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The role of visual imagery and verbal coding in short-term memory conjunctive binding: evidence from aphantasia

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ABSTRACT

Conjunctive binding – as opposed to relational binding – refers to our short-term memory for integrated representations of a series of features into a complex – unitized – object. The mechanisms necessary to encode conjunctive representations in memory are, to date, unknown. In this study, we tested whether mental visual imagery and verbal coding are necessary to encode conjunctive representations in short-term memory. We also explored the memory processes supporting retrieval of these representations. To explore specifically the role of visual imagery, we tested a population of aphantasic participants (N = 29) that we compared with typical imagers (N = 49), as assessed by the VVIQ. To assess the role of verbal coding, we had participants memorise colour-shape conjunctive representations while manipulating the ease with which labels could be used to define the shapes. Results showed a robust effect of the use of verbal coding on performance and confidence ratings, accompanied by an increase in both automatic and controlled memory processes. There was however no difference between aphantasics and typical imagers on these measures. In addition, even in the difficult-to-label condition, aphantasics performed well above chance, suggesting that neither visual imagery nor verbal coding are necessary to perform conjunctive binding. This supports the idea that binding is automatic, and the existing hypothesis according to which the first stage of conjunctive binding is implicit. It is possible that aphantasic participants used implicit representations, unavailable to their phenomenological experience, to solve the task, or non-visual spatial or sensorimotor strategies.

1. Introduction

To recognise objects, we fundamentally rely on our ability to integrate their features, like their shape, size, texture, colour, etc., into coherent representations. This is classically referred to as the "binding problem" (for review, Hardcastle, 2017; Treisman, 1996). Feature binding has been studied at length across several domains of cognitive science. It is referred to as feature integration in the domain of perception (Treisman & Gelade, 1980), while encoding and holding these complex integrated representations in memory are designated as conjunctive binding in short-term memory (Parra et al., 2010), and as unitization in episodic memory (Graf & Schacter, 1989).

Yet, the most recent views propose that regardless of the task and the function involved, whether perceptual or mnemonic, these conjunctive representations are supported by the apex regions of the ventral visual stream, within the medial temporal lobe, mainly the perirhinal cortex (see Bastin et al., 2019 for review). Visual conjunctive representations are thought to result from the progressive integration of visual features along the ventral visual stream (for review, Cowell et al., 2019), to support both short- and long-term memory (Yonelinas, 2013). These complex, integrated visual representations are classically opposed to relational mnemonic representations, that are flexible associations between distinct objects or elements and rely on the hippocampus (Yonelinas, 2013). Conjunctive and relational representations are also distinguished based on the processes they engage during recognition, be it in short-term memory or in episodic memory. Conjunctive representations can be recognized using automatic processes in short-term memory, or familiarity in episodic memory (i.e., recognition in the

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absence of retrieval of details from encoding), while relational representations require controlled processes in short-term memory, and recollection in episodic memory (i.e., controlled retrieval of the information associated to the item during encoding, Yonelinas, 2002). However, there is no strong consensus among researchers regarding the necessary mechanisms of the formation and memory encoding of conjunctive representations (Li et al., 2022).

In short-term memory, the hierarchical binding model proposes that binding occurs in two stages. In a first, implicit, stage, spread attention allows for rapid, coarse processing of highly distinctive basic features in parallel, whose products enter short-term memory, forming a rough object representation. This implicit stage would already contain bound, object-based, representations (i.e., conjunctive, in which the individual features are not accessible separately) (Gao & Shen, 2024). In a subsequent, explicit stage, focused attention allows for the details of the object (including binding relationships) to be re-processed to form stable and accurate bound representations (see Gao & Shen, 2024 for review).

In general, in visual short-term memory tasks, visual mental imagery (i.e., the ability to generate visual mental representations in the absence of external visual stimulation; Kosslyn & Thompson, 2003; Pearson & Kosslyn, 2015) and semantic/phonological labelling are the two main strategies described. Good imagers especially recruit visual imagery to perform those tasks, while worse imagers use some semantic encoding or strategies based on non-representational geometry or symbols (reviewed in Pearson, 2019). Indeed, most memoranda can be remembered either via verbal codes or visual memory traces, or both (Lewis-Peacock et al., 2015). Translation of visual representations into verbal codes has been found to improve visual memory span in healthy young adults (e.g., Brown et al., 2006; Souza & Skóra, 2017). However, little research has been carried on concerning the mechanisms at play during the encoding of conjunctive representations specifically.

In parallel, in episodic memory, an – under-explored – hypothesis suggested that conjunctive representations are encoded using visual imagery, before being anchored within our preexisting knowledge in semantic memory (Ryan et al., 2013). In support of this claim, empirical evidence showed that both visual imagery (Lucas et al., 2017; Rhodes & Donaldson, 2008; Tu et al., 2017) and preexisting semantic knowledge (Tibon et al., 2014) strongly promote the processing of information in a unitized, and thus, conjunctive, manner.

The last decade has brought increasing attention to a phenomenon known as aphantasia, a condition that manifests as an inability to voluntarily form mental visual images (Zeman et al., 2015; Zeman et al., 2010). The precise neurobiological cause underlying aphantasia is far from being understood, and only few neuroimaging studies exist to date. During attempts of mental imagery or during rest, in aphantasics, fMRI studies converge to show hypo-activation in occipito-parietal regions and hyper-activation in a frontal network (Milton et al., 2021; Zeman et al., 2010), as well as decreased connectivity between fronto-parietal areas and regions from the visual network (Milton et al., 2021), including the left fusiform gyrus ("fusiform imagery node") (Liu et al., 2025; Spagna et al., 2021). In autobiographical memory, one study showed decreased hippocampal and increased visual-perceptual cortex activation during memory retrieval in aphantasia (Monzel et al., 2024).

Behaviourally, several studies showed globally intact cognitive performance in aphantasia (Pounder et al., 2022), notably in visual working memory (Jacobs et al., 2018; Keogh et al., 2021; Reeder et al., 2024), despite the use of different strategies (Keogh et al., 2021), and in episodic associative memory despite lower confidence for correct answers (Wittmann & Şatırer, 2022; but see Monzel et al., 2022 for results of impaired visual and verbal short-term and episodic memory). However, one study showed that, when drawing a scene picture from memory, although aphantasic participants remembered as many and as accurate spatial information as typical imagers, they remembered fewer visual details about objects of the scenes (Bainbridge et al., 2021). This finding is consistent with self-evaluation questionnaires showing a dissociation between impaired object visual imagery and intact spatial imagery (Bainbridge et al., 2021; Keogh & Pearson, 2018). Altogether, the study of aphantasia thus points to the idea of a dissociation between specific alteration of visual mental imagery emerging from the ventral visual stream dedicated to object processing (« what » stream), in the face of seemingly intact imagery emerging from the dorsal visual stream dedicated to spatial processing (« where » stream) (Bergmann & Ortiz-Tudela, 2023).

One possible interpretation for the fact that the lack of mental visual imagery does not translate into visual short-term memory impairment (Jacobs et al., 2018; Keogh et al., 2021; Zeman et al., 2015) nor into episodic memory impairments, even for intra-item associations (often thought of as conjunctive associations (Mayes et al., 2007; Wittmann & Şatırer, 2022) is that visual imagery is only one among several possible cognitive strategies to solve visual memory tasks. The idea that aphantasics use verbal codes to perform memory tasks is supported by reports of aphantasic participants using distinct strategies, such as verbal coding or categorical associations (Bainbridge et al., 2021; Keogh et al., 2021), or displaying a preference towards non-visual spatial and sensorimotor strategies over verbal ones (Reeder et al., 2024), contrary to typical imagers who report relying mostly on visual strategies. It is thus possible that aphantasics use different representational systems for on-line representation of object features.

On the other hand, one fMRI study showed that single features held in visual short-term memory could be decoded from the early visual cortex, similarly in participants with strong imagery and in those with weak visual imagery, although, based on their score on the Vividness of Visual Imagery Questionnaire (VVIQ, Marks, 1973), they did not qualify as aphantasics (mean VVIQ = 40.75/80) (Weber et al., 2024). In the same vein, several studies showed that the content of imagery in aphantasic participants can be decoded in early visual areas equally to typical imagers (Cabbai et al., 2024; Chang et al., 2025; Montabes De La Cruz et al., 2024). However, in aphantasia only, the neural representations elicited during imagery attempts could not be matched to those observed during actual perception of the same stimuli (Chang et al., 2025), and decoding accuracy did not correlate with subjective imagery vividness (Cabbai et al., 2024). This suggests that the visual information during short-term memory maintenance is somehow represented in the early visual cortex in the absence of phenomenal visual imagery, despite presenting different sensory qualities, This is in line with the idea proposed by some authors that while aphantasics do not have explicit access to their visual mental images, they could still experience unconscious visual imagery (Nanay, 2021). In this line, one recent priming study suggests that such unconscious imagery could be specific to those who report some remaining imagery abilities as characterized by a VVIQ score > 16/80 (i.e., lowest possible score) (Purkart et al., 2025).

In this study, we assessed whether visual imagery on the one hand, and verbal coding on the other hand, are necessary strategies to form and maintain conjunctive representations in visual short-term memory. We tested participants with aphantasia to assess the impact of the absence of visual imagery, and especially of object imagery, on conjunctive binding. We also manipulated the ease to use verbal labels to perform the task, to assess the impact of verbal coding on the formation and maintenance of conjunctive representations. Moreover, to gain better understanding on the possible differences in strategies used to perform the task, the strategies underlying retrieval during visual short-term memory were examined (Engle & Kane, 2003), separating between top-down controlled processes (which would include verbal coding), and more automatic processes that might be at work when retrieving integrated objects-features (Van Geldorp et al., 2015). Based on an adapted version of the Process Dissociation Procedure (Jacoby, 1991; see Bastin & Besson, 2021), we used an Inclusion condition, in which participants were instructed to retrieve studied associations, and an Exclusion condition, where they had to provide non-studied pairs among a set of possible combinations. These two conditions enabled us to calculate the contribution of automatic and controlled processes to the task: in the Inclusion condition, correct answers could rely on both controlled and automatic memory processes; in contrast, in the Exclusion condition, producing a studied pair would reflect its automatic reactivation when controlled processes failed. Automatic processes would thus contribute to both correct Inclusion and incorrect Exclusion responses. Controlled processes would in turn only contribute to correct Inclusion responses, not to Exclusion errors.

We reasoned that, if mental imagery is necessary to form ventral visual stream-dependent conjunctive representations, conjunctive binding should be impaired in aphantasia, especially so when preventing participants from using verbal coding strategies. In addition, if verbal coding is necessary for conjunctive binding, we reasoned that aphantasics, as well as typical imagers but to a lesser extent, should display impaired performance when verbal coding is prevented. We expected that both groups would mobilize more controlled processes when verbalisation is possible, and that typical imagers would rely more on automatic processes when it is prevented, while it was uncertain whether these would be accessible to aphantasics.

2. Methods

2.1. Participants

A total of 127 subjects completed the online experiment. Aphantasic participants were recruited from aphantasia specific online forums and social media, and were screened using Zeman's qualitative Imagery Questionnaire (2015) and the VVIQ. Typical imagers were recruited in the community at-large and through social media. All participants were between 18 and 63 years old, had normal or corrected-to-normal vision, and did not report history of neurological or psychiatric disorders. Among those subjects, 10 were excluded because they did not meet inclusion criteria in terms of VVIQ score (aphantasics: ≤ 23, in accordance with Zeman et al., 2020; typical imagers: ≥ 40, based on Bainbridge et al., 2021). Thirty-nine additional subjects were excluded because they did not perform all the blocks on the same day (N = 22), or because they did not respect the instructions (N = 17). Among the remaining 78 subjects, 29 were aphantasics and 49 were controls.

The study was approved by the ethics committee of the Faculty of Psychology of the University of Liège, and all participants gave informed consent by pressing a "yes" button at the start of the experiment.

2.2. Materials

The stimuli were shape–colour pairs. Eight shapes were built to be easy to verbalise (e.g., square, triangle, circle, etc.) and were paired with 8 distinct colours. In addition, in the difficult-to-verbalise condition, 8 additional shapes were taken from Bastin & Besson (2021; adapted from Parra et al., 2010; Van Geldorp et al., 2015) and were paired with the same colours as easy-to-verbalise ones. The ease with which shapes could be verbalised was validated in an independent sample of participants.[1] Combinations of shapes and colours were pseudo-randomised in such a way that all possible combinations appeared in the task at least once and no more than twice.

2.3. Procedure

Materials and structure of the task are illustrated in Fig. 1.

Participants took part in the study on their personal computer at home. The task was computerised on the Gorilla platform. The procedure was based on Bastin & Besson (2021, Exp. 1, inspired by van Geldorp et al., 2015). The task consisted of four blocks of 20 trials each. Each trial started with the simultaneous presentation of 4 shape–colour pairs (with the colour integrated into the shape) for 4 s, during which participants were instructed to study the pairs, followed by a blank screen for 1 s. Then, the test screen displayed 5 shapes and 5 colours. Four shapes and four colours were part of the study, and there was an extra shape and an extra colour to act as distractors to reduce the likelihood of correct answer by chance. The four blocks differed in terms of the ease of verbalisation of the shapes (easy versus difficult) and of the instructions for the test phase (inclusion versus exclusion), following a 2 by 2 factorial design. The order of the blocks was counterbalanced across participants, and within each block, the order of the trials was fully randomized. Each block was preceded by a video illustrating how to perform the task, and a brief practice session involving 3 trials to ensure understanding of the instructions.

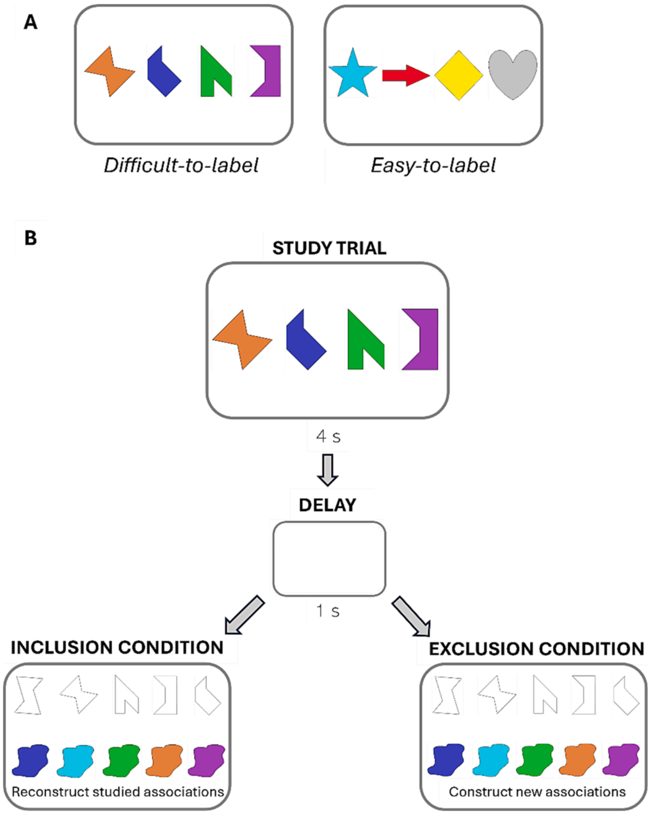

Fig. 1. Illustration of the study task and design. A. Illustration of the shapes in the easy-to-label and difficult-to-label conditions. B. Illustration of the structure of the task with the study trial followed by a short delay and then retrieval phase, either in the Inclusion (left) or in the Exclusion (right) condition

Based on the Process Dissociation Procedure, test instructions were either inclusive or exclusive. In the inclusion instructions, participants were asked to reconstruct the four colour-shape pairings that were studied in the trial. In the exclusion instructions, participants had to select 4 shape–colour combinations that they had not seen during the trial. Correct answers could be any combinations between the 5 shapes and the 5 colours that were different from the studied pairings. Participants responded by dragging a colour upon a shape with the computer mouse. Self-correction was not allowed, so the trial was complete once 4 shape-colour combinations had been constructed, in a self-paced manner. Each trial was followed by a confidence rating on a 5-point scale, from 1 (low confidence in the provided combinations) to 5 (high confidence in the provided combinations). In each block, there were a total of 80 responses to make (20 trials x 4 pairings). Chance level

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[1] Difficult-to-verbalise shapes led to fewer naming hits (within a time limit of 4s per shape), $t(16)=-5.09$, $p < 0.001$ ($\text{Mean proportion}_{\text{difficult-to-verbalise}}=0.64$; $\text{Mean proportion}_{\text{easy-to-verbalise}}=0.96$), hits were slower, $t(15)=6.19$, $p < 0.001$ ($\text{Mean}_{\text{difficult-to-verbalise}}=2.06$ s; $\text{Mean}_{\text{easy-to-verbalise}}=1.06$ s), and they led to longer names, $t(15)=2.44$, $p < 0.05$, than easy-to-verbalise shapes ($\text{Mean}_{\text{difficult-to-verbalise}}=11.11$ characters; $\text{Mean}_{\text{easy-to-verbalise}}=9.02$ characters) (N=17 participants).

corresponded to 16% (van Geldorp et al., 2015). Participants whose proportion of incorrect answers on the Exclusion task (i.e., their production of studied pair, contrary to the instructions to provide non-studied ones) was not significantly different, or was significantly higher, than their production of correct answers on the Inclusion task (i.e., production of studied pairs, in line with the instructions), as suggested by a χ^2 test, were suspected not to have followed the exclusive test instructions and were excluded from all analyses (cf. Participants section).

Before the visual short-term binding task, all participants were administered the French version of the Object Spatial Imagery and Verbal Questionnaire (OSIVQ, Bled & Bouvet, 2020), and for control participants only, the VVIQ.

2.4. Statistical analyses

All analyses were run using JASP (JASP Team, 2024). Demographics were compared between the groups using independent-sample t-tests on age, and on the object, spatial and verbal scores on the OSIVQ questionnaire. For these frequentist analyses, in case of violation of the equal variance assumption based on the Brown-Forsythe test, the non-parametric test of Mann-Whitney was used.

Then, in the experimental task, in blocks with inclusion instructions, the score was the proportion of correctly recalled studied pairs. In blocks with exclusion instructions, the score was the proportion of pairs erroneously constructed identical to a studied pair. These scores were submitted to a 2 (group: aphantasics, controls) by 2 (verbalisation: easy, difficult) Bayesian ANOVA, in which group was a between-subject factor and verbalisation a within-subject factor, separately for the inclusion and the exclusion conditions.

Following Process Dissociation Procedure equations, an estimate of the contribution of controlled processes was obtained by subtracting the score in the exclusion condition from the score in the inclusion condition, so that Controlled = Inclusion–Exclusion. This score reflects mainly the proportion of bindings that were consciously and actively maintained in short-term memory throughout the trial. The estimate of the contribution of automatic processes was obtained by the formula: Automatic = Exclusion/(1–Controlled). This score reflects the proportion of bindings that would yield a sufficient match with previously activated representations (either of pairs or of both items) to influence memory decisions in the absence of controlled retrieval. Controlled and automatic estimates were calculated separately for each level of verbalisation (easy or difficult) and analysed with a 2 (group: aphantasics, controls) by 2 (verbalisation: easy, difficult) Bayesian ANOVA.

Finally, confidence judgements provided at the end of each trial were also compared using a 2 (group: aphantasics, controls) by 2 (verbalisation: easy, difficult) Bayesian ANOVA, in which group was a between-subject factor and verbalisation a within-subject factor, separately for the inclusion and for the exclusion blocks. In addition, because several studies have observed longer reaction times with equivalent performance in aphantasia (e.g., Liu & Bartolomeo, 2023; Pounder et al., 2022; Zeman et al., 2010), suggesting the use of alternative strategies, similar analyses were run on reaction times. They are presented in detail in Supplementary Materials.

We report the inclusion Bayes factor (B_{incl}) for each main effect and interaction. The BF_{incl} allows to characterise, beyond classical Bayesian model comparison, which components of a model improved its predictive performance, thus allowing to make inferences about the independent contribution of each component (Keysers et al., 2020). Here, the BF_{incl} of each main effect and interaction was estimated only for matched models, that is, by including models that only differ in the presence or absence of a particular component to quantify its contribution. The BF_{incl} quantifies the change from prior inclusion odds (the probability that a predictor is included before seeing the data) to posterior inclusion odds (the probability that a predictor is included after seeing the data) and can be interpreted as the evidence for or against including a predictor. Conventionally, a BF_{incl} between 1 and 3 is interpreted as anecdotal evidence *in favor* of an effect's inclusion, a BF_{incl} between 3 and 10 as moderate evidence, and a $BF_{incl} > 10$ as strong evidence. Conversely, a BF_{incl} between 1 and 0.33 is interpreted as anecdotal evidence *against* an effect's inclusion, a BF_{incl} between 0.33 and 0.1 as moderate evidence, and $BF_{incl} < 0.1$ as strong evidence (Lee & Wagenmakers, 2014; Van Den Bergh et al., 2020).

3. Results

In terms of demographics, there was no significant age difference between the groups, $t(75) = 1.72$, $p = 0.09$, Cohen's d = 0.40. There was no significant difference on the OSIVQ in terms of verbal score, $t(76) = -0.08$, $p = 0.94$, Cohen's d = −0.02, but the difference for the object score was significant, $t(76) = -7.68$, $p < 0.001$, Cohen's d = −1.80, with lower scores in aphantasics, and surprisingly, the difference for the spatial score was significant as well, U(76) = 492.5, $p < 0.05$, rank biserial correlation = −0.31, with aphantasics displaying lower spatial scores (see Purkart et al., 2025, for similar patterns). Demographics can be found in Table 1.

Results of the experimental tasks are plotted in Fig. 2. In the inclusion condition, there was strong evidence in favour of a main effect of verbalisation, $BF_{incl} = 2.04\text{x}10^6$, with better performance for easy than for difficult to verbalise shapes. There was anecdotal evidence against a main effect of group, $BF_{incl} = 0.37$, and as well as moderate evidence against an interaction, $BF_{incl} = 0.26$. In the exclusion condition, there was moderate evidence against a main effect of verbalisation, $BF_{incl} = 0.32$, as well as anecdotal evidence against a main effect of group, $BF_{incl} = 0.41$, and moderate evidence against an interaction, $BF_{incl} = 0.24$.

When analysing the contribution of automatic processes, there was strong evidence in favour of a main effect of verbalisation, $BF_{incl} = 19.05$, with easily verbalizable shapes engaging more automatic processes than difficult to verbalise ones, but moderate evidence against a main effect of group, $BF_{incl} = 0.33$, and against a verbalisation x group interaction, $BF_{incl} = 0.26$.

As for controlled processes, there was strong evidence in favour of a main effect of verbalisation, $BF_{incl} = 4976.88$, with easy-to-label shapes engaging more controlled processes, but anecdotal evidence against a main effect of group, $BF_{incl} = 0.39$, and moderate evidence against an interaction, $BF_{incl} = 0.27$.

In terms of confidence judgements, in the inclusion condition, there was strong evidence in favour of a main effect of verbalisation, $BF_{incl} = 163.55$, with higher confidence when retrieving easy-to-label shape-colour associations, but anecdotal evidence against a main effect of group, $BF_{incl} = 0.68$, and moderate evidence against an interaction, $BF_{incl} = 0.24$. In the exclusion condition, there was anecdotal evidence against a main effect of verbalisation, $BF_{incl} = 0.73$, as well against a main effect of group, $BF_{incl} = 0.50$, and moderate evidence against an interaction, $BF_{incl} = 0.33$.

There was no evidence in favour of group or condition effect, nor interaction between these variables, regarding the reaction times. These results are presented in Supplementary Materials.

Table 1
Demographics information across aphantasics and typical imagers.

	Aphantasics	Typical imagers
Age	38.86 (12.45)	33.35 (14.27)
VVIQ (/80)	16.62 (1.59)	61.12 (8.50)
OSVQ		
Object (/65)	24.90 (14.29)	48.22 (12.12)
Spatial (/55)	29.38 (5.22)	32.94 (7.65)
Verbal (/45)	25.34 (3.59)	25.41 (3.56)

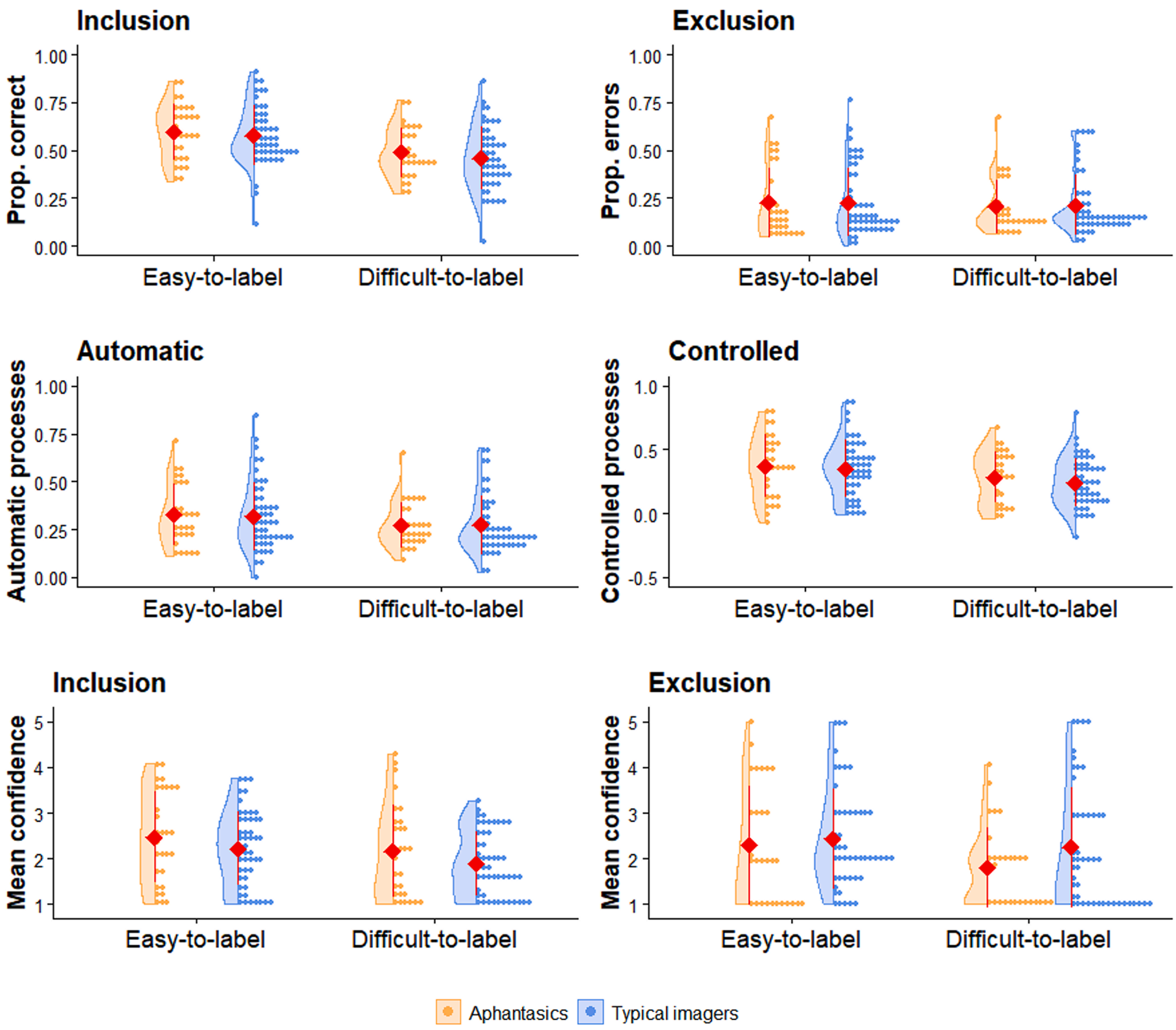

Fig. 2. Half-violin and dot plot of the results in the Inclusion and Exclusion conditions. Top: mean correct associations per trial in the Inclusion condition (associations correctly reconstructed identical to encoding), and mean errors per trial in the Exclusion condition (associations incorrectly reconstructed identical to encoding), for each condition of ease of labelling the shapes (easy versus difficult). Middle: contribution of automatic and controlled processes for each condition of ease of labelling the shapes (easy versus difficult). Bottom: mean confidence per trial in the Inclusion and Exclusion conditions, for each condition of ease of labelling the shapes (easy versus difficult). Each dot represents a participant. Red diamond represents the mean and error bars are standard deviation.

4. Discussion

The aim of this study was to assess the role of visual imagery and verbal coding in conjunctive binding. To explore the impact of visual imagery, a group of aphantasic participants, who report an absence of, or a diminished, visual imagery, took part in the study, alongside typical imagers. To estimate the role of verbal coding, we manipulated the ease with which the stimuli to be maintained in short-term memory could be labelled. We also implemented a Process Dissociation Procedure to estimate the contribution of automatic and controlled processes to retrieval.

To our surprise, the study did not show any difference between aphantasics and typical imagers. Regarding short-term memory performance, this is in line with previous studies that showed preserved visual short-term memory in aphantasia (Jacobs et al., 2018; Keogh et al., 2021; Reeder et al., 2024). However, among these studies, there was evidence that aphantasics used alternative strategies, such as verbal coding (Keogh et al., 2021), to maintain their memory performance, or take longer to respond, suggesting alternative strategies. Here, the manipulation of the ease to use labels did not affect aphantasic participants to a greater extent than typical imagers, and measuring automatic and controlled processes did not show any difference in the use of these processes in aphantasics. One study in episodic memory for conjunctive representations also showed no difference between aphantasics and typical imagers in terms of performance, but reported diminished confidence ratings in aphantasics (Wittmann & Şatırer, 2022). Here, aphantasics appeared as confident as typical imagers. Of note, the task was reported as difficult by the participants, and confidence ratings tended to be generally low across both groups.

There was, however, a main effect of the ease to use verbal labels to perform the task in both groups, so that performance was systematically better when labels were more easily accessible to code the names of the shapes. This supports the idea that verbal coding is a strategy classically used to solve visual short-term memory tasks (Brown, Forbes, & McConnell, 2006; Souza & Skóra, 2017), including conjunctive binding ones, which was never shown before. Interestingly, however, it is also worth noting that in a condition of difficult verbal coding, participants maintained a well-above chance performance despite decreased confidence judgements, regardless of their ability to use visual imagery.

The absence of group difference suggests that mental imagery is not a necessary component to maintain conjunctive representations in visual short-term memory either. It is interesting to note that aphantasics manage to perform the task well above chance, even in a condition in which verbal coding is prevented. The mechanisms tested in the current study as the most probable ones to support visual short-term memory conjunctive binding thus do not seem to be necessary, as neither verbal coding, nor visual imagery, prevented participants from solving the task. More precisely, while verbal coding was still a beneficial strategy, visual imagery was not even particularly favourable to memory accuracy.

At least, these conclusions seem to apply when it comes to the phenomenal experience of visual imagery, which aphantasic participants lack. Studies showing that information held in visual short-term memory of weak imagers, or during attempted imagery in participants with aphantasia, is decodable in low-level visual regions, suggest that the phenomenal experience of imagery might not always be present despite some information – possibly different in nature compared with typical imagers – being represented in the brain (Chang et al., 2025; Weber et al., 2024).

This echoes an important question in working memory research, which is the automaticity of binding, and the role of conscious attention. While some authors hold that binding must occur within the focus of attention (see Cowan et al., 2024, for a review), others argued that binding occurs automatically through perceptual and visuospatial working memory processes, before being fed into the episodic buffer and conscious awareness (Allen et al., 2012; Baddeley et al., 2011). In the same line, the hierarchical binding model proposes that the first stage of binding is implicit, while still forming a rough – apparently conjunctive – object representation (see Gao & Shen, 2024 for review). The present results could support this view. This question thus needs to be further investigated in the future, but the idea of being able to use implicit representations, not accessible to phenomenal experience, in short-term memory conjunctive binding might explain why aphantasics display well-above chance memory, even in a condition in which verbal coding is prevented. Alternatively, there might have been other strategies that contributed to memory performance, that were not accounted for in the current study. For instance, we cannot ensure that associations were represented in a conjunctive manner, as opposed to a relational one, that non-visual spatial or sensorimotor strategies were not used, as was shown by Reeder et al. (2024), or that aphantasics did not succeed to use labels even in a difficult-to-label condition, even though absence of a group difference in reaction times could justify ruling out this option, on top of the robust effect of ease-to-label the shapes observed in aphantasia, which also seems to suggest that there was a clear enhanced difficulty of verbal coding. Yet, future studies should explore the possibility that aphantasics create labels more efficiently, even in difficult-to-label conditions, than their typical imagers counterparts. Future studies should also implement the use of articulatory suppression, use unique complex abstract shapes, and/or reduce items presentation time at encoding, to further control for the use of verbal coding. In addition, following existing working memory literature, future studies should also intentionally manipulate attention to test the idea of the preservation of an automatic binding stage in aphantasia, for instance, through a dual task paradigm. Finally, another future perspective would be to compare memory for single features vs. for bound representations in those two populations while manipulating attention (Allen et al., 2006).

Finally, we expected that automatic processes would be more at play in a condition where stimuli are difficult to label, in which controlled processes (such as verbal coding) might be challenged. Our results showed a contrary pattern of more automatic, alongside more controlled, processes, contributing to memory in the condition in which shapes were easier to label. This might be explained by a mechanical limitation of the Process Dissociation Procedure, which requires equal performance between the conditions for them to be meaningfully compared (Yonelinas & Jacoby, 2012), which was not the case in this study.

In sum, our results suggest that neither the phenomenal experience of visual imagery, nor verbal coding, supported our aphantasic participants' performance to the point of being well above chance, despite verbal coding being a helpful strategy. This supports the idea of an automaticity of conjunctive binding and the possibility of having an implicit content of brain representations in the absence of associated phenomenal experience, in line with the hierarchical binding model (Gao & Shen, 2024). This study however opens the question of whether aphantasics generate and use labels more efficiently than typical imagers. Beyond this, the current study contributes to opening new avenues, showing how aphantasia can provide a promising window into the study of the mechanisms underlying memory.

CRediT authorship contribution statement

Emma Delhaye: Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Pauline Fritz:** Writing – review & editing, Methodology, Conceptualization. **Charlotte Martial:** Writing – review & editing, Methodology, Conceptualization. **Christine Bastin:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, 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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2026.104036.

Data availability

The final dataset is available on the OSF platform, https://osf.io/g5kem/?view_only=5b979457477342baa1a92d6a9d18c396.

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