying on non-visual strategies.
	Monzel and Reuter (2024b)	Empirical	104	104	M = 31.66	VVIQ	Aphantasics were slower than controls in finding hidden objects in hidden object pictures when controlling for age and general processing speed.
Aphantasia and Emotion	Dawes et al. (2020)	Empirical	control group 1 = 203; control group 2 = 197	267	17–75	Self-identified; VVIQ	*See results in Subtypes of Aphantasia*
	Monzel et al. (2023)	Empirical	120	112	Aphantasic (M = 35.75), Controls (M = 30.08)	VVIQ	Aphantasics scored lower on the verbalized Pictorial Empathy Test than controls, but not in

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							the visual domain of the assessment. Controls showed higher empathy in a description-based version of the PET, but not in the image-based PET.
	Wicken et al. (2021)	Empirical	E1: 24, E2: 15	E1: 22, E2: 16	Aphantasic (M = 33), Control (M = 23)	Self-identified, VVIQ, Binocular Rivalry Task	E1: Aphantasics had lower skin conductance level during imagery trials compared to controls. E2: this difference was not observed in perception trials.
	Zeman et al. (2020)	Empirical	400	2200	Aphantasia (M = 41.31), Control (M = 56.80)	VVIQ	*See results in Visual Deficit or Metacognitive Deficit?*
Aphantasia and Motor Engagement							
	Dupont et al. (2024a)	Empirical	14	14	18–26	VVIQ; Vividness of Movement Imagery Questionnaire (VMIQ-2)	*See results in Aphantasia Comorbidities*
	Dupont et al. (2024b)	Empirical	17	17	N/A	N/A	While reading, manual action sentences, cortical excitability increased for phantasic participants but not aphantasics. Also reading comprehension abilities were impaired for aphantasics. They presented difficulty in selecting words that best fit the context of the sentences.
	Speed et al. (2024)	Empirical	51	47	Aphantasic (M = 43.67) Control (M = 38.64)		Aphantasics are less likely to be engaged in a short story and empathize with characters. But there is no difference in overall liking of the story or reading habits.
Aphantasia, Dreams, and Involuntary Imagery							
	Beran et al. (2023)	Empirical	1,821 typical imagers; 298 hyperphantasics	77	18–50+	Self-identified; VVIQ	Aphantasics were likely to report “few or no dreams” and less likely to report “dream sometimes.” They also were more likely to report never engaging in self-talk. Scored lower on memory task compared to typical images.
	Cabbai et al., (2024)	Empirical	E1:609, E2:32	E1: 30. E2: 34 and 32	18–29	E1: VVIQ; E2: Self-identified	In E1, there was no evidence for a relationship between hypnotizable and self-repported aphantasia. There was a positive relationship between the phenomenological control scale and VVIQ scores, suggesting that more vivid imagery is related to greater ability to control conscious experience. Aphantasics did score lower on the PCS than non-aphantasics; although 30 % of aphantasics were above the PCS mean of the full sample. In E2, aphantasics scored significantly lower on the Sussex-Waterloo scale of

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							hypnotisability than non-aphantasics. Mean PCS scores were higher in the non-aphantasic group.
	Dawes et al. (2020)	Empirical	control group 1 = 203; control group 2 = 197	267	17–75	Self-identified; VVIQ	*See results in Subtypes of Aphantasia*
	Ganczarek et al. (2020)	Case Study	N/A	1	24	VVIQ & Spontaneous Use of Imagery Scale; SUIS	*See results in Subtypes of Aphantasia*
	Königsmark et al. (2021)	Empirical	63 (25 Students)	143 (3 Students)	M = 27.18, student: M = 21.6	0—–10 scale rating visual and auditory imagery	Aphantasics are less likely to experience pseudo-hallucinations during the Ganzflicker stimulation.
	Palermo et al. (2022)	Empirical	434	32	18–78	Object and Spatial Imagery Questionnaire (OSIQ)	*See results in Subtypes of Aphantasia*
	Reeder (2022)	Empirical	Not clear	Not clear	mean = 39.746 years, SD = 23.993		Replicated the main results of Königsmark et al. (2021)
	Zeman et al. (2015)		N/A	21	M = 41.65	Self-identified; VVIQ	Participants became aware of their condition in their teens or 20 s. About half reported all modalities of imagery were affected, majority reported involuntary imagery such as flashes during wakefulness and/or during dreams. Over half reported difficulties with autobiographical memory. They reported they rely on compensatory strengths in verbal, mathematical and logical domains.
	Zeman et al. (2020)	Empirical	400	2200	Aphantasia (M = 41.31), Control (M = 56.80)	VVIQ	Aphantasia is associated with difficulty in face recognition and impoverished autobiographical memories. Aphantasics were more likely to report absence of dreams, but a majority report they dream visually. About half of aphantasics report no imagery in any sensory modality, but many have imagery in one or more, often times auditory.
Aphantasia and Memory							
	Bainbridge et al. (2021)	Empirical	52	61	Aphantasic (M = 41.88), Control (M = 32.12)	VVIQ	Researchers found that VVIQ scores and object subscale OSIQ scores had a significant difference for aphantasics. Aphantasic participants showed impairment in object memory and a greater dependance on symbolic information, but no impairment in spatial memory
	Beran et al. (2023)	Empirical	1,821 typical imagers; 298 hyperphantasics	77	18–50+	Self-identified; VVIQ	Aphantasics were likely to report "few or no dreams" and less likely to report "dream sometimes." They also were more likely to report never engaging in self-talk. Scored lower on memory task compared to typical imagers.
	Dando et al. (2023)	Empirical	60	60	Aphantasic (M = 35.20), Control (M = 32.02)	VVIQ	Aphantasic participants recalled fewer correct units of episodic information compared to controls. Aphantasic participants recalled less

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							correct items in interview compared to the no support control condition. Finally, aphantasic participants in a sketch condition recalled more correctly than other retrieval conditions, suggesting a carry-over effect for sketching
	Dawes et al. (2020)	Empirical	control group 1 = 203; control group 2 = 197	267	17–75	Self-identified; VVIQ	*See results in Subtypes of Aphantasia*
	Dawes et al. (2022)	Empirical	30	30	18–68	Self-identified	Aphantasic individuals scored higher on the cognitive domain of the Subjective Experiences Rating Scale (SERS) compared to control participants
	Dawes et al. (2022b)	Empirical	30	30	18–68	VVIQ	Aphantasics show weaker visual imagery, object imagery, and scene imagery when remembering past events. Aphantasics report altered subjective experience of trial-by-trial memory and imagination phenomenology compared to controls.
	Ganczarek et al. (2020)	Case Study	N/A	1	24	VVIQ & Spontaneous Use of Imagery Scale; SUIS	*See results in Subtypes of Aphantasia*
	Jacobs et al. (2018)	Empirical	11	1	Aphantasic (M = 31.75), Control (M = 31.0)	Self-identified	The one aphantasic individual's general working memory was found to be unimpaired. She was able to mentally construct visual stimuli. However, her metacognitive performance on a mental imagery task was lower than the controls. When a visual working memory task required high precision, the aphantasic participant's performance was worse.
	Kay et al. (2024)	Empirical	E1: 114, E2: 164	E1: 95, E2: 150	Aphantasic (E1: M = 46.63, E2: 44.68), Control (E1: M = 46.5, E2: 44.54)	Self-identified; VVIQ	Across both experiments, aphantasics were slower but more accurate with imagery. Moreover, there was an increase in response time when stimulus orientation differed.
	Keogh et al. (2021)	Empirical	68	21	18–48	Self-identified; VVIQ	No differences were found between aphantasics and controls in capacity limits for visual, number, or spatial working memory. Aphantasic individuals showed no significant differences in performance on visual components of clinical working memory tests when compared to verbal components. However, aphantasic individuals reported different strategies from that of the general population for remembering visual information, being less visual in nature, such as labelling the image and holding this information in mind.
	Monzel et al. (2021)	Empirical	E1: 1324, E2:742	E1: 568, E2: 355	18–69	Self-identified	E1: aphantasics can be primed the same way controls can. E2: interaction effect between groups suggest aphantasics cannot be primed by their own imagery compared to controls.

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							Aphantasics must rely on solely nonvisual search strategies. Researchers examined if attentional guidance in aphantasics is impaired. Amongst aphantasics, there is a lack of attentional guidance through visual imagery as there is no priming of visualization of whole objects by their own imagery, suggesting that mental imagery may influence information processing. After subjects were primed by words or images, they were shown two stimuli and asked to indicate which corresponded to the mental representation cue. Aphantasics reacted slower to images than controls, relying on non-visual strategies.
	Monzel et al. (2022)	Empirical	131	156	Aphantasic (M = 35.23), Control (M = 28.88)	VVIQ; Aphantasia Distress Questionnaire	Aphantasics scored higher in forgetting and lower in remembering in the FEAG. There was a subgroup of aphantasics who experienced distress due to aphantasia. Aphantasia is statistically rare. There were no differences found for aphantasics and controls regarding theory of mind. Overall, aphantasia should not be classified as a mental disorder.
	Monzel et al. (2024)	Empirical	16	14	Aphantasic (M = 31.47, SD = 10.45); Control (M = 28.19, SD = 12.27)	VVIQ, Binocular Rivalry Task	Poor autobiographical retrieval can lead to an episodic memory deficit which can be reflected through neural altered activation and connectivity between the hippocampus and visual-perceptual cortices
	Pounder et al. (2021)	Empirical	20	20	Aphantasic (M = 40), Control (M = 39.6)	VVIQ	There were no differences in performance between aphantasics and controls in declarative memory tasks nor in visuospatial working memory tasks. Differences were seen in the One Touch Stocking of Cambridge task and Mental Rotation task where aphantasics took more time to complete the task due to higher executive functioning demands.
	Reeder et al. (2024)	Empirical	38	21	33.24	VVIQ	Aphantasics mainly used nonvisual spatial strategies for visual working memory tasks. Aphantasics preferred verbal over visual strategies. The study showed nonvisual spatial and sensorimotor strategies can be just as effect in remembering precise visual information. No difference in working memory precision accuracy across groups
	Siena & Simons (2024)	Empirical	N/A	N/A	N/A	N/A	Researchers objectively examined episodic memory in a sample of aphantasic participants since most reports on episodic memory rely on self-report measures. Using a 3D object and a spatial memory task, aphantasic participants were found to be unimpaired on all objective

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							memory measures, including those for object memory features, despite reporting weaker overall mental imagery experience and lower subjective vividness ratings on the memory task.
	Wittmann & Satirer (2022)	Empirical	41	55	Aphantasic (M = 37.6, SD = 14.6); Control (M = 33.4, SD = 12.2)	VVIQ	Aphantasics when compared to controls showed lower rates of high confidence hits in associative memory tests; Aphantasics scored lower on the object scale of the OSIQ but not on the spatial scale; there was also a report of lower auditory imagery.
	Zeman et al. (2020)	Empirical	400	2200	Aphantasia (M = 41.31), Control (M = 56.80)	VVIQ	*See results in Visual Deficit or Metacognitive Deficit?*
"Diagnosing" Aphantasia	Kay et al. (2022)	Empirical	42	18	18–54	Self-identified; VVIQ; Binocular Rivalry Task	Researchers explored if imagery plays a causal role in endogenous pupil size changes. In aphantasic participants, it was found that using a non-visual strategy (as seen in aphantasia) to think about bright and dark objects does not induce a pupillary light response. They found that pupils respond to the vividness and strength of a visual image being held in mind; the stronger and more vivid the image, the greater the pupillary light response
	Monzel et al. (2022)	Empirical	131	156	Aphantasic (M = 35.23), Control (M = 28.88)	VVIQ; Aphantasia Distress Questionnaire	Aphantasics scored higher in forgetting and lower in remembering in the FEAG. There was a subgroup of aphantasics who experienced distress due to aphantasia. Aphantasia is statistically rare. There were no differenced found for aphantasics and controls regarding theory of mind. Overall, aphantasia should not be classified as a mental disorder
	Takahashi et al. (2023)	Empirical	2,465	105	Aphantasic, Self-identified (M = 35.29, SD = 9.38); Aphantasic, not self-identified (M = 40.67, SD = 9.53); Control (M = 38.20, SD = 11.65)	VVIQ	*See results in Aphantasia Comorbidities*
Neuroimaging findings	Gaber & Eltmamy (2021)	Case Study	0	1	59		59-year-old female was diagnosed with acquired aphantasia after a COVID-19 diagnosis. Her COVID-19 infection – respiratory or olfactory symptoms. An MRI showed diffuse white matter changes consistent with small vessel disease.
	Milton et al. (2021)	Empirical	Hyperphantasia = 25; Phantasics = 20	24	Aphantasic (M = 33.71; SD = 11.25); Control (M = 34.6; SD = 12.78); Hyperphantasics (M = 35.36; SD = 11.10)	VVIQ	During resting state fMRI, hyperphantasics revealed stronger connectivity between prefrontal cortices and the visual network than aphantasic participants. During task-based fMRI, there was greater anterior parietal activation

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Table 1 (*continued*)

Theme	Authors	Study Design	n (control)	n (aphantasia)	Ages	Aphantasia Assessment	Results
							among hyperphantasic and controls than aphantasic participants when comparing visualization of famous faces and places
Can Mental Imagery Improve?	Monzel et al. (2024)	Empirical	16	14	Aphantasic (M = 31.47, SD = 10.45); Control (M = 28.19, SD = 12.27)	VVIQ, Binocular Rivalry Task	Poor autobiographical retrieval can lead to an episodic memory deficit which can be reflected through neural altered activation and connectivity between the hippocampus and visual-perceptual cortices
	Bumgardner et al. (2021)	Case Study	N/A	1	62	VVIQ	Acquired aphantasia of a 62-year-old man with IgG kappa multiple myeloma after an autologous stem cell transplant following high-dose melphalan with a complicated hospital admission. Day 12 in the ICU, patient reported subjective improvement – 'constantly morphing shapes when closing my eyes' but scored 16 on VVIQ. After 6 months patient reported mild improvement and scored a 23 on the VVIQ. It has been concluded by researches the acquired aphantasia was due to a hypoxemic insult to the central nervous system
	Rhodes et al. (2024)	Empirical	N/A	6 Aphantasics; 21 Low imagers	N/A	Plymouth sensory imagery questionnaire (Psi-Q)	Researchers examined how an imagery-based intervention training can help athletes develop their skills. 21 individuals who scored low on the Plymouth sensory imagery questionnaire were categorized as low imagers and 6 were identified as aphantasics. The intervention improved the performance for both aphantasics and non-aphantasics, and these improvements were maintained over the span of six months.
	Zhao et al. (2022)	Case Study	12	1	Aphantasic (71), Controls (M = 70.8)	VVIQ	Aphantasic participant had acquired aphantasia after a coronary angioplasty. Results showed that there were no differences in ERP or behavioral data between controls and the aphantasic participant. The participant was able to execute spatial transformations and create mental representations of letters.

Note. VVIQ = Vividness of Visual Imagery Questionnaire, OSIQ = Object and Spatial Imagery Questionnaire, IQ = Imagery. Questionnaire, SUIS = Spontaneous Use of Imagery Scale, Psi-Q = Plymouth sensory imagery questionnaire.

aphantasic participant in this sample presented no listening comprehension difficulties, scoring just above the mean score.

Additionally, five studies explored aphantasia and its relationship to prosopagnosia, or face blindness (Dance et al., 2023; Milton et al., 2021; Palermo et al., 2022; Takahashi et al., 2023; and Zeman et al., 2020). Using self-report and behavioral measures, Dance et al. (2023) found aphantasics report weaker face recognition and more traits associated with prosopagnosia when compared to control participants. However, aphantasics were able to construct facial composites from memory and show the ability to remember and recognize target faces from distractor faces. Furthermore, Monzel et al. (2023b) investigated whether recognition impairment in aphantasia is specific to faces. They found that aphantasics scored lower in face recognition and object recognition tasks when compared to controls; suggesting that visual imagery influences visual recognition. The researchers suggest a mild visual recognition deficit, not specific to face recognition, may exist in aphantasia. Milton et al. (2021) found that aphantasics report their face recognition abilities significantly worse than controls do. However, there was no group difference in performance on a famous face recognition test. Yet, aphantasics performed worse than hyperphantasics on a famous buildings test (Milton., 2021). Interestingly, Palermo et al., 2022 found that object aphantasics reported significantly poorer face recognition skills than spatial aphantasics (Palermo et al., 2022), and in a sample of 105 aphantasics, there was no correlation of face recognition ability and low VVIQ scores (Takahashi et al., 2023). Finally, a case study of a patient with acquired aphantasia showed significant deficits in face recognition, including recognizing his own face, learning new faces, and recognizing famous faces (Thorudottir et al., 2020).

Overall, it has been found that some aphantasics report reduced imagery in all sensory modalities, or at least in one other domain (e.g. olfactory, gustatory), and diminished sensory sensitivity (Dance et al., 2022; Dance et al., 2021; Takahashi et al., 2023). Zeman et al. (2015) found that half of the aphantasic participants in a sample of 21 subjectively reported that all modalities of imagery were affected. The same researchers reported similar findings with a lager sample of 2,000 aphantasics. Approximately half of the aphantasics report no imagery in any sensory modality, but many have imagery in one or more, often auditory (Zeman et al., 2020). In a recent study, Takahashi et al. (2023) found that only some aphantasics within their sample lacked all types of sensory imagery where others showed only low visual imagery (Takahashi et al., 2023). This reduced sensory imagery could suggest an underlying general process for sensory imagery, as suggested by Pounder et al. (2024) after finding auditory imagery deficits co-occur with visual imagery deficits. Interestingly, researchers have also examined aphantasia and its relation to synesthesia, a sensory crossover phenomenon such as tasting colors or feeling sounds. Aphantasic participants were less likely to report an experience of synesthesia compared to hyperphantasics (Zeman et al., 2020). Hyperphantasia is known as an abundance of visual imagery – "as vivid as real seeing" (Zeman et al., 2015, 2020). Another study showed synesthesia was no less prevalent in aphantasics versus non-aphantasics (Dance et al., 2021).

No studies reviewed have exclusively examined the relationship between aphantasia and autism. However, three studies in this review examined ASD traits within individuals with aphantasia. Individuals with aphantasia score significantly higher on the Autism Spectrum Quotient (AQ) compared to typical control participants (Milton et al., 2021). Additionally, aphantasics scored higher than controls on the social skill and imagination subscale of the AQ (Dance et al., 2021). In a recent study, Dance et al. (2023) associated the deficits seen in face recognition in ASD with face recognition deficits in visual imagery. However, in a recent study with 14 aphantasics and 14 control participants, there were no significant differences in AQ scores (Dupont et al., 2024a). Overall, the research has shown some correlations between aphantasia and ASD and suggests autistic traits are more likely to be present in aphantasics than in controls.

3.4. Aphantasia and attention

Four studies investigated the relationship between aphantasia and attention. Monzel et al. (2021) examined if attentional guidance in aphantasics is impaired. Amongst aphantasics, there is a lack of attentional guidance through visual imagery as there is no priming by their own imagery, suggesting that mental imagery may influence information processing (Monzel et al., 2021). In a separate study, researchers assessed visual attention in congenital aphantasics finding that aphantasics showed evidence of feature-based attention when stimuli were present but no evidence of attentional templates. The inability to create attentional templates may impair abilities in daily life visual search tasks, such as searching for a pen on a cluttered desk (Keogh & Pearson, 2021). Competing results suggest there are differences between the mechanisms of imagery and attentional templates. Using the contingent capture task, Cabbaiet al (2023) found that there were no differences in the capture effect, or the success of distinct attentional tools to help cue a target stimulus. Through three experiments in Cabbai et al. (2023), it was shown that there were no significant differences between aphantasics and non-aphantasics in this task for the capture effect. Experiment 3 showed there was a slower and overall, less efficient search performance in aphantasics compared to non-aphantasics, which is consistent with prior literature. Furthermore, a recent study (Monzel and Reuter, 2024b) examined the influence of visual imagery vividness on visual search speed. Aphantasics and age-matched controls were asked to find hidden objects without visualizing the objects in several pictures derived from children's books and then in complicated search puzzles to measure search time. On average, aphantasics were slower than controls. Additionally, age was determined to be a significant factor, indicating longer search times with older age (Monzel and Reuter, 2024b).

3.5. Aphantasia and emotion

Four studies examined the role of impaired visual imagery with emotions. One study found aphantasia was not related to mood or arousal differences in response to stressful life events (Dawes et al., 2020), and another found that the overall mood was less likely to influence imagery (Zeman et al., 2020).

One study explored a possible link between fear-based imagery and aphantasia (Wicken et al., 2021). Aphantasics showed a significantly reduced skin conductance response to imagined fear scenarios, indicating that there was not a heightened emotional response to the scenarios. This result is contrasted with the control group which showed significantly higher skin conductance levels.

This validates the notion that the arousal response created by fictitious scenarios may be highly correlated with mental imaging ability (Wicken et al., 2021).

Furthermore, using an objective measure of empathy, participants observed a picture of people in distress or listened to a verbal description of people in distress. Afterwards, they rated how emotionally moved they were. Aphantasics scored lower on the verbal assessment, but not in the visual domain. The researchers suggest that empathy via verbal descriptions may be influenced by mental imagery and empathy vignettes may be confounded with imagery skills because of an emotional amplification effect (Monzel et al., 2023a).

3.6. Aphantasia and motor engagement

Two studies examined aphantasia and its relation to motor system engagements. For example, in Dupont et al (2024a), aphantasics did not explicitly generate motor images when prompted to imagine a maximal pinch movement, nor present an increase in corticospinal excitability during explicit motor imagery. The same effect was observed during an implicit form of motor stimulation – observation of a video showing a pinching movement. Using transcranial magnetic stimulation, researchers triggered motor-evoked potentials in the target right index finger. This did not increase amplitude in aphantasics. Aphantasics presented limited abilities in kinesthetic modalities, but not a complete impairment. The researchers suggest aphantasics may have limited ability to simulate movements (Dupont et al., 2024a).

In a separate study by the same researchers, it was found that aphantasics did not present an increase in cortical excitability while reading manual action sentences, whereas controls did. Interestingly, reading comprehension abilities were impaired for aphantasics in this study. Aphantasics presented difficulty in selecting words that best fit the context of the sentences they read (Dupont et al., 2024b).

Regarding reading and reading comprehension, Speed et al. (2024) examined the experience of reading in 47 aphantasics and 51 matched control participants through survey methods. They found little differences between aphantasics and controls in story appreciation and overall liking when instructed to read a short fiction story. However, aphantasics reported being less absorbed, engaged, and interested in the story world, and they were less likely to feel sympathy for story characters. There were no group differences in the extent to which the story resonated with their own memories and in recalling the story. Additional analysis from the study did not yield any differences in how frequently both groups read fiction and non-fiction (Speed et al., 2024).

3.7. Dreams and involuntary imagery

The current research on dreams suggests aphantasics have the ability to dream. However, they are more likely to report fewer or no dreams and less vividness compared to controls (Beran et al., 2023; Dawes et al., 2020). Zeman et al. (2020) also found aphantasics are less likely to experience visual imagery in their dreams. Interestingly, Palermo et al. (2022) found all object aphantasics reported imagery in their dreams, and one spatial aphantasic reported no mental imagery during dreaming. A case study subject reported the ability to dream, but the dreams lacked imagery. This subject also reported no experience of involuntary imagery (Ganczarek et al., 2020).

Regarding involuntary imagery, Zeman et al. (2015) reported that the majority of their aphantasic sample ($n = 21$) described the experience of involuntary imagery, such as flashes during wakefulness and imagery during dreams (Zeman et al., 2015). Yet, aphantasics are less likely to experience pseudo-hallucinations during the Ganzflicker simulation, a rhythmic flicker stimulation (Königsmark et al., 2021). These main results were replicated using a much larger sample size in 2022 (Reeder, 2022). In another study, aphantasics were able to generate experiences in response to imaginative suggestions but to a lesser extent than controls. Aphantasics also scored lower on a hypnotizability scale than non-aphantasics (Cabbai et al., 2024).

3.8. Aphantasia and memory

Nineteen studies explored memory and memory deficits in aphantasia. In a large sample of 5,010 people in the U.S., the prevalence rate of self-reported aphantasia was 8.9 %. All participants in this study completed three trials of a working memory task in which they were presented with a cartoon-like image for 30 seconds and then instructed to answer four multiple-choice questions about the image. And it was found that self-reported aphantasic participants showed the poorest memory performance (Beran et al., 2023). Additionally, aphantasics compared to controls showed lower rates of high confidence hits in associative memory tests; however, there was no significant difference on accuracy rates in location memory and feature memory tasks (Wittmann & Şatırer, 2022).

A study by Zeman and colleagues (2020) found that aphantasics were more likely to endorse the belief of poor memory compared to controls and hyperphantasics. Additionally, based on questionnaire data, aphantasics report a reduced ability in remembering specific life events, little to no ability in generating visual sensory information when remembering the past (Dawes et al., 2020), and difficulty in remembering personal past events (Dawes et al., 2022). Moreover, aphantasics report less memory details, less episodic richness and vividness, less memory confidence, and greater difficulty to recall autobiographical memories when compared to controls (Monzel et al., 2024).

Interestingly, Siena and Simons (2024) used episodic memory tasks, including a 3D object, and a spatial memory task to objectively assess the performance of aphantasics compared to controls. They found aphantasics to be unimpaired in performance despite reporting a weaker mental imagery experience (Siena & Simons, 2024). However, Dando et al. (2023) found aphantasic participants recall fewer correct units of episodic information compared to controls and show significantly fewer complete answers in conditions that require a mental reconstruction of the context.

Moreover, diminished autobiographical information and poorer performance on both short term and long-term memory tests are seen in individuals with aphantasia. Two studies explored deficits of short term (STM) and long-term memory (LTM) in aphantasics. Monzel et al. (2021), found that aphantasics performed worse than non-aphantasics in visual and verbal STM and LTM memory components with larger differences between aphantasic participants and controls in visual STM. In another study, Monzel et al. (2023b) found that aphantasics report and show worse autobiographical memory than controls. Self-reports of distress due to aphantasia in this sample are associated with the severity of impairment in everyday memory, but not impairments in autobiographical memory. This suggests that visual imagery plays an important role in many components of memory and that there may be a general information generation deficit based on lack of visual representations. A study of working memory found aphantasics' metacognitive performance to be lower than controls, although they were able to mentally construct visual stimuli; and worse performance on a visual working memory task that required high precision (Jacobs et al., 2018).

Furthermore, another study found that participants with poor visual imagery showed slightly better spatial memory and slightly worsened object memory in tasks of drawing pictures from memory. They also found that aphantasic participants had a significant increase in the tendency to label their drawings with words as compared to controls, perhaps suggesting an alternate recall technique with a more symbolic memorization strategy (Bainbridge et al., 2021). Additionally, when completing two mental rotation tasks, the Shepard and Metzler task and the Manikin test, aphantasics compared to controls were more accurate in completing each task (Kay et al, 2024).

Interestingly, despite the differences in self-reported conscious experience of visual imagery, individuals claiming to experience the symptoms associated with aphantasia performed as accurately as individuals with typical ability to form imagery in a study examining declarative and visuospatial working memory. It has been suggested that aphantasics use a different non-visual process or specific strategy that results in similar performance level as the typical imager, such as spatial representations (Pounder et al., 2021). Keogh et al. (2021) investigated the different strategies for remembering visual information due to reports that not all individuals use visual imagery for visual working memory. After assessing visual working memory, number working memory, and spatial location visual working memory, there were no significant differences in performance when comparing the aphantasic participants to the general population group. However, the strategies that aphantasic individuals reported were consistently different from that in the general population, being less visual in nature, such as labelling the image and holding the information in mind. This has also been found in Reeder et al. (2024), where aphantasics used more nonvisual, spatial and verbal strategies over visual strategies and were just as efficient in performance. Taken together, these results show the role of visual imagery in memory.

These results can be exemplified in a case study of a 24-year-old female who became aware of her lack of visual imagery skills in college and reports an inability to have voluntary and involuntary visual imagination. She reports using knowledge as opposed to visualization regarding memories. Her autobiographical memories have little visual characteristics or any sensory descriptions. Rather they focus on actions and cause-effect relationships, creating an emotional distance from memory. However, she has intact working memory, especially visuospatial working memory (Ganczarek et al., 2020).

3.9. "Diagnosing" Aphantasia

The VVIQ has been the primary tool for identifying individuals with aphantasia, along with self-identification reports for inclusion in research studies. However, it is apparent that different researchers use different inclusion/exclusion criteria when using the VVIQ scores. Some use a score range of 16–23 while others use a range of 16 – 32. Even then, others utilize self-reports as the primary method of identifying aphantasics. Takahashi et al. (2023) examined the discrepancies in self-report over objective report of aphantasia diagnosis and different characteristics in an online sample of 2,871 participants. Of that sample, 3.7 % fulfilled VVIQ criteria of aphantasia, which ranged from 16 to 32; 12.7 % fulfilled self-identification criteria showing a discrepancy of the proportions. More individuals self-identified as aphantasic when they did not meet the VVIQ criteria for aphantasia compared to those who did. This percentage of individuals who meet criteria for aphantasia through the VVIQ matches population estimates found in Dance et al. (2022) of 3.9 %. The self-identification criterion contains items related to facial recognition, while the VVIQ does not. In further analysis, the study found that self-identified participants scored moderately high for imagery, but low for facial recognition ability. They also found that the aphantasia group included individuals with all types of sensory imagery and they did not exhibit one cognitive style, which could explain the discrepancies found. (Takahashi et al., 2023). These results highlight the complexities in attempting to diagnose aphantasia with different measures.

Kay et al (2022) found that aphantasic individuals display pupil contraction to perceptual brightness and dilation with effort (cognitive load), and they do not show any evidence of pupil change in response to attempts at imagery. These results provide novel evidence that pupils respond to the vividness and strength of a visual image being held in mind; the stronger and more vivid the image, the greater the pupillary light response (Kay et al. 2022). In the current review, three studies (Kay et al., 2022; Monzel et al., 2024; Wicken et al., 2021) used the binocular rivalry paradigm (Pearson et al., 2011) as a method to assess aphantasia, along with the VVIQ. Aphantasic participants typically show a significant reduction or absence of imagery-based priming in the paradigm; therefore, their perception during binocular rivalry is not influenced by priming and this further supports the diagnosis of aphantasia.

In the realm of diagnosing aphantasia as mental disorder, a recent study set out to verify the statistical rarity, violations of social norms, and distress associated with the disorder. The results verified that the statistical rarity of a 3.5 % prevalence of aphantasia in the pooled population met the criteria for a mental disorder. However, the aphantasia population did not significantly meet the other four criteria: violation of social norms, inappropriate behavior, impairment in activities of daily living, and personal distress. Therefore, the authors concluded that with the current research available, aphantasia does not meet the necessary qualifications to be classified as mental disorder (Monzel et al., 2023c).

3.10. Neuroimaging findings

Two studies examined the differences in brain responses in aphantasics versus controls using neuroimaging techniques. In the first systematic brain imaging study of aphantasia, Milton et al. (2021) found that during resting state fMRI, hyperphantasics revealed stronger connectivity between prefrontal cortices and the visual network than aphantasic participants. During task-based fMRI, there was greater anterior parietal activation among hyperphantasic and controls than aphantasics when comparing visualization of famous faces and places (Milton et al., 2021).

A recent neuroimaging study examined the interaction between the hippocampus and the brain areas primarily underlying visual-perception during autobiographical memory (Monzel et al., 2024). Aphantasics displayed decreased hippocampus activation and increased visual-perceptual area activation during autobiographical retrieval; in addition, they displayed almost no functional connectivity (synchronization of brain activity across regions) between the right hippocampus and left visual-perceptual cortices during autobiographical memory tasks. During resting state functional MRI, control participants showed strong connectivity between the hippocampus and visual-perceptual cortices. These findings indicate that a diminished visual construction during autobiographical retrieval leads to an episodic memory deficit which can be reflected through neural altered activation and connectivity between the hippocampus and visual-perceptual cortices (Monzel et al., 2024).

A case study of acquired aphantasia found structural difference that could provide insight into the neural correlates of aphantasia (Gaber & Eltemamy, 2021). A 59-year-old woman was diagnosed with a mild form of COVID-19 in 2021. Two months later, she reported inability to see while imagining or to visualize her dreams. Gaber and Eltemamy (2021) reported MRI results that showed diffused white matter changes that was consistent with small vessel disease.

3.11. Can mental imagery improve?

In a case study of a 62-year-old man with acquired aphantasia, Bumgardner et al. (2021) found evidence of improvement in imagery. This patient had an autologous stem cell transplant following a hospitalization. Nine days after the procedure, he reported “an inability to picture things in [his] head” and scored a16, the lowest score on the VVIQ, meeting criteria for an assessment of aphantasia. Over the course of 6 months, the patient reported spontaneous mild improvements. While his VVIQ score increased 7 points, he would still be classified as having aphantasia.

However, spontaneous improvements are not always seen. A different case study reported a 71-year-old man who lost the ability to experience visual mental imagery 12 years earlier after a coronary angioplasty (Zhao et al., 2022). Yet, years later, he still reported deficits in mental imagery. Moreover, in an event related potential experiment, the patient was capable of completing mental rotation tasks compared to control participants while having no ability to experience mental imagery Zhao et al., 2022).

A recent study examined the efficacy of an imagery-based intervention on developing the skills of athletes. Within the total sample ($n = 329$), there were 27 individuals who scored low on the Plymouth sensory imagery questionnaire who were categorized as aphantasic. The imagery intervention consisted of motivation-based coaching that targets the exploration, application, refinement, and development of imagery to improve performance. This intervention improved the performance for both aphantasics and non-aphantasics, and these improvements were maintained over the span of six months (Rhodes et al., 2024).

4. Discussion

Overview: Zeman et al. (2015) first gave name to a group of individuals who reported the inability to produce visual imagery: congenital aphantasia. Since this publication, a growing number of studies have explored aphantasia and its relation to memory, emotions, dreams, and comorbidities. There are a few emerging studies investigating the neural correlates of aphantasia, and there are some clear understandings of aphantasia including that it is a visual deficit and is not a mental disorder. This review brings together the different domains of knowledge relating to aphantasia in an attempt to understand how research must move forward.

Findings: It is generally accepted in current literature that aphantasia is a deficit in creating visual imagery (Keogh & Pearson, 2018; Wicken, Keogh, & Pearson, 2021; Pounder et al., 2021. There is still room for continued research as there is minimal support for characterizing aphantasia as a metacognitive deficit. There is a suggestion of aphantasia subtypes, object and spatial, as weaknesses in visual imagery seem to have a greater impact on object imagery rather than spatial orientation (Palermo et al., 2022). Overall, most studies examining the relationship between aphantasia and sensory processing find that a portion of aphantasics lack all types of sensory imagery, yet there is evidence that aphantasics only present deficits in visual imagery. Regarding recognition deficits in aphantasia, findings are inconclusive, but there is support for facial recognition deficits (Dance et al., 2021; Hinwar & Lambert, 2021; Monzel et al., 2023b; Takahashi et al., 2023). More research is needed to derive firm conclusions on the percentage of aphantasics that present deficits in all sensory and recognition domains.

Researchers have been interested in aphantasia’s relationship with autistic symptoms because some of the deficits seen in both conditions overlap, such as difficulties in face recognition and imagination. Aphantasics also tend to score significantly higher on the AQ than control participants (Milton et al., 2021; Dance et al., 2021; Dance et al., 2023). One thing to note, the AQ measures the presence of autistic traits, and within the AQ there is an imagination scale that includes few visual imagery questions (Baron-Cohen, 1987). These findings suggest a potential correlation between aphantasia and specific domains of ASD, and more research must be conducted to further investigate this. Furthermore, there is space for more examination on the relationship between aphantasia and attention. Thus far, it has been found that attentional differences in aphantasia can present as difficulties in a lack of attentional guidance and templates that interfere with information processing (Monzel et al., 2021; Keogh & Pearson, 2021).

There are two studies that suggest potential alterations in the motor system in aphantasia (Dupont et al., 2024a; Dupont et al., 2024b). Although these are novel findings, the sample sizes are small; therefore, further research is warranted. The limited or lack of visual imagery in aphantasia seems to impact emotion processing and empathizing, but not the ability to dream; although aphantasics are likely to report less vividness during dreams (Dawes et al., 2020; Monzel et al., 2023; Wicken et al., 2021; Zeman et al., 2020). There is some evidence that aphantasics can experience involuntary imagery; however more research is needed on this as well.

In the aphantasia literature, the relationship between aphantasia and memory has the most empirical evidence. The overall results show aphantasia impacts memory encoding and recall subjectively, and that aphantasics report feeling their memory and autobiographical memory are impaired. In specific tasks, aphantasics were shown to have worse performance on remembering specific life details, reduced vividness, and deficits in short- and long-term memory. These findings are consistent with the proposition that poor memory, such as language comprehension skills, is carefully associated with difficulty in generating mental imagery (Bell, 1991). While aphantasia is correlated with deficits in memory, it should be noted that there are aspects of memory that are not impacted by aphantasia. For example, in declarative and visuospatial working memory tasks, there were no differences in performance accuracy between aphantasics and non-aphantasics (Pounder et al., 2021). This could possibly be explained by the nonvisual strategies used to compensate for the visual deficits, such as the use of symbolic memorization (Bainbridge et al., 2021).

The exploration of the neural correlates of visual imagery is an emerging area of interest. Yet, to date there are only two systematic studies on aphantasia. The findings show that during resting state, aphantasics reveal less connectivity between prefrontal cortices and the visual network than hyperphantasics (Milton et al., 2021). Aphantasics also reveal altered brain activation and connectivity patterns between the hippocampus and visual-perceptual cortices during autobiographical retrieval (Monzel et al., 2024).

5. Future research recommendations

Since research on aphantasia is limited, more empirical research is needed for any breakthrough to happen. However, there are specific recommendations for future research directions based on the results of this review. Primarily, there must be more research and innovation in the ways to assess aphantasia. The VVIQ self-report measure may be an imperfect tool that has the potential to be improved or used in conjunction with more objective, observational methods to assess aphantasia. Additionally, there seems to be no accepted standard for the VVIQ cut off scores, with some studies using a range between the lowest score (16 and 23) and others using below 32 as the threshold. More research can help establish an accepted cut-off score for VVIQ or innovate other ways to measure aphantasia. This will ensure that there is a commonly accepted standard when recruiting and assessing individuals with aphantasia. While it would be difficult to gain absolute objectivity, standardized measures across the field for assessing aphantasia will ensure better, replicable data. Additionally, future studies can look at different age groups of participants to investigate developmental differences. Most research included in this review have mean ages of around 30 years or included a wide range of adults from 18-69 years. Future studies may include children and younger populations in efforts to provide further insight into understanding developmental differences in aphantasia. Future research can examine the differences in cognitive functions, such as language comprehension, spatial reasoning, and memory.

Future research should also focus on neuroscientific methods for a better mechanistic understanding of aphantasia. Few studies have examined aphantasia using fMRI or other neuroscience methods to examine neuroanatomical and functional differences. More such research is needed to identify structural and functional differences underlying imagery utilization in aphantasia. Since memory differences seem to occur frequently in aphantasia, future studies should include more objective measures to assess memory (Most studies included used self-reports of memory).

A few studies included in this review briefly mentioned aphantasia and ASD, most notably how aphantasics had higher AQ scores compared to controls. Future studies can further investigate this connection, beginning with assessing prevalence rates of ASD within individuals who have aphantasia. Future research is also needed regarding involuntary imagery and the ability in imagining future events. In one study it was subjectively found that aphantasics report less ability in imagining future events (Dawes et al., 2020). Dawes et al (2022) and Milton et al (2021) both found objective differences in future thinking and imagination between aphantasics and controls, with aphantasics showing less episodic richness (Dawes et al., 2022; Milton et al., 2021). The construction of future and past events has been shown to exhibit similar neural activity in the left hippocampus and right occipital gyrus (Addis et al., 2007). It is worth considering if this is true within a sample of aphantasics. Additionally, more studies should examine the cognitive impacts of less vivid and detailed future thinking on setting future goals, plans, and decision making within a sample of aphantasia.

Another direction to focus is how reading and listening comprehension can be improved using visual mental imagery, which has been found to be important in developing situational models that aid in comprehension (Aryadoust, 2020). A case study reviewed here found an aphantasic individual who could not use mental imagery and imagination while reading (Ganczarek et al., 2020). Future research examining the reading comprehension difficulties in aphantasics could elucidate how visual imagery facilitates reading comprehension and other strategies that can function in the same way.

Finally, some research has identified possible ways in which alternative strategies in place of visual imagery can be used to help compensate and carry out tasks. Only one method was readily identified, using symbolic memorization, such as words or non-visual tools (Bainbridge et al., 2021). Whether or not the role of multisensory imaginal skills is completely excluded from these methods is yet to be determined. However, more research must be done to examine other avenues of compensation for a lack of visual imagery, or that can potentially foster an altered sense of visual imagery.

6. Strengths

There are several strengths of this systematic review. The use of solely empirical evidence ensures there is a rigorous standard for the articles that are included. Because visual imagery and one's experience are subjective, using these standards increases the rigor that can be applied to the research and findings of the studies included. The research on aphantasia is very limited; however, themes around the most generally studied aspects show where research is and where it can grow. The review highlights where research is needed, including comorbidities, emotion, neuroimaging, and objective measures of individual differences in imaginal brain processing abilities, including any findings as to whether some aphantasics have absolutely no ability to imagine anything.

7. Limitations

There are a few limitations in this review. Many studies of the already limited search were excluded because of their lack of rigor to meet the standards of the review. While this is a needed step, it does reduce the number of studies thus requires a level of scrutiny when concluding generalizability of results. Reviewing the research prior to the term of aphantasia regarding individual differences in imagery generation may shed additional clarity as well. To date, there is still a gap in the aphantasia empirical research. Of the total 106 records screened, only 52 articles met the inclusion criteria. This shows there is space for more rigorous, empirical research in this domain. A limitation of the literature lies in the measures that have been used to identify aphantasia across studies. There is not one accepted way to measure aphantasia. The most used measure amongst researchers is the VVIQ questionnaire; however, this is a self-report measure, and many studies using a sample as small as individuals with aphantasia may encounter participants who know how to score on the questionnaire. This means there is a potential for more individuals who report having aphantasia than those who experience it.

8. Conclusions

This review examined the empirical evidence relating to aphantasia, or the experience of a lack of visual imagery. A field of study gaining more interest in recent years, there is still much research to be conducted within the field. Current research has identified the impacts of aphantasia on emotion, memory, and other sensory alterations primarily, but has also included some neuroimaging studies, the source of aphantasia, and potential subtypes. More research, especially using neuroimaging techniques and focusing on compensating for visual deficits, must be conducted.

Author contributions

PA contributed to conceptualization, methodology, analysis, and writing. JD contributed to conceptualization, methodology, analysis, and writing. JZ contributed to analysis and writing. PW contributed to writing, preparation of the manuscript, and resources. RKK contributed to conceptualization, the writing, preparation of the manuscript, supervision, and resources.

CRediT authorship contribution statement

Paula Argueta: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Julia Dominguez:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Josie Zachman:** Writing – review & editing, Methodology, Data curation. **Paul Worthington:** Writing – review & editing, Conceptualization. **Rajesh K. Kana:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition, Conceptualization.

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.

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Data availability

No data was used for the research described in the article.

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