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Challenging dual-coding theory: Picture superiority effects persist in aphantasia

Muhan Yan [a,*], Brady R.T. Roberts [a,b], Wilma A. Bainbridge [a,b,c]

[a] Department of Psychology, University of Chicago, Chicago, IL, USA
[b] Institute for Mind and Biology, University of Chicago, Chicago, IL, USA
[c] Neuroscience Institute, University of Chicago, Chicago, IL, USA

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ABSTRACT

Dual-coding theory proposes that superior recall for pictures relative to words (the picture superiority effect; PSE) results from encoding information both verbally and visually, creating dual memory codes that aid subsequent retrieval. The current study tested this dual-coding theory by examining recall in individuals with aphantasia, who cannot voluntarily generate mental imagery and thus should not benefit from a secondary visual memory code. We compared recall performance between aphantasics and typical imagers across four stimulus types: pictures, symbols, picture names, and symbol names. Contrary to what dual-coding theory would predict, aphantasic individuals showed a robust picture superiority benefit in memory. While typical imagers recalled pictures and symbols at similar rates, aphantasics recalled symbols significantly better than pictures. These findings challenge dual-coding theory's account of the PSE, revealing that its core assumption—that conscious access to image codes is required for enhanced picture recall—is flawed. Alternative accounts based on distinctiveness are offered, as well as potential substantive revisions that would be required for dual coding to remain a tenable explanation of picture superiority.

1. Introduction

The picture superiority effect (PSE) describes the robust phenomenon whereby pictures yield superior recall compared to words. For over 50 years, researchers have sought to understand the cognitive mechanisms underlying this phenomenon, with Paivio's (1971) dual-coding theory emerging as a popular theoretical explanation. This theory's central premise relies on the role of visual imagery in memory formation and retrieval, making it uniquely testable through the study of individuals who lack this cognitive ability. Aphantasia, a condition characterized by the absence of voluntary mental imagery, offers an unprecedented opportunity to examine whether dual-coding theory's explanation for the picture advantage in memory remains tenable.

1.1. Theoretical explanations for picture memory advantages

The picture superiority effect refers to the consistent observation that pictures are better remembered than words. This phenomenon has been demonstrated repeatedly across numerous studies, highlighting a robust advantage for pictures over words. For example, Paivio and Csapo (1973) found significantly higher free recall for items presented as pictures compared to the same items presented as printed words.

One influential framework that has explained this phenomenon, particularly in free recall, is dual-coding theory (Paivio, 1971; Paivio and Csapo, 1973). This theory proposes that memory encoding occurs through two distinct yet interconnected pathways: verbal ('logogen') and nonverbal ('imagen'). For example, when one encounters text such as "apple," it is typically encoded as a verbal memory code. According to dual-coding theory, upon reading the word, one might also spontaneously generate a mental image of an apple, although this is not guaranteed (Paivio and Csapo, 1969). Conversely, encountering a picture of an apple naturally and automatically prompts encoding via both visual and verbal codes: The imagen code itself is provided by the picture, and its associated logogen (verbal code) is typically generated if the pictured object is understood. Therefore, in the case of a picture of an apple, the image itself provides a rich visual code in memory, and upon being seen the observer is likely to recognize it as an apple and therefore obtain the verbal code "apple" in memory as well. According to dual-coding theory,

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* Corresponding author. Department of Psychology, University of Chicago, 940 East 57th Street, Chicago, IL, 60637, USA.
E-mail address: ymuhannah@gmail.com (M. Yan).

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this dual representation provides two separate memory traces, enhancing recall likelihood. For instance, even if you later forget exactly what the apple looked like, recalling the verbal label "apple" remains possible, or vice versa. Thus, having both visual and verbal memory codes increases retrieval probability by providing two distinct routes to memory, ensuring successful recall even if one memory code fails.

Although dual-coding theory provides a compelling explanation for the picture superiority effect, alternative theories have been proposed. One prominent example is the distinctiveness account, which suggests that pictures are better remembered due to both their richer semantic content (conceptual distinctiveness; Hamilton and Geraci, 2006; Nelson et al., 1977) and their greater perceptual variability compared to words (physical distinctiveness; Ensor et al., 2019; Mintzer and Snodgrass, 1999). Early evidence for this distinctiveness account came from recognition memory studies. Mintzer and Snodgrass (1999) found that increasing the perceptual distinctiveness of words significantly reduced or even eliminated the picture advantage in recognition tests. Following this, Ensor et al. (2019) extended this work by systematically manipulating distinctiveness in both directions: They enhanced the physical distinctiveness of words through varied fonts, colors, sizes, and capitalization patterns, while simultaneously reducing the distinctiveness of pictures by presenting them in black and white. This manipulation eliminated and even reversed the picture superiority effect in recognition memory when comparing distinctive words to black-and-white pictures. These findings suggest that physical distinctiveness, rather than dual coding, might drive the picture superiority effect in recognition memory.

For many years, distinctiveness accounts were primarily associated with a recognition memory advantage for pictures, while dual-coding theory remained the dominant explanation for a free recall advantage for pictures. However, recent research has challenged this dichotomy. Following Ensor et al.'s approach, Higdon et al. (2025) demonstrated that distinctiveness accounts can also explain the picture superiority effect in free recall tasks: The picture memory advantage was eliminated in both recognition and free recall tasks when distinctiveness was reduced for images and heightened for words. This pattern occurred despite dual-coding theory's prediction that black-and-white pictures should still show superior recall due to their ability to generate dual memory codes. These findings raise important questions about whether dual-coding theory adequately explains the picture superiority effect, even in free recall where some have considered it to be a leading explanation.

In addition to a memory advantage for pictures relative to words, researchers have also identified a similar memory enhancement for other visual stimuli. Recent research by Roberts et al. (2023) has examined how graphic symbols (e.g., $, @, #) are represented in memory relative to pictures and words. They discovered that symbols, similar to pictures, are consistently better remembered than words, a phenomenon termed the 'symbol superiority effect.' Specifically, recall performance for symbols was comparable to that for pictures, and symbols and pictures were recalled significantly better than their corresponding word labels.

From a dual-coding perspective, this "symbol superiority" could arise because symbols, like pictures, are easily encoded in both visual and verbal formats. For example, the visual form of the symbol "$" can readily be encoded visually, while its corresponding verbal meaning ("dollar") provides a verbal memory code. Having dual representations of both visual and verbal codes facilitates recall through multiple retrieval pathways, thereby enhancing recall performance for symbols in a manner similar to pictures. Just as a distinctiveness account could explain picture superiority effects, the same explanation could apply to symbol superiority as well. Physically, symbols vary more in their visual appearance than words: Symbols have almost limitless design possibilities, whereas the appearance of English words is always comprised of just 26 shapes (letters). Conceptually, symbols also tend to have fewer semantic neighbors than their word counterparts. For instance, the word "play" has many related terms such as "begin," "start," and "commence," and is further crowded in semantic space as it can also refer to games, theatrical performances, or a strategy. In contrast, the play symbol (▶) stands in relative semantic isolation, with no other symbol conveying a similar meaning (Roberts et al., 2023). These physical and conceptual distinctiveness properties could make symbols more memorable than words, independent of any dual-coding benefit.

In addition to explaining advantages for visual stimuli, dual-coding theory has been widely applied to explain memory phenomena within verbal stimuli as well, particularly the concreteness effect (Jessen et al., 2000), the observation that concrete words tend to be recalled better than abstract words. For instance, the concrete word "apple" is typically remembered better than the abstract word "belief." Dual-coding theory attributes this difference to the higher probability of spontaneously generating mental images for concrete compared to abstract words. Upon encountering the word "apple," people are more likely to automatically visualize an apple in their mind's eye, thus creating dual codes (verbal and visual). In contrast, abstract words like "belief" rarely evoke spontaneous mental imagery, usually resulting in only a verbal memory representation. Consequently, concrete words are thought to more frequently benefit from dual encoding, increasing their likelihood of successful recall relative to abstract words.

Taken together, dual-coding theory predicts a clear hierarchy of memory recall performance based on the likelihood of dual-code formation. Pictures and symbols are readily encoded both visually and verbally. By contrast, according to dual-coding theory, picture names (e.g., "dog" for a picture of a dog) and symbol names (e.g., "stop" for the stop sign symbol) are relatively less likely to evoke spontaneous imagery (Paivio and Csapo, 1969). Abstract words without common visual referents (e.g., "jealousy") are thought to be even less imageable, leading to even worse recall (the concreteness effect; Jessen et al., 2000). In the present case, this imageability hierarchy provides a set of testable predictions of dual-coding theory: Pictures and symbols should be recalled better than picture and symbol names. Central to this hierarchy of predicted performance is the assumption that visual imagery is necessary for generating and retrieving image-based memory codes. Therefore, examining memory performance in individuals who lack voluntary visual imagery provides a unique opportunity to evaluate the validity of dual-coding theory.

1.2. *Aphantasia: individuals without visual imagery*

In 2015, Zeman et al. introduced the term "aphantasia" to describe individuals who are unable to voluntarily generate mental images. Derived from the Greek word "phantasia" meaning imagination, the term was initially applied to 21 individuals reporting a lifelong absence of visual imagery. Studies suggest that aphantasia affects approximately 2–5% of the general population (Zeman et al., 2015; Dance et al., 2022). Individuals typically become aware of their condition during adolescence or early adulthood, when conversations reveal that others can vividly "see things in their mind's eye," an experience completely foreign to those with aphantasia. Previous research indicates that aphantasic individuals specifically show impairments in recalling visual details of objects from memory, while spatial reconstruction from memory remains largely intact (Bainbridge et al., 2021).

Since aphantasia is typically identified through subjective self-report measures like the Vividness of Visual Imagery Questionnaire (VVIQ), one might question whether aphantasia is merely due to poor metacognition (i.e., individuals having mental images but failing to recognize them; de Vito and Bartolomeo, 2016). However, substantial evidence supports aphantasia as a real visual imagery impairment rather than merely a metacognitive limitation. Montabes de la Cruz et al. (2024) demonstrated reduced feedback signals from higher-order brain regions to early visual areas in aphantasic participants, finding decreased sound decoding in early visual cortex compared to both typical imagers and congenitally blind participants. Similarly, Megla et al. (2025) found significantly less decodable visual information in aphantasic individuals' neural representations during a familiar imagery task, along with reduced connectivity between brain regions supporting visual memory processing. Most compellingly, Chang et al. (2025) demonstrated that aphantasics show reduced perceptual responses in early visual cortex compared to typical imagers, and that neural patterns during imagery attempts were fundamentally different from those during perception: Cross-decoding between imagery and perception completely failed in aphantasics but not in typical imagers. Additionally, aphantasics showed abnormal functional connectivity patterns, with stronger ipsilateral responses and altered connections between higher-order and visual regions. These findings suggest that aphantasia involves transformed or distorted neural processing in the visual system, representing a genuine visual imagery deficit.

Aphantasic individuals thus represent a critical population for testing dual-coding theory. Because they lack the voluntary visual imagery that the theory assumes is necessary for enhanced memory performance, examining their memory patterns can reveal whether dual coding truly underlies picture superiority and related memory effects.

1.3. *Current study*

Dual-coding theory assumes that visual imagery is necessary to generate and retrieve image-based memory representations, and that having both verbal and visual codes enhances recall performance via multiple retrieval routes. Then, according to dual-coding, individuals with aphantasia, who lack voluntary visual imagery, should be unable to experience a memory benefit from the addition of visual codes. This makes aphantasia a powerful and novel approach to evaluate the validity of dual-coding theory. As previously discussed, in the general population, dual-coding theory predicts that pictures and symbols should be better recalled than words, and that concrete words should be recalled better than abstract words, due to their greater likelihood of engaging both visual and verbal codes. However, individuals with aphantasia should not be able to take advantage of these dual codes at retrieval. As a result, dual-coding theory would predict that aphantasics should not exhibit the picture superiority effect, symbol superiority effect, or the concreteness effect. Instead, their recall performance should be relatively uniform across stimulus types, relying solely on verbal encoding and therefore resulting in performance roughly matching that of abstract word recall in typical imagers.

If this prediction holds, that is, if aphantasics show no memory advantage for pictures, symbols, or concrete words, such an outcome would strongly support dual-coding theory. It would confirm that voluntary visual imagery is necessary for the memory enhancements typically associated with image-based stimuli.

On the other hand, if aphantasics do exhibit any of these memory advantages, this would challenge the core assumptions of dual-coding theory, suggesting either that the theory is flawed or that voluntary imagery is not essential for generating or retrieving image codes. Thus, the recall performance of individuals with aphantasia serves as a powerful and novel test of dual-coding theory.

By examining memory in those who naturally lack visual imagery, we can directly assess whether dual-coding mechanisms truly underlie enhanced recall for pictures, symbols, and concrete words, offering a unique window into the cognitive mechanisms that underlie our ability to remember different types of visual information.

2. Method

All pre-registrations, data, analysis code, experiment programs, and other materials are made available on the Open Science Framework (OSF; https://osf.io/v6q83/).

2.1. *Participants*

Prior to data collection, we conducted and pre-registered an *a priori* power analysis using the Superpower package (v. 0.2.0) for *R* to determine the required sample size. For our 2 × 4 mixed ANOVA design with Group (aphantasics, controls) and Condition (pictures, symbols, picture names, symbol names), we specifically predicted a between-within interaction effect. This interaction would manifest as controls showing the picture superiority effect while aphantasics would not show this effect, resulting in different patterns of performance across conditions between the two groups. Using effect size estimates derived from Roberts et al. (2023), who recruited participants only from the general population, we used a within-subject correlation of $r = 0.70$ and a common standard deviation of 0.1675 across conditions. A simulation with 2000 iterations ($\alpha = .05$) indicated a minimum of 45 participants per group were required to achieve 80% power, with an ideal target of 60 participants per group for 90% power to detect the expected main effects and interaction.

All study procedures were approved by the University of Chicago Institutional Review Board, and all participants provided informed consent before taking part in the experiment. We recruited participants from several sources. To target individuals likely to have aphantasia, we recruited from social media platforms (Reddit, Facebook, Discord) with groups or forums related to aphantasia, subscribers to the Aphantasia Network email list, and participants who had previously taken part in other aphantasia-related experiments. We primarily recruited control participants through Prolific to achieve an age and gender match to our aphantasia group.

We defined aphantasia using the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973), a measure of mental imagery with a score range of 16-80. Higher scores indicate more vivid self-reported visual imagery. Previous research on aphantasia has primarily relied on this questionnaire to identify aphantasia. After data collection, all participants were classified into either the aphantasia group or control group based on their VVIQ scores. We identified those with VVIQ scores between 16 and 25 out of 80, inclusive, as aphantasic based on previous aphantasia research (Bainbridge et al., 2021). Control participants were those whose VVIQ scores ranged from 40 to 63 out of 80, inclusive (Bainbridge et al., 2021; Zeman et al., 2020). We excluded individuals with VVIQ scores of 26-39 and 64-80 for two reasons. First, participants scoring just above the aphantasia cutoff (25) may represent borderline cases whose imagery abilities are not sufficiently distinct from those of aphantasics, which would obscure the contrast between group. Second, individuals scoring from 75 to 80 out of 80, inclusive, are considered to have hyperphantasia, which is the opposite of aphantasia, implying visual imagery that is as vivid as real seeing (Zeman et al., 2020). These individuals might demonstrate better memory compared to typical imagers. While we considered conducting separate tests comparing hyperphantasics to typical imagers, in the end we only had data from 7 hyperphantasic participants which was insufficient for adequately powered analyses. Therefore, no hyperphantasia-related analyses were conducted in the current study. By implementing these exclusion criteria, we ensured a clear buffer in mental imagery abilities between the groups, allowing us to compare the most extreme lack of imagery against the most typical imagery. Eligible participants volunteered to participate in the experiment lasting 30 min, for which they received a $10 USD Amazon eGift Card in compensation or the equivalent on Prolific.

We initially recruited 215 participants (77 aphantasics, 138 controls) for this study. After applying data quality screening procedures, our final sample consisted of 131 participants (62 in the aphantasia group and 69 in the control group), exceeding our sample size target, and successfully achieving clear separation of VVIQ scores between the aphantasia group ($M = 17.0$, $SD = 2.06$) and control group ($M = 53.4$, $SD = 6.60$; see Fig. 1).

In addition to the VVIQ, participants also completed the Object-

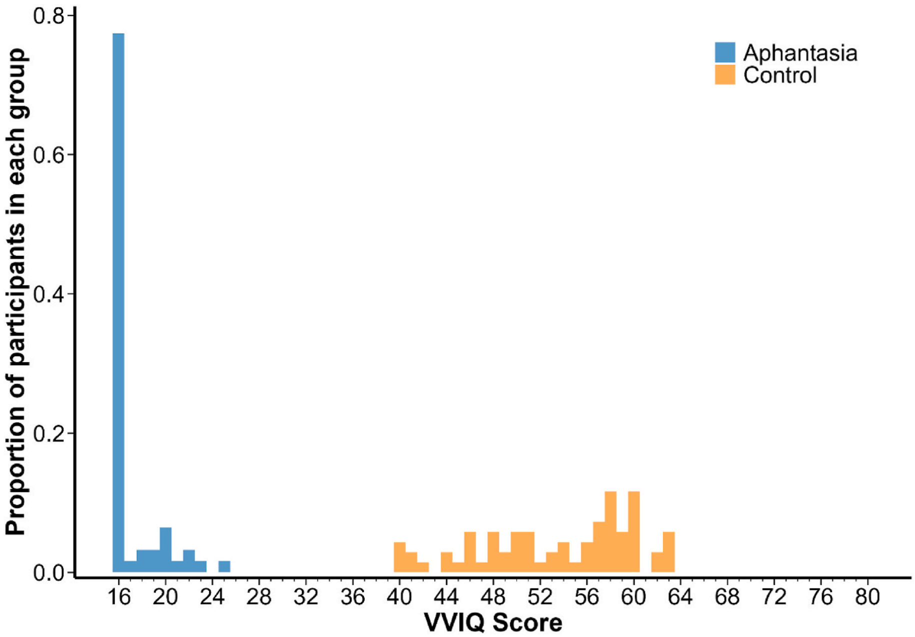


Fig. 1. Distribution of VVIQ Scores by Group. *Note.* This density histogram shows how participants' Vividness of Visual Imagery Questionnaire (VVIQ) scores are distributed within each group. The VVIQ measures self-reported imagery vividness on a scale from 16 (no imagery) to 80 (as vivid as real seeing). Each bar's height represents the proportion of participants achieving that score within their respective group (not across the entire sample). Blue bars depict the aphantasic group (n = 62; scores 16–25), and orange bars depict the control group (n = 69; scores 40–63). Note the unfilled regions between scores 26–39 and 64–80, reflecting our deliberate exclusion of borderline imagery cases and extreme "hyperphantasia" to ensure clear separation between typical imagers and those with aphantasia.

Spatial Imagery Questionnaire (OSIQ; Blajenkova et al., 2006), which measures two distinct dimensions of visual imagery on a scale from 1 (low imagery ability) to 5 (high imagery ability). Its object imagery subscale captures the ability to vividly represent the visual appearance of objects (color, shape, texture), similar to what the VVIQ measures. Its spatial imagery subscale measures the ability to represent spatial relationships between objects, transformations, and rotations. As expected, aphantasic participants scored significantly lower on object imagery ($M = 1.5$, $SD = 0.35$) than control participants ($M = 3.1$, $SD =$ 0.37), $t(128.5) = -25$, $p < .001$, $d = -4.37$, $BF_{10} = 2.63\text{e}{+}47$. Contrary to prior work, aphantasic participants also scored lower on spatial imagery ($M = 2.6$, $SD = 0.56$) compared to controls ($M = 2.9$, $SD = 0.42$), though with a much smaller effect size, $t(111.9) = -2.45$, $p = .016$, $d =$ -0.43, $BF_{10} = 3.03$.

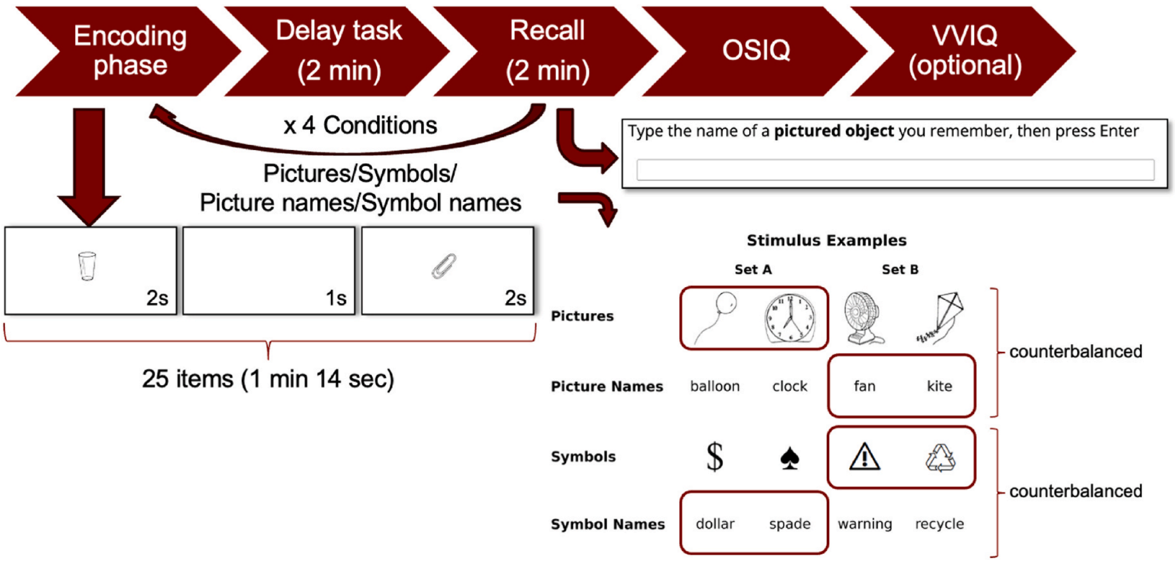
Our data cleaning procedure included several rigorous steps. The majority of data attrition occurred in the control group, where 38 participants were excluded based on VVIQ scores that did not meet our predetermined criteria for typical imagery (scores between 40 and 63), rather than due to data quality issues. Detailed information about the screening process is presented later in the Data section. Despite differences in imagery abilities, the two groups were well-matched on other demographic characteristics. The aphantasia group (M = 43.57 years, SD = 16.56, *range* = 18-77 years) and control group (M = 43.65 years, SD = 10.73, *range* = 18-58 years) showed similar age distributions. Gender distribution was also comparable between groups, with the aphantasia group comprising 45 females (73.77%), 15 males (24.59%), and 1 participant identifying as other or providing no response (1.64%). The control group included 50 females (72.46%) and 19 males (27.54%).

2.2. Materials

In this experiment, we included four types of stimuli: pictures, symbols, picture names, and symbol names. Pictures and symbols served as visual stimuli, while picture names and symbol names served as their corresponding word labels. This design allowed us to simultaneously examine the picture superiority effect (pictures vs. picture names) and symbol superiority effect (symbols vs. symbol names) within each participant group. We also pre-registered a comparison between picture names and symbol names as a potential test of the concreteness effect, given that picture names refer to concrete objects while symbol names often represent more abstract meanings or functions. However, our symbol names may not represent a strong test of the concreteness effect because while symbol names (M = 3.30, SD = 0.84) had significantly lower concreteness ratings than picture names (M = 4.82, SD = 0.27) according to the English Lexicon Project (Balota et al., 2007), $t(87) =$ 11.59, $p < .001$, many of the symbol names (e.g., ‘dollar') were not very abstract, and all symbol names had corresponding visual referents (the symbols themselves), unlike typical abstract words used in studies of the concreteness effect (e.g., 'honor,' 'belief').

We used the exact same stimuli as those used in Roberts et al. (2023)'s experiments that were run with a sample of participants from the general population (i.e., unconstrained by mental imagery ability). The picture stimuli consisted of 50 line drawings selected from the International Picture Naming Project (IPNP) database. These drawings portrayed common, easily identifiable objects with high naming agreement and frequency (see Roberts et al., 2023 for more details). The symbol stimuli comprised 50 graphical symbols formed using the Segoe UI Symbol font. Each symbol was confirmed to be familiar to participants based on average recognizability scores obtained from an online quiz database containing metrics of over 200,000 plays (Sporcle; www.sporcle.com). Both pictures and symbols were standardized to 110 × 116 pixels and presented on a white background (see Fig. 2 for examples).

For the experimental design, the 50 picture stimuli and 50 symbol stimuli were each randomly divided into two sets of 25 items. The word counterparts for these visual stimuli formed corresponding sets of picture names and symbol names. Therefore, parallel to the visual stimuli, we created two sets each of picture names and symbol names, with each set comprising 25 items. All word stimuli were single-word labels presented in black, lowercase, size 36 Calibri font on a white background.



Type the name of a **pictured object** you remember, then press Enter

Fig. 2. Overview of the Experimental Procedure. *Note.* The figure illustrates the core experimental procedure beginning with four randomized study–test blocks. The stimuli for these blocks were drawn from a pool where the 50 picture and 50 symbol images were each split into two randomized sets of 25 items, with their corresponding word labels forming matching sets of 25 picture names and 25 symbol names. Participants were randomly assigned to one set of visual stimuli, and the corresponding word stimuli were drawn from the counterbalanced set to ensure participants never encountered the same concept in both visual and verbal forms (e.g., if they studied the picture of a balloon, they would not see the word "balloon"). The rounded boxes offer an example of the counterbalanced stimuli a given participant would encounter. In each encoding phase, 25 items were presented individually for 2 s with 1 s intervals, followed by a 2 min tone-classification delay task and a 2 min free recall test. During the recall test, the instruction wording (shown in the figure as "Type the name of a pictured object you remember") was adapted to match each condition's stimulus type. After completing all blocks, participants filled out the Object–Spatial Imagery Questionnaire (OSIQ) and the VVIQ (if they had not been pre-screened with it).

2.3. Procedure

This study was administered online using participants' personal computers. After obtaining informed consent, participants underwent four blocks of study-test cycles, one each for pictures, symbols, picture names, and symbol names. Each block contained 25 stimuli. Due to our word-based stimuli being the labels for the image-based stimuli, we implemented a counterbalancing procedure to ensure that participants never saw both the pictorial and textual versions of the same concept. In other words, if participants viewed one set of 25 pictures, they would later view the picture names from the other set of 25 objects. Similarly, they studied a single set of symbols and the symbol names from the non-overlapping set. This arrangement ensured that each concept appeared only once per participant, either in its visual or verbal form. The sequence in which the blocks were presented was randomized, as was the order of stimuli within each block. Fig. 2 provides an overview of this experimental procedure and illustrates the counterbalancing design.

Within each block, participants first went through a study session, where stimuli were presented on the screen one at a time for 2 s, with a 1-s blank screen interval between them. After all 25 stimuli for the block were presented, participants completed a filled delay task. They were instructed to listen to a tone and respond by pressing '1,' '2,' or '3' depending on whether they perceived the pitch of the tone as 'low,' 'medium,' or 'high', respectively, with examples of each pitch provided in the task instructions. Tones were played for 500 ms, with a new tone played every 1500 ms, and participants had to respond to the pitch of the tone before the next one played. This task lasted for 2 min and was designed to prevent potential ceiling effects by eliminating recency effects and minimizing post-list rehearsal.

Following the filled delay, participants had 2 min to complete the free recall memory test for the items viewed during the study phase. They were instructed to enter the stimuli they remembered (for word blocks) or the label of the stimuli (for picture or symbol blocks) into the input boxes. Importantly, while participants were asked to provide labels for pictures and symbols, they were never presented with these labels during the study phase due to our counterbalancing procedure. For picture and symbol blocks, participants were informed that if they did not know the conventional label for a stimulus, they could instead provide a description of what the study item looked like.

Upon completing the four study-test blocks, participants filled out the Object-Spatial Imagery Questionnaire (OSIQ; Blajenkova et al., 2006). The timing of VVIQ administration varied across participants. Participants recruited from social media platforms were pre-screened with the VVIQ, while participants contacted through the Aphantasia Network, from previous studies on aphantasia, or recruited through Prolific completed the VVIQ after the OSIQ at the end of the study.

Participants also completed several attention check questions throughout the study. At the beginning of the experiment, participants completed three bot check questions, which required them to type the city and state they live in, identify the term for a baby dog (puppy), and state the month Valentine's Day falls in (February). After completing the four blocks of memory tests, participants completed several additional attention check questions. The first was embedded within the OSIQ with the text "Click 'agree' below." The second question asked participants if they completed the experiment under ideal conditions, such as fully understanding the task, trying their best and not being distracted. The third attention check question was a multiple-choice question that asked, "Which choice below is not a type of visual content you studied in the experiment?" with the correct answer being "numbers." Control participants received an additional question asking whether they had used any external memory aids during the study (e.g., taking notes, screenshots), with assurance that their compensation would not be affected by their response. This additional check was implemented only for control participants because they were primarily recruited through Prolific, and we had observed poor data quality in our initial collection with Prolific participants. Following these attention checks, we collected demographic data including age, gender, ethnicity, and race. Finally, a feedback letter was provided that detailed the study's purpose.

2.4. Data cleaning and recall scoring

Prior to analyzing the experimental data, we implemented a comprehensive data quality screening process. From the initial 215 participants (77 aphantasics, 138 controls), we excluded participants based on the following criteria: incomplete study (1 aphantasic), failed bot checks or attention checks (3 aphantasics, 8 controls), self-reported unideal conditions (6 aphantasics, 10 controls), self-reported use of memory aids (1 control), low filler task accuracy (<50%) (2 aphantasics, 9 controls), extended delays between encoding and recall (>7 min; 1 aphantasic, 3 controls), and VVIQ scores outside our inclusion criteria for either group (38 from Prolific, 2 from other recruitment sources). Notably, of the 138 control participants recruited from Prolific, 31 (22.5%) were removed for data quality issues (excluding those removed solely for VVIQ scores outside our target range), which is consistent with typical attrition rates reported for online participant recruitment platforms (Peer et al., 2017, 2022).

To score the free recall responses, two research assistants (RAs) independently evaluated participants' responses (inter-rater reliability $\alpha = .93$). RAs were blind to the study's hypotheses, as well as to participants' group membership (aphantasia vs. control) during scoring. RAs scored each recall response with 0, 1, or 2 points based on its accuracy. Responses that were incorrect and completely unrelated to the studied items received 0 points. Responses that captured the gist of the studied item but weren't exact matches (e.g., recalling "puppy" when "dog" was studied) received 1 point. Exact matches with studied items received 2 points. The final score for each response was determined by comparing the evaluations from both RAs. When their scores were consistent, that score was used. When inconsistent, a consensus score was determined through consultation with the researchers on this study. For each condition, we calculated participants' final recall scores as the total number of responses that received either 1 or 2 points. We also conducted analyses using strict scoring (counting only exact matches) to ensure the robustness of our findings. Since these analyses yielded largely consistent results with our lenient scoring approach, we present only the lenient scoring results in the main text. See the Supplementary Materials for detailed comparison of the results from the two scoring methods.

After scoring was complete, we conducted outlier analyses. No participants were statistical outliers (±3 *SD*) on recall scores when examined separately for each group (aphantasia and control) and each condition (pictures, symbols, picture names, and symbol names), resulting in our final sample of 131 participants (62 in the aphantasia group and 69 in the control group).

3. Results

We conducted a 2 × 4 mixed ANOVA with group (aphantasia, control) as a between-subjects factor and condition (pictures, symbols, symbol names, picture names) as a within-subject factor, with the dependent measure being the number of items recalled in each condition block.[1] Results revealed a significant main effect of Group, $F(1, 129) = 5.97$, $p = .016$, $\eta_p^2 = 0.044$, $BF_{10} = 16.12$, indicating that overall recall performance was higher in control participants compared to aphantasic participants.[2] A significant main effect of Condition was also observed, $F(3, 387) = 43.31$, $p < .001$, $\eta_p^2 = 0.25$, $BF_{10} = 3.52\text{e}{+}13$, demonstrating substantial differences in recall performance across the four types of stimuli. However, the Group × Condition interaction was not significant, $F(3, 387) = 1.34$, $p = .261$, $\eta_p^2 = 0.01$, $BF_{01} = 18.94$, indicating that the difference in recall patterns across stimulus types did not change substantially between aphantasic and control participants.

3.1. Testing predictions from dual-coding theory

As shown in Fig. 3, our planned comparisons revealed better recall performance for image-based stimuli than for their word counterparts. As expected, the control group showed a picture superiority effect (PSE), with significantly better recall for pictures ($M = 10.7$, $SD = 3.34$) compared to picture names ($M = 7.72$, $SD = 3.43$), $t(68) = 5.87$, $p < .001$, $d = 0.71$, $BF_{10} = 9.59\text{e}{+}4$. Contrary to predictions from dual-coding theory, the aphantasic group also demonstrated a PSE: pictures ($M = 9.11$, $SD = 2.91$) were recalled significantly better than picture names ($M = 6.69$, $SD = 3.57$), $t(61) = 6.08$, $p < .001$, $BF_{10} = 1.58\text{e}{+}5$, with a similarly large effect size ($d = 0.77$). To further test whether these picture superiority effect sizes differed significantly between groups, we calculated for each participant a difference score (pictures minus picture names) and compared these scores between groups using an independent-samples *t*-test. The analysis confirmed that the difference scores were similar between groups, $t(125.47) = 0.80$, $p = .427$, $BF_{01} = 4.04$, indicating that the picture superiority effect is not only preserved in aphantasia but is also of similar magnitude as in typical imagers.

In addition, each group demonstrated a symbol superiority effect. Recall was significantly better for symbols ($M = 10.7$, $SD = 3.73$) compared to symbol names ($M = 7.81$, $SD = 3.45$) in the aphantasia group, $t(61) = 4.81$, $p < .001$, $d = 0.61$, $BF_{10} = 1.78\text{e}{+}3$, and for symbols ($M = 11.0$, $SD = 3.38$) compared to symbol names ($M = 9.19$, $SD = 3.73$) in the control group, $t(68) = 3.19$, $p = .004$, $d = 0.38$, $BF_{10} = 12.96$, consistent with findings from Roberts et al. (2023). A test of symbol minus symbol name difference scores showed no significant difference between groups, $t(127.19) = 1.33$, $p = .187$, $BF_{01} = 2.40$, indicating comparable symbol superiority effect sizes. These findings demonstrate

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[1] To ensure the robustness of these effects for each image-word pairing independently, we conducted two separate 2 × 2 ANOVAs. For the pictures and picture name pairings, there was a significant main effect of Group, $F(1, 129) = 7.06$, $p = .009$, $\eta_p^2 = 0.05$, $BF_{10} = 7.05$ such that typical imagers demonstrated better memory overall, and there was a significant main effect of Condition, $F(1, 129) = 10.68$, $p < .001$, $\eta_p^2 = 0.35$, $BF_{10} = 1.51\text{e}{+}7$, with pictures recalled better than picture names. The interaction was non-significant, $F(1, 129) = 0.62$, $p = .434$, $\eta_p^2 = 0.01$, $BF_{01} = 4.45$. For symbols and symbol names pairings, there was no main effect of Group, $F(1, 129) = 3.16$, $p = .078$, $\eta_p^2 = 0.02$, $BF_{01} = 1.66$, but there was a significant main effect of Condition, $F(1, 129) = 32.47$, $p < .001$, $\eta_p^2 = 0.20$, $BF_{10} = 4.81\text{e}{+}4$, with symbols recalled better than symbol names. The interaction was once again non-significant, $F(1, 129) = 1.77$, $p = .187$, $\eta_p^2 = 0.01$, $BF_{01} = 3.32$. These results indicate that each group experienced both picture superiority (pictures > picture names) and symbol superiority (symbols > symbol names) effects in memory, and that the size of these effects did not differ as a function of visual imagery ability. This pattern replicates the key findings from the overall 2 × 4 ANOVA and subsequent *t*-tests in the main results.

[2] Bayes factors were calculated using the *BayesFactor* package (v. 0.9.12–4.7; Morey et al., 2011) for *R*, enlisting the default Jeffreys-Zellner-Siow (JZS) prior with a Cauchy distribution (center = 0, $r = 0.707$). Bayes factors for interaction terms are relative to models including both main effects.

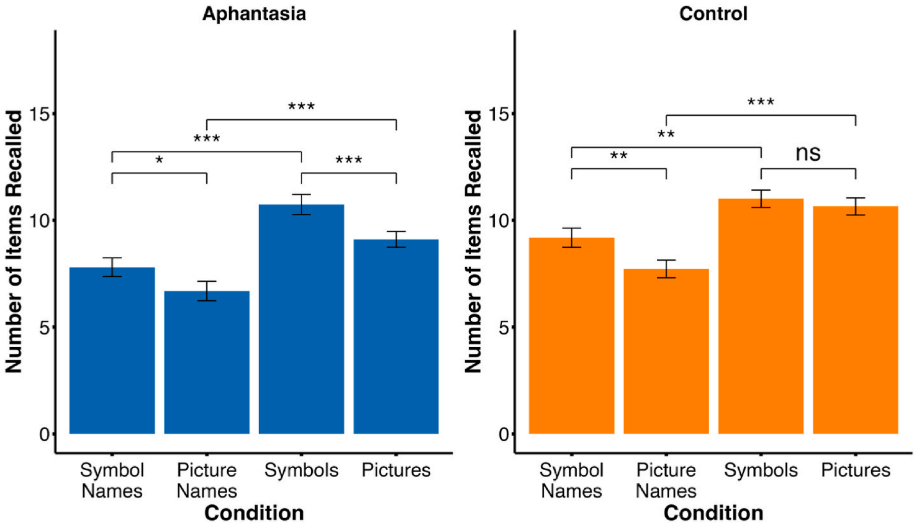

Fig. 3. Within-Subject Comparisons of Memory Recall Performance. *Note.* Bar plots displaying mean number of items recalled per condition separately for the aphantasia group (left) and the control group (right). Error bars represent ±1 *SE*. Asterisks denote Holm–adjusted paired *t*-test significance: $p < .05$ (*); $p < .01$ (**); $p < .001$ (***); ns = non-significant.

that the picture and symbol superiority effects are preserved in aphantasia for both images and symbols, respectively, with effect sizes similar to those observed in typical imagers.

Unexpectedly, although picture names referred to concrete physical objects while symbol names referred to more abstract concepts, both groups recalled symbol names significantly better than picture names. However, the strength of this evidence varied between groups. In the aphantasic group, symbol names were recalled better than picture names based on the *p*-value ($t(61) = 2.14$, $p = .036$, $d = 0.27$), but the Bayes factor was uninformative ($BF_{10} = 1.17$), suggesting this difference may not be reliable. In contrast, the control group showed more consistent evidence for better recall of symbol names compared to picture names ($t(68) = 3.67$, $p = .001$, $d = 0.44$, $BF_{10} = 50.25$). This unexpected finding may be a quirk of our specific stimulus lists rather than a theoretically meaningful pattern.[3]

When comparing between sets of visual stimuli, we found that the aphantasic group recalled symbols significantly *better* than pictures ($t(61) = 4.04$, $p < .001$, $d = 0.51$, $BF_{10} = 147.42$), whereas the control group showed no significant difference between these two stimulus types ($t(68) = 0.81$, $p = .423$, $d = 0.10$, $BF_{01} = 5.54$), the latter of which is consistent with prior work (Roberts et al., 2023).

3.2. Group comparisons

Beyond the core dual-coding predictions, we also examined how the two groups processed different types of visual stimuli relative to each other. As illustrated in Fig. 4, between-group comparisons revealed that control participants significantly outperformed aphantasic participants only in the picture condition, $t(128.9) = 2.82$, $p = .023$, $d = 0.49$, $BF_{10} = 6.13$ (although picture recall did *not* correlate with VVIQ score when tested within each group individually; see Supplemental Materials). No other significant between-group differences were observed ($ps \geq 0.088$), although Bayesian evidence for the null was inconclusive for symbol names ($BF_{01} = 0.63$) and picture names ($BF_{01} = 1.48$), whereas it was moderate for symbol recall ($BF_{01} = 4.90$). To investigate why symbols, despite being visual stimuli like pictures, did not show a similar recall disadvantage in the aphantasic group relative to the control group, we conducted additional analyses examining the relationships between recall performance for symbols and their frequency, familiarity, and concreteness, but did not observe a clear explanation for aphantasics' enhanced performance (see Supplemental Materials).

3.3. Memory representations between formats and groups

Exploratory analyses were also conducted to determine (1) whether both groups showed similar memory behavior for concepts across presentation formats (image or word), and (2) whether those with aphantasia share the same item-level memory performance as typical imagers.

To address the first question, we analyzed correlations between the number of valid responses each concept received when presented as an image versus as a word (e.g., a picture of a clock versus the word 'clock;' Fig. 5, top row). For concepts represented by pictures or their corresponding names, both groups showed significant positive correlations between the number of times a given concept was recalled as a picture and the number of times it was recalled as a word (aphantasia: $r = .34$, $p = .016$, $BF_{10} = 4.34$; control: $r = .43$, $p = .002$, $BF_{10} = 27.08$). Similarly, for concepts represented by symbols or their corresponding names, both groups demonstrated significant correlations between the number of times a given concept was recalled as a symbol and the number of times it was recalled as a word (aphantasia: $r = .46$, $p < .001$, $BF_{10} = 53.25$; control: $r = .30$, $p = .035$, $BF_{10} = 2.36$). These consistent correlations across both groups indicate that the likelihood a concept will be recalled remains stable regardless of its presentation format. Put another way, concepts that are easily remembered as pictures are also likely to be

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[3] The pattern of better recall for symbol names than picture names appears to be primarily a list effect. Participants were randomly assigned to one of two randomly split symbol name lists, and recall performance differed significantly between these lists across all participants ($t(129) = 5.67$, $p < .001$). Only participants across groups who received the easier (by chance) symbol names list showed significantly better recall of symbol names compared to picture names (aphantasia: $t(30) = 5.17$, $p < .001$; control: $t(40) = 6.26$, $p < .001$), while those who received the more difficult list showed no significant difference between symbol name and picture name recall (aphantasia: $p = .184$; control: $p = .235$). In addition, we note that this comparison does not constitute a test of the traditional concreteness effect, as both our picture names and symbol names had relatively high concreteness ratings according to the English Lexicon Project (Balota et al., 2007). Our symbol name stimuli had relatively low ratings compared to our picture name stimuli, but were still more concrete than the database average. Furthermore, all our symbol names had corresponding visual symbols that participants were likely familiar with, which may have facilitated their symbol name recall in ways that differ from recall of abstract words lacking standard visual referents (e.g., 'honor').

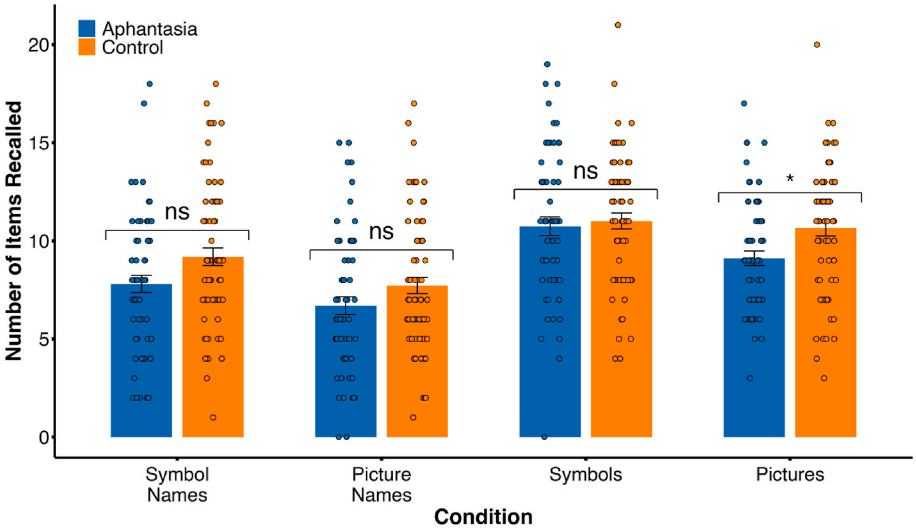

Fig. 4. Between-Group Comparisons of Memory Recall Performance. *Note.* Side-by-side bar plots for each condition comparing mean recall in the aphantasia (blue) and control (orange) groups. Individual data points are overlaid. Error bars represent ±1 *SE* (same values as in Fig. 3). Asterisks denote Holm–adjusted paired *t*-test significance: $p < .05$ (*); ns = non-significant. Only picture recall differed between groups after Holm correction ($p = .023$).

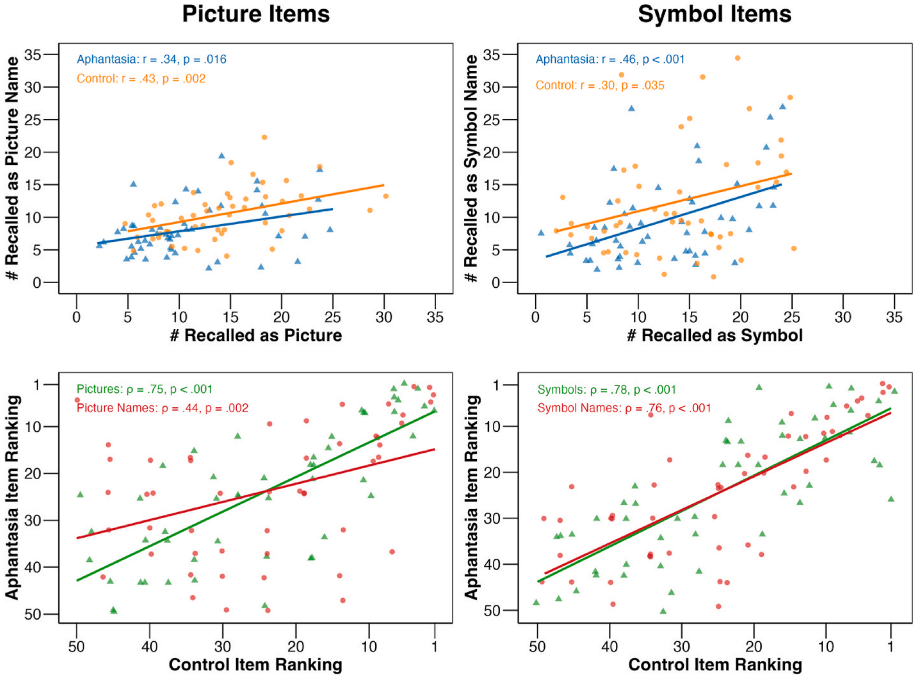

Fig. 5. Concept Memorability Correlations and Inter-Group Item Ranking Correlations. *Note.* The top row shows correlations between recall counts for the same concepts presented in different formats. **Top Left.** Correlations between picture and picture name recall for each pair of items, with separate correlation lines for the aphantasia group (blue) and control group (orange). **Top Right.** Correlations between symbol and symbol name recall, with the same color coding. The bottom row displays correlations between aphantasia and control group item memorability rankings within each condition. **Bottom Left.** Ranking correlationsbetween control and aphantasia group item memory rankings for pictures (green) and picture names (red). **Bottom Right.** Ranking correlations between control and aphantasia group item memory rankings for symbols (green) and symbol names (red). In the ranking plots, axes are inverted so that better-remembered items (lower rank numbers) appear toward the upper right. All correlations were statistically significant, indicating that item memorability remains consistent across presentation formats and that both groups show similar patterns of item-level recall within each stimulus type. Data points were slightly jittered along both axes to improve visibility where multiple points overlapped.

easily remembered as words, and the same applies to concepts presented as symbols or their associated labels. These correlations persist regardless of participants' visual imagery abilities, suggesting that how well a concept is remembered (its 'memorability') may be an intrinsic property of the concept itself, transcending both the specific form in which it is presented and individual differences in mental imagery capacity. This also suggests that there may be similarities in how the two groups represent concepts across formats (verbal and visual).

We next examined whether the memory ranking patterns of item-level performance were similar between groups across all four stimulus conditions (Fig. 5, bottom row). Spearman correlations revealed strong positive relations between memory rankings in the two groups across all conditions: pictures ($\rho = .75$, $p < .001$, $BF_{10} = 1.05\text{e}+07$), symbols ($\rho = .78$, $p < .001$, $BF_{10} = 7.93\text{e}+07$), picture names ($\rho = .44$, p

$= .002$, $BF_{10} = 10.85$), and symbol names ($\rho = .76$, $p < .001$, $BF_{10} = 4.39e{+}06$). To explore why the correlation might be lower for picture names, we also analyzed word length, familiarity, and concreteness of those items, but did not observe a clear feature-based explanation (see Supplemental Materials). Regardless, these correlations indicate that items which were well-remembered by one group tended to be well-remembered by the other group, and items that were poorly remembered by one group tended to be poorly remembered by the other group. The strong correlation for pictures is particularly notable, as it suggests that despite aphantasics' overall lower picture recall performance, both groups showed fundamentally similar patterns in which specific pictures were easier or harder to remember. This preliminary analysis indicates that both groups may share similar underlying memory representations, with a difference only in the overall strength of picture memory.

4. Discussion

The picture superiority effect—the robust finding that pictures are consistently better remembered than words—is a widely replicated phenomenon in memory research. According to dual-coding theory, pictures are better remembered than words because they activate both verbal and visual memory codes, while words typically activate only verbal codes. Having two distinct memory codes increases recall probability, as either code can independently lead to successful retrieval, and one code can serve to cue the other. If this explanation were accurate, individuals with aphantasia, who cannot voluntarily generate mental imagery, should theoretically be unable to form and retrieve image codes. Consequently, they should not show any picture superiority effect, as both their picture and word recall would only rely on verbal memory codes. Our study investigated whether the picture superiority effect persists in aphantasia, directly testing dual-coding theory's explanation of this memory phenomenon. We compared recall performance between aphantasic and typical imagers across four stimulus types (pictures, symbols, picture names, and symbol names) to test this critical prediction and determine whether other mechanisms beyond dual-coding might contribute to these well-established memory effects.

4.1. Challenges to dual coding theory

Our results revealed several important findings that challenge dual-coding theory's explanation of the picture superiority effect. First, despite their inability to voluntarily generate mental imagery, aphantasic individuals demonstrated a robust picture superiority effect, with pictures recalled significantly better than picture names, and with an effect size nearly identical to that of control participants. Second, aphantasic participants showed significantly better recall for symbols compared to symbol names, demonstrating the symbol superiority effect as well. In addition, while controls showed comparable recall for pictures and symbols, aphantasics unexpectedly recalled symbols significantly better than pictures. Importantly, this pattern did not reflect aphantasics performing better with symbols than controls, but rather aphantasics performing worse than controls specifically in the picture condition and equivalent to controls in the symbol condition. This differential pattern suggests that control participants process both types of visual stimuli (pictures and symbols) similarly, whereas aphantasics show a distinct processing advantage for symbols over pictures.

This pattern of results presents a significant challenge to dual-coding theory's explanation of the picture superiority effect and related memory phenomena. The advantage of visual stimuli in memory appears to persist independently of one's ability to generate a visual image code, suggesting that other mechanisms beyond those proposed by dual-coding theory must contribute to the memory advantages observed for pictures and symbols over their word-based counterparts.

Specifically, these findings leave us with two broad theoretical possibilities. First, dual-coding theory may remain viable but require substantial modifications to accommodate our results, such as reconsidering when and how dual codes exert their benefits or by broadening what qualifies as a secondary memory code. Alternatively, dual-coding theory may be fundamentally inadequate for explaining these memory phenomena, and an alternative mechanism, such as a distinctiveness account, may better account for the picture and symbol superiority effects we observed. In what follows, we examine each of these alternatives.

4.2. Modifications to dual coding theory

One possible way in which dual-coding theory may be preserved in light of our findings is to reconsider the stage at which dual codes confer their memory advantage. The enhanced memory for image-based stimuli may indeed result from dual coding, but this may primarily benefit an individual during the encoding phase rather than during retrieval. While dual-coding theory traditionally emphasizes having two retrieval pathways to increase recall probability during the memory test, our findings are compatible with the idea that the benefits might stem simply from having two forms of representations during initial encoding. Since aphantasics cannot recreate image memory codes during retrieval, they would not benefit from multiple retrieval routes at test. However, they can still label images during the encoding phase, allowing them to form dual codes for image-based stimuli when there are 'free' image representations provided via the pictures and symbols on-screen. In this scenario, the way in which dual codes conferred at encoding benefit later recall would remain an open question (perhaps they enhance overall memory strength). Furthermore, symbols may offer more 'efficient' encoding of the visual memory code relative to pictures for aphantasics due to the former's simpler visual designs. This could explain why aphantasics' symbol recall matched that of controls while their picture recall was comparatively attenuated.

A second way dual-coding theory might accommodate our results is by expanding what constitutes a secondary memory code. Rather than requiring visual imagery specifically, aphantasics may have recalled symbols better than pictures because they employ different compensatory strategies for encoding visual stimuli that serve a similar dual-coding function. For instance, the secondary memory code does not have to be visual imagery, but could involve other forms of mental representation such as spatial or motor imagery. In this interpretation, dual-coding theory would require a much broader conceptualization of what constitutes a secondary memory code beyond just visual and verbal representations.

One such compensatory dual code may be spatial imagery, mentally encoding information in relation to imagined locations to enhance memory through distinct spatial associations (Ren et al., 2025). Our OSIQ results provide suggestive evidence that aphantasics could rely on their relatively intact spatial imagery as a compensatory strategy. Although aphantasics scored lower than controls on both object and spatial imagery, the effect size was dramatically larger for object imagery ($d = -4.37$) than for spatial imagery ($d = -0.43$). Furthermore, previous studies by Bainbridge et al. (2021) and Dawes et al. (2020) found no significant differences in OSIQ-Spatial scores between aphantasics and controls. These mixed findings across studies indicate that the lower OSIQ-Spatial scores we observed in aphantasia may reflect chance recruitment of controls with slightly better spatial imagery, or aphantasics with atypically poor spatial imagery, rather than a true population difference. Beyond self-report measures, Bainbridge et al. (2021) also found that aphantasics demonstrated intact spatial memory despite the absence of visual object imagery, showing equivalent spatial accuracy to controls in object placement and sizing during drawing-from-memory tasks, paralleling patterns observed in congenitally blind individuals (Cattaneo et al., 2008; Eardley and Pring, 2007; Kerr, 1983; Zimler and Keenan, 1983). Taken together, these patterns suggest that spatial imagery abilities may remain largely intact in aphantasics, providing a potential compensatory mechanism for encoding information in the absence of visual imagery.

Another possible dual code could be formed via motor imagery.

Symbols' simpler geometric properties may allow aphantasics to mentally trace their shapes. This motor-based encoding would be more feasible for simple symbols than for complex pictures, potentially explaining the differential recall performance in aphantasics. Unlike the novel object pictures in our study, the standardized and minimal representations of symbols may be particularly amenable to motor tracing strategies. The consistent shape of symbols may have allowed them to be encoded via motor simulation despite the relatively brief presentation time in our study. Supporting this interpretation, aphantasics in Bainbridge et al.'s (2021) drawing study relied on verbal or schematic encoding strategies and tended to draw simple, prototypical representations rather than exact visual details. This preference for schematic representations in prior work aligns with the notion that symbols represent standardized forms and are therefore more amenable to motor imagery encoding relative to more complex picture representations.

We acknowledge that this motor imagery hypothesis remains speculative, as we did not measure motor imagery abilities in this study. This hypothesis emerged from the first author's own experience as someone with aphantasia who participated in pilot testing for this experiment. The first author reported using mental tracing while studying symbols, essentially simulating the process of drawing the symbols to remember them. Supporting this interpretation, the first author's own recall performance mirrored the recall pattern observed in our aphantasic participants—showing both picture and symbol superiority effects, with particularly strong recall for symbols. Although this hypothesis currently lacks direct empirical validation, we believe this perspective from someone with lived experience of aphantasia provides valuable insight worthy of future empirical investigation.

4.3. *Distinctiveness as a parsimonious alternative*

The modifications to dual-coding theory outlined above, whether emphasizing encoding over retrieval or broadening the definition of secondary codes, could potentially reconcile the theory with our findings. However, these amendments may not be necessary if an alternative account can better explain the picture and symbol superiority effects. Distinctiveness-based accounts represent such an alternative. In fact, proponents of dual-coding theory have acknowledged that physical distinctiveness may better explain the picture superiority effect in recognition tasks (Paivio and Csapo, 1973). The persistence of picture and symbol superiority effects in individuals with aphantasia provides a unique opportunity to evaluate these competing theoretical accounts in the context of free recall.

Our findings challenge dual-coding theory's explanation and suggest that distinctiveness-based mechanisms may better account for these memory advantages. If distinctiveness mechanisms primarily drive picture and symbol superiority in memory, then the inability to generate voluntary visual imagery should not eliminate the memory benefit. This is because the distinctive visual properties of pictures and symbols, such as their varied shapes, orientations, and unique visual features, remain intact at encoding even when an individual's voluntary imagery generation is impaired. Consistent with this prediction, our results demonstrate that both picture superiority and symbol superiority effects were preserved in aphantasic individuals. This pattern suggests that distinctiveness-based accounts align better with our findings than dual-coding theory, providing a more compelling explanation for the memory advantages observed for visual stimuli over verbal stimuli.

However, some of our results reveal patterns that may require additional explanation beyond distinctiveness alone. If distinctiveness of visual stimuli fully governed all aspects of recall performance in our task, we would expect several patterns that we did not observe. First, we would expect no group differences in picture memory, since the physical distinctiveness of the pictures themselves was identical across groups. Yet controls outperformed aphantasics on picture recall. Second, we might expect consistent relative patterns across groups when comparing symbol and picture recall, that is, either equivalent recall for these two stimulus types, or the same relative advantage in both groups. Instead, aphantasics recalled symbols better than pictures, while controls showed no difference between the two. Taken together, these patterns suggest that while distinctiveness provides a more compelling explanation than dual-coding theory for the picture and symbol superiority effects we observed, additional factors may also play a role in shaping overall memory performance. Future research will be needed to identify what other mechanisms might contribute to these group-specific differences.

4.4. *Limitations and future research directions*

Our theoretical interpretations rest on the assumption that aphantasia represents a genuine visual imagery deficit, an assumption supported by converging behavioral and neural evidence reviewed earlier in the article. Under this assumption, our results challenge dual-coding theory's reliance on visual codes to explain picture superiority and symbol superiority effects, and instead suggest that alternative mechanisms must account for the memory advantages observed for visual stimuli. However, a different class of accounts proposes that aphantasia does not always reflect a structural imagery deficit but can, in some cases, arise from metacognitive or motivational factors (De Vito and Bartolomeo, 2016). For example, some individuals may misinterpret or under-report their imagery experiences, or "refuse" to imagine despite preserved cognitive capabilities. In this metacognitive interpretation, some aphantasic individuals might possess visual representations that are not fully accessible to conscious awareness, raising the possibility that subjective reports alone may underestimate one's underlying representational capacity.

At the same time, recent neuroimaging work indicates that early visual activity in aphantasia is not, by itself, sufficient to constitute imagery. Cabbai et al. (2024) showed that aphantasic individuals exhibit decodable stimulus-specific representations in primary visual cortex (V1) during sound-evoked tasks despite reporting no subjective imagery, demonstrating that low-level visual processes can operate without giving rise to conscious imagery. Crucially, these findings do not imply that aphantasics possess "unconscious imagery;" rather, they suggest that early visual cortex representations, although necessary, are not sufficient for the subjective experience that defines imagery. Furthermore, even if some aphantasic individuals retain such low-level visual processes, it remains unclear how these processes could enhance memory performance within a dual-coding framework which specifically attributes the picture advantage to conscious access of a secondary image code at retrieval. Nonetheless, future research should incorporate more comprehensive assessments of visual imagery, including behavioral tasks and neuroimaging measures, to further clarify the nature of aphantasia and how it shapes memory formation and recall.

Our stimulus selection strategy also limits our ability to examine concreteness effects. Although we initially intended to test whether aphantasics show preserved concreteness effects by comparing recall of picture names versus symbol names, our stimulus set proved inadequate for this purpose. By using word labels corresponding directly to visual stimuli, we ensured that memory differences (e.g., pictures vs picture names) reflected stimulus format rather than conceptual differences. However, symbol names proved unsuitable for testing the concreteness effect because they do not appear to be processed like other abstract words that lack symbolic referents. Unlike typical abstract words used in concreteness effect studies, all our symbol names had corresponding symbols that could evoke clear mental images. This visual pairing likely enhanced their imageability: Rather than representing abstract concepts without clear visual referents, our symbol names functioned as labels for visual stimuli, similar to picture names. Consequently, the comparison between picture names and symbol names does not constitute a valid test of the concreteness effect as both are highly imageable sets of words, and we therefore cannot draw conclusions about whether aphantasics show preserved concreteness effects in memory. Future studies should employ more extreme abstract concepts that lack visual referents to provide a clearer test of this question. Such research would help determine whether the memory advantages typically attributed to concrete words' imageability are similarly preserved in aphantasia, or whether they require conscious visual imagery as dual-coding theory would predict.

Furthermore, future studies should directly test the motor imagery hypothesis we propose. While our results suggest aphantasics may employ motor imagery as a compensatory mechanism, this remains speculative. To test this hypothesis, future research should investigate whether motor imagery differentially benefits recall for symbols versus pictures, particularly in aphantasics but also in typical imagers. For instance, studies could measure participants' motor imagery abilities using the Movement Imagery Questionnaire (Hall and Martin, 1997) and examine whether MIQ scores correlate with recall performance for symbols versus pictures in aphantasic and typical imagers.

Finally, given that distinctiveness has been a longstanding competing explanation with dual-coding theory, future research should further investigate whether distinctiveness can fully account for our findings in aphantasic participants. Some of our results remain puzzling even from a distinctiveness perspective. For instance, aphantasics recalled symbols better than pictures, while typical imagers showed equivalent performance between these conditions. However, if successful memory retrieval is driven primarily by the distinctiveness of the stimuli, then both groups should show similar patterns of performance. Future studies could manipulate physical distinctiveness systematically to determine whether differential patterns in aphantasics reflect differences in how these individuals perceive or encode distinctive features. By building on our research, future work in this area can further unravel the complex relationship between visual imagery and memory, potentially leading to revised theoretical frameworks that better account for the cognitive processes underlying memory for different types of stimuli.

4.5. Conclusion

Dual-coding theory proposes that pictures are better remembered than words because they generate both visual and verbal memory codes, while words typically generate only verbal codes. We tested this theory by examining recall performance in aphantasic individuals who cannot voluntarily generate mental imagery and should therefore, according to dual-coding theory, be unable to benefit from visual memory codes during recall. However, our results clearly contradict this prediction and challenge the traditional dual-coding explanation for the picture superiority in memory recall. The key findings from our investigation reveal that aphantasic individuals, despite their inability to voluntarily generate mental imagery, still exhibit the picture superiority and symbol superiority effects. Additionally, we observed that aphantasics recalled symbols better than pictures while controls showed no such difference, and that aphantasics performed as well as controls across most stimulus types, with the exception of picture memory.

Collectively, these findings indicate that voluntary visual imagery, while potentially enhancing overall memory performance, is not essential for the relative advantages typically associated with image-based stimuli. The persistence of these memory effects in aphantasics suggests that other mechanisms beyond those proposed by dual-coding theory must contribute to memory advantages for pictures and symbols. These alternative mechanisms might include distinctiveness account, more efficient encoding processes, or compensatory strategies such as spatial and motor imagery.

CRediT authorship contribution statement

Muhan Yan: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Brady R.T. Roberts:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Wilma A. Bainbridge:** Writing – review & editing, Writing – original draft, Supervision, Resources, Funding acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2026.109391.

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