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Multimodal mental comparisons in those with and without aphantasia

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ABSTRACT

People self-report a vast range of mental imagery experiences, from vivid and realistic to none whatsoever (i.e., aphantasia). Aphantasia aside, quantifying and measuring individual differences in mental imagery skill remains a significant challenge, with research reliant on the self-report Vividness of Visual Imagery Questionnaire (VVIQ). Currently, there are very few behavioural tasks measuring mental imagery, hence we used the mental comparisons task (MCT – Suggate, 2024) in which participants mentally compare a visual, auditory, or tactile property of stimuli in the physical absence of those objects. Using an online pre-registered study, we tested performance on the MCT for participants who have aphantasia ($n = 48$) versus those without ($n = 95$). In addition to the MCT and VVIQ, measures included the Plymouth Sensory Imagery Questionnaire, and questions on how they solved the MCT task. Consistent with other work, there appeared to be small non-significant correlations between self-report and behavioural measures. Aphantasics as a group appeared generally slower, but *more* accurate, on the MCT. Correcting for speed-accuracy trade-offs via balanced integration scores revealed that aphantasics had an advantage on tactile stimuli. In summary, findings support the idea that aphantasic participants have preserved performance generally, with better tactile mental processing. The extent to which the MCT measures voluntary mental imagery, or can be solved without imagery altogether, is discussed.

1. Multimodal mental comparisons in those with and without aphantasia

Many people consider the ability to play with thoughts and experiences—both real and fictional, in their minds, re-creating and imagining these as if they were real—as a fundamental part of human experience and cognition (Kosslyn, 2010). However, mental imagery, defined as the ability to internally re-experience external stimuli and events in their physical absence, has led to controversy (Pylyshyn, 2002), despite its intuitive appeal. Further, the recent recognition of aphantasia (Zeman et al., 2015), whereby people report experiencing no voluntary mental imagery, has further heightened interest in understanding the precise role of mental imagery in human experience and cognition.

The identification and classification (Williams and Suggate, 2024) of visual imagery ability has typically relied on the Vividness of Visual Imagery Questionnaire (VVIQ), which is a subjective self-report scale asking participants to rate the vividness of everyday mental images (Blomkvist and Marks, 2023). Given concerns around people's ability to rate their own images reliably and hence concerns around the comparability of these images with others, research has attempted to develop physiological (i.e., binocular rivalry, Pearson et al., 2008, pupillometry, Kay et al., 2022) and behavioural measures of mental imagery (Liu and Bartolomeo, 2023; Martzog and Suggate, 2019; Moyer, 1973). Mental comparisons tasks (MCT) have been developed as a purportedly behavioural measure of mental imagery in visual (Liu and Bartolomeo, 2023) and other modalities (Suggate, 2024).

In the current study, a multimodal version of the MCT measured participant speed and accuracy at mentally comparing two stimuli on visual, auditory, and tactile sensory properties. However, previous multimodal research on the MCT has used non-aphantasic samples, hence it is not known whether aphantasics show deficits or strengths in making mental comparisons, particularly across different imagery modalities, namely the visual, auditory, and tactile modalities.

1.1. Mental imagery

Mental imagery is often defined as internal perceptual-like experiences of external events, scenes, or objects, in the absence of direct

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sensory stimulation caused by those objects (Kosslyn et al., 2010). Mental imagery can be thought of as comprising four processes, encompassing image generation, maintenance, inspection, and transformation (Kosslyn et al., 1990). Mental imagery is also not confined to the visual modality, but can also occur for other sensory modalities (Lacey and Lawson, 2013b). In this sense, mental imagery can be conceived of as a form of sensorimotor simulation (Muraki and Pexman, 2021). Additionally, mental imagery differs along a number of dimensions including spontaneity, vividness, and realness (Lacey and Lawson, 2013a).

Less certain is the epistemological contribution of mental imagery. On the one hand, mental imagery including visualisation techniques has long been vaunted in multiple domains of popular psychology and education (e.g., Klerkx et al., 2014). Interventions and training programmes exist that use mental imagery strategies to target improvement in a range of domains, from reading comprehension to motor skills (Koning et al., 2017; Leopold et al., 2019; Malouin et al., 2009; Pressley, 1976). However, in these designs it cannot be ascertained whether another aspect of cognition instead of mental imagery, such as attention, was the active ingredient.

Theories differ vastly on the role that is afforded to mental imagery. The behaviourist John Watson is reported to have thought that imagery was mere sentimentality (Thomas, 2020). Others have argued that, whether mental imagery exists or not, its existence has not been empirically established (Pylyshyn, 2002). For instance, many of the tasks used by Kosslyn to demonstrate the existence of mental imagery can be solved using non-imagery schema (Pylyshyn, 2002). Further theorists see imagery as one code of thought and propositional information as another (Paivio, 2013). However, it is widely acknowledged that the majority of people do indeed experience mental imagery (Pearson and Kosslyn, 2015).

Leaving theories of imagery to one side, it would be expected that if mental imagery played a role in cognition, then mental imagery skill should relate to intelligence and learning. Evidence, however, is hampered by the scarcity of measures of mental imagery. In the first instance, there are a large number of self-report measures (Suica et al., 2022). However, self-report measures rely on introspection and often show minimal correlations with behavioural measures in a number of domains of psychology (Kramer and Tree, 2024). In the case of mental imagery, it is difficult to know whether one person's images of a stimulus are more vivid than another person's. Perhaps it is therefore not surprising that links between self-report mental imagery and behavioural measures are generally very low (e.g., LeBoutillier and Marks, 2003; Suggate, 2024), with factor analyses showing that behavioural and self-report measures load onto different factors (Burton, 2003). Some have argued that the mental rotation task (Shepard and Metzler, 1971) taps visual-spatial processing, likely requiring image manipulation – perhaps in the visuo-spatial sketchpad. However, work with congenitally blind participants suggests that visual imagery is not necessary for mental rotation (Marmor and Zaback, 1976). Furthermore, it has been found that the most successful performers on mental rotation tasks use non-imagery strategies (Hegarty, 2004, 2018). Not surprisingly, it has also been argued that the infrequent use of behavioural measures of mental imagery, and in particular those going beyond the visual domain, has hampered establishing mental imagery's role in cognition and learning (Suggate, 2024).

1.2. Mental imagery and aphantasia

Aphantasia can be contrasted with hyperphantasia, whereby mental images are experienced as being vivid, much like direct perceptual experiences (Milton et al., 2021). People can theoretically be aphantasic in any sensory modality (Monzel et al., 2022; Simner and Dance, 2022), although most research refers to the visual modality and no research has used the same behavioural measure to compare across modalities. Further, the standard screening measure for aphantasia is the Vividness of Visual Imagery Questionnaire (VVIQ), even if the test author himself warned against an overreliance on this task (Blomkvist and Marks, 2023). Using the VVIQ, it is generally estimated that aphantasia has a prevalence of around 4 % (Dance et al., 2022) and latent profile analyses have indicated the existence of at least three groups of imagers, corresponding to aphantasic, mid-range, and hyperphantasic people (Williams and Suggate, 2024).

Generally, aphantasics show subtle, but not marked cognitive differences to non-aphantasic participants (Zeman, 2024), not sufficient to justify classifying aphantasia as a mental disorder (Monzel et al., 2023). The most common difference between aphantasic and non-aphantasic participants is on measures of memory (Monzel et al., 2023), particularly autobiographical memory (Watkins, 2018) and object memory (Bainbridge et al., 2021) – although concerns exist about inherent bias in some measures (Phillips, 2025). Some studies indicate facial processing differences (Dance et al., 2023; cf. Milton et al., 2021) and elevated scores on the Autism Spectrum Quotient (Milton et al., 2021; Dance et al., 2021). Significantly lower performance has also been found on aspects of drawing (Bainbridge et al., 2021), but aphantasics may show better performance at mental rotation (Kay et al., 2024, cf. Pounder et al., 2022). However, optimal mental rotation performance may not use imagery strategies (Hegarty, 2018) and Kay and colleagues found that aphantasic respondents used propositional criteria instead of imagery when solving a mental rotation task. Turning to visual working memory, research has found similar performance, with aphantasics using a different strategy (Keogh et al., 2021). Finally, initial evidence indicates some differences in neural activation for aphantasic participants when performing a mental imagery task, particularly for the connections between frontal and fronto-parietal areas (Liu et al., 2025).

1.3. Measuring mental imagery with mental comparison tasks (MCT)

In the MCT, participants are required to form sensory judgments about stimuli, deciding which of two objects best corresponds to a sensory adjective (e.g., what is louder, a train or a car). This task has high intuitive appeal – if asked to make comparisons between two objects that people do not see in front of them, and which they have been unlikely to compare mentally before, it would seem like a good strategy to generate both images, and maintain them while they are being mentally inspected to allow a comparison (Suggate, 2024). Thus, the MCT may invoke imagery processes such as generation, maintenance, and inspection (Kosslyn et al., 1990). A mental comparison would be more probable if the object comparisons are unlikely to be stored as declarative facts in memory due to their rarity (e.g., memorizing that dough is stickier than soup).

Although it would seem clear that the MCT requires mental comparisons of some kind, a question arises as to whether conscious mental imagery is necessary or whether a mental simulation without imagery is possible. For instance, the individual items might be stored according to their perceptual features in semantic space (e.g., giraffe is big, beetle is small), facilitating rapid mental comparison (e.g., giraffe is larger than a beetle) without needing to construct images. Moyer (1973) tried to test whether mental comparisons were made based on perceptual-like comparisons using mental imagery (Moyer, 1973). In a sample of students ($n = 24$), he found that participants could highly accurately rate the relative sizes of pairs drawn from a list of 21 animals. Further, participants were faster at rating the size when the actual size differences of the animals were greater. Moyer (1973) argued that this was most consistent with participants responding using mental imagery, although it could also be due to a more ambiguous perceptual categorization in semantic space (e.g., giraffe is clearly larger than a beetle, but is a fly?).

Martzog and Suggate (2019) developed a new set of stimuli for the MCT, expanding this to the tactile modality and including a broader range of everyday objects likely to be highly familiar to both adults and children. From an embodied cognition perspective, they argued that mental imagery as measured by the MCT represented a form of sensorimotor simulation. Accordingly, MCT performance should correlate with skills that facilitate sensorimotor knowledge acquisition, in this case children's ($n = 294$) fine motor skills, which it did. Finally, based on the idea that reading requires the mental simulation of text through image generation, maintenance and inspection, the MCT correlated with adult's reading comprehension (Suggate and Lenhard, 2022). Thereby, initial evidence for the external validity of the MCT has been provided.

Recent research on the MCT expanded the range of items to include tactile, visual, and auditory items to allow multimodal imagery comparisons (Suggate, 2024). Across three experiments on adults (n = 96, 345, and 448), the variance explained by the MCT was reliable, independent of the influence of lexical features, and processing speed. As found in other research (see Phillips, 2025), the MCT also showed minimal correlations with self-report vividness and spontaneous mental imagery scales. The MCT also showed modality differences, with responses being fastest for visual, followed by auditory, and then tactile items, which was taken as evidence for perceptual like processing patterns (Suggate, 2024).

If the MCT does measure mental imagery, then it would be expected that people with aphantasia would experience difficulty solving this task. The only previous study investigating mental comparisons in aphantasic participants used the enhanced Battérie Imagination Perception (eBIP), which is a different task to the MCT (Liu and Bartolomeo, 2023). In the eBIP, participants are first played visual stimuli via a voice recording with a property (e.g., "shape") followed by two items (e.g., "beaver" and "fox"), then a specific adjective of the property stimulus (i.e., "long"), to then select which of the items best matched the property stimulus (i.e., fox, because the shape of the fox is longer than the beaver). Interestingly, the participants also rated the vividness of the mental comparison stimuli and also performed comparisons for perceptual versions of the same stimuli. Aphantasic participants showed similar accuracy, but were slower than typical imagers and vivid imagers on both the imagery and perceptual tasks. Accordingly, based on one study, it seems that aphantasics can perform visual mental comparison tasks well, although more slowly, however, more work is needed to confirm this finding. Further, little is known about mental comparisons in non-visual (e.g., auditory and tactile) modalities for aphantasic samples.

1.4. Current study

Generally, research on mental imagery and aphantasia has relied on self-report measures, specifically, the VVIQ to identify participants with aphantasia. Given inherent problems in relying on self-report imagery scales, it would be helpful to add an easy to administer behavioural measure with an emerging arsenal of tasks used to identify and classify aphantasia. Alongside the eBIP (Liu and Bartolomeo, 2023), the MCT shows promise as a measure of mental imagery (Suggate, 2024), seemingly relying on mental comparisons of self-generated images to solve. Further, as well as visual, the MCT has been developed to measure tactile and auditory imagery showing evidence of reliability and validity (Suggate, 2024). However, we know little about how aphantasic samples perform on an MCT, aside from the studies indicating slightly longer response latencies in the visual modality on the eBIP (Liu and Bartolomeo, 2023; Liu et al., 2025).

Accordingly, we conducted a study testing mental comparisons in aphantasia. We recruited an aphantasic and non-aphantasic sample and administered a range of measures including the VVIQ and the MCT. Because the MCT purportedly captures mental imagery in a number of modalities (i.e., visual, auditory, and tactile), we also administered the Plymouth Sensory Imagery Questionnaire (PSIQ), which captures self-report imagery in seven modalities (Andrade et al., 2014). Finally, we asked respondents about their experience of imagery and which strategies they used while solving the MCT. A key reason for asking participants about how they solved the MCT is that we hoped to gain insight into whether the task was actually completed using imagery versus propositional strategies and, consequently, the association with performance. We formulated four hypotheses concerning participants with extremely low scores on the VVIQ (<24) compared to normal imagers.

First, we hypothesised that participants with aphantasia would show lower scores on all modalities of the PSIQ, as self-report aphantasia is often found in other modalities (Zeman, 2024).

Second, we expected aphantasics to exhibit slower response latencies on the MCT, but similar accuracy scores. Previous research using the MCT has found that better imagers have faster response latencies (e.g., Suggate, 2024; Suggate and Lenhard, 2022), potentially representing more efficient mental comparisons.

Third, reflecting differences in mental imagery, we expect the aphantasic participants to adopt different, generally propositional, strategies when solving the MCT.

Fourth, if aphantasics have no mental imagery and solve the task with a different strategy, then in contrast to non-aphantasics, we expected them to show no modality effects on the MCT (modality × aphantasia interaction). This hypothesis assumes that a modality effect implies sensory-related mental imagery and that a propositional approach anchored in declarative comparisons would be indifferent to modality.

2. Methods

2.1. Participants

Participants in this study were initially 171 adults, however, after data curation (see below), 143 remained, of which 48 were classified as aphantasic (VVIQ <24, Milton et al., 2021; Zeman et al., 2020). The pre-registered *a priori* power analysis to detect a large effect, d = .60, alpha = .05, beta = .95, suggested a required sample size of 46 aphantasic and 92 non-aphantasic participants, which we slightly surpassed. The aphantasic participants were significantly older, M = 43.230, SD = 12.673, than the non-aphantasic participants, M = 38.26, SD = 13.339, $t(141) = 2.137$, $p = .034$, $d = .378$). In total, 58.00 % identified as female, 39.90 % as male, and 2.10 % as diverse or other. 76.2 % of the sample was resident in the UK, followed by 16.80 % in the US.

As a function of aphantasia, there were no group differences in gender (male, female, diverse, other), $\chi^2(3, 143) = 6.296$, $p = .098$, or whether English was the main language, 89.50 % vs 89.60 %, $\chi^2(1, 143) = .984$, $p = .615$. There were group differences in the highest educational attainment, $\chi^2(6, 143) = 18.129$, $p = .006$. Comparatively more of the non-aphantasic sample had a secondary school qualification, 24.20 % vs. 4.20 %, $\chi^2(1, 143) = 7.526$, $p = .006$, as their highest, and a larger proportion of the aphantasic sample had attained a post-graduate education, 17.90 % vs. 39.60 %, $\chi^2(1, 143) = 7.963$, $p = .005$, with remaining differences being similar for no school qualification (1.10 % vs. 2.10 %), university entrance (23.20 % vs. 16.70 %), professional/vocational (2.10 % vs. 8.30 %), and other (2.10 % vs. .00 %).

2.2. Measures

Measures included self-report imagery, the MCT, demographic questions, and questions on how participants solved the MCT.

2.2.1. VVIQ

The VVIQ is a 16-item self-report questionnaire and is currently the standard measure for establishing whether someone has aphantasia (Blomkvist and Marks, 2023). Participants are asked to think of four scenes (i.e., a friend, a rising sun, the front of a shop, and the countryside) and are asked to rate the vividness of their visual images of these scenarios and places on a five-point Likert scale (from 1 = "No image at all, you only "know" that you are thinking of an object" to 5 = "Perfectly clear and as vivid as normal vision"). The psychometric properties indicate good reliability and validity with other self-report measures

(Suica et al., 2022). Internal consistency in the current study was high, $\alpha_{cr} = .982$. Consistent with previous research (Milton et al., 2021; Zeman et al., 2020) and recent latent profile analyses (Williams and Suggate, 2024), we categorised those with a VVIQ score below 24 as aphantasic, resulting in a mean VVIQ score of 16.771 ($SD = 1.859$, range 16–23) for the aphantasic and 50.853 ($SD = 12.434$, range 25–78) for the non-aphantasic sample.

2.2.2. Plymouth Sensory Imagery Questionnaire (PSIQ)

The PSIQ is a self-report mental imagery measure that assesses participant experience of mental images in seven sensory domains, namely: vision, hearing, touch, taste, smell, body, and emotional imagery (Andrade et al., 2014). Each sensory modality has five items answered on an 11-point Likert scale (from "no mental image" to "clear and alive, like in real life"). Scores were aggregated into their respective subscales and into a single imagery score and the internal consistency was high overall, $\alpha_{cr} = .992$, and for subscales, all $\alpha_{cr} > .943$.

2.2.3. MCT

Participant skill at conducting mental comparisons was assessed using the MCT (Suggate, 2024). The MCT is designed as a behavioural measure of mental imagery in different sensory modalities, with stimuli here pertaining to the visual, auditory, and tactile modalities. The MCT requires participants to indicate which of two imagined stimuli best matches a given sensory property: "What is [stimulus property, e.g., "rounder"] [stimulus name 1, e.g., "lemon"], "or" [stimulus name 2, e.g., "avocado"]. The stimuli here were presented as text on a screen and two practice items were given followed by 68 test items. On average, participants required 3.421 s per item including stimulus presentation, such that the test was typically completed in fewer than 5 min including instructions. There were different items in each modality, namely 22 visual (brighter, and colours e,g., browner), 27 auditory (louder), and 19 tactile (scratchier, softer, smoother, stickier). Response latency and accuracy were recorded. Findings indicate low correlations with self-report scales (Suggate, 2024) but evidence of external validity (correlations with reading skill, Suggate and Lenhard, 2022). Internal consistency in the current study was high, for both response accuracy, $\alpha_{cr} = .819$, and response latency, $\alpha_{cr} = .986$.

2.2.4. Mental comparisons strategies

Immediately after completing the MCT, participants completed seven questions asking them how they solved the task. The first question was an open response following the instruction: "Think back to the task you just performed asking you to compare two objects (e.g., "what is louder, a train or an aeroplane?"). How did you solve this task?". Following this open question, six further questions were answered on a five-point Likert-scale (1 = Not at all, 2 = Occasionally, 3 = Sometimes, 4 = Often, 5 = Always). The first three questions asked about the strategies participants used to solve the task: (a) based on facts about the objects, (b) using gut feeling, and (c) thinking what each object was like and comparing them. The next three questions asked whether participants experienced sensations in the mind during the task pertaining to the (d) visual, (e) auditory, and (f) tactile modalities. In one difference to the pre-registration, we did not include any propositional items because of difficulty determining adequate criteria and items.

We also included an open-ended question as to how participants solved the MCT. Responses were categorised according to whether (a) a purely propositional approach was taken with no reference to imagery, (b) mental imagery, defined as mentioning imagination, picturing, or thinking with mention of a sensory modality, (c) answering based on experience or memory, (d) reflex without thinking, or just knowing, and (e) non-codable into these categories. Interrater reliability between the first and second authors was generally excellent, $\alpha = .868$, .965, 924, 769, and .929, respectively.

2.3. Procedure

To ensure a sufficient sample of aphantasic participants, a sample was recruited via the Eye's Mind Database (https://www.gla.ac.uk/research/az/cspe/projects/the-eyes-mind/). In terms of not-specifically aphantasic participants, a small group of students ($n = 30$) were recruited from the third author's UK university, and another sample from the US and UK via the platform Prolific. Ethics approval was obtained from all three universities of the study authors (24-3798-101, 7862888, and 12286, in order of authorship).

The study was conducted online in Pavlovia and programmed in Psychopy (Peirce et al., 2019). After providing informed consent, participants completed demographic questions. The three mental imagery tasks (i.e., MCT, PSIQ, and VVIQ) were presented as complete tests but in a randomized order. Further, the item order for the MCT was randomized, but this was not done for the VVIQ or PSIQ because items are delivered in blocks to pertain to the same visual image. Data and code for the analyses are available (https://osf.io/e487h/?view_only=5e3a81a8ddbd4961b4a9a35233dfb180).

3. Results

Three people had missing VVIQ data and were excluded. As indicated in the pre-registration and consistent with previous research (Suggate, 2024), the MCT were winsorized at 3SD above the individual mean. To calculate the individual mean and standard deviation, we first needed to remove the influence of extreme outliers on these estimates, capping extremely slow responses at 10sec ($k = 171$). In the next step, the raw MCT response latencies were capped at 3SD above the mean ($k = 171$) and three individual latencies were capped at 150msec (implausibly fast). Next, we removed participants whose overall MCT response accuracy was below 75 % ($n = 3$). Finally, it appeared that some participants had implausibly long variances in MCT performance. Upon inspecting histograms, these participants showed many items with normal response latencies (e.g., around 2sec) but with a number of those that were implausibly long (e.g., 60sec). Accordingly, we cut participants whose standard deviations in MCT response latency were greater than 3sec ($n = 23$). The resulting sample size was 146 participants. Inspection of the response accuracy performance of the individual MCT items revealed that two items were responded to at a low response level (i.e., <75 % accurate), and these were dropped for subsequent analyses ("What is louder, rattle or whistle", 53 %, and "What is greyer, rain or drizzle", 67 %).

3.1. Performance on the MCT, VVIQ, and PSIQ as a function of aphantasia

Descriptive statistics for the MCT responses as a function of aphantasia are presented in Table 1. Data indicated a skew, with the median being consistently above the mean, however, with the exception of MCT overall accuracy, skew and kurtosis statistics were generally acceptable at an individual level (i.e., <1), but high at an item level (kurtosis and skewness >2). An independent-samples t-test indicated that non-aphantasic participants were less accurate, although quicker on the MCT, except for in the tactile modality. One-way ANOVA confirmed that MCT response latency, $F(2, 9435) = 45.128$, $p < .001$, and accuracy, $F(2, 9435) = 50.472$, $p < .001$, differed across MCT modality.

Using the mean scores for each participant, descriptive statistics and t-tests for the mental imagery measures for aphantasic and non-aphantasic participants are presented in Table 2. As can be seen in Table 2, aphantasic participants showed extremely large and significant differences, indicating extremely low imagery, on the VVIQ and all aspects of the PSIQ. However, in contrast to Table 1, at a subject level, response latencies for the MCT no longer significantly favoured the non-aphantasic group.

Table 1
Descriptive statistics for the mental comparisons task items as a function of aphantasia.

Variable	Group	N_{obs}	Mean	Median	*SD*	Minimum	Maximum	*d*	*t*	*p*
MCT overall (sec)	Non-aphantasic	6270	1.767	1.482	1.054	.150	11.936	.022	−6.032	<.001
	Aphantasic	3168	1.823	1.570	.934	.452	9.488			
MCT visual (sec)	Non-aphantasic	6270	1.675	1.584	.499	.963	2.996	.022	−7.371	<.001
	Aphantasic	3168	1.754	1.677	.464	.985	2.891			
MCT auditory (sec)	Non-aphantasic	6270	1.767	1.644	.531	1.029	4.011	.022	−8.218	<.001
	Aphantasic	3168	1.858	1.771	.452	1.126	2.722			
MCT tactile (sec)	Non-aphantasic	6270	1.905	1.782	.575	1.010	3.741	.022	−1.253	.210
	Aphantasic	3168	1.920	1.837	.468	1.185	3.157			
MCT overall (acc)	Non-aphantasic	6270	.941	1.000	.235	.000	1.000	.023	−35.808	<.001
	Aphantasic	3168	.969	1.000	.174	.000	1.000			
MCT visual (acc)	Non-aphantasic	6270	.945	.955	.057	.727	1.000	.022	−25.014	<.001
	Aphantasic	3168	.973	1.000	.038	.864	1.000			
MCT auditory (acc)	Non-aphantasic	6270	.942	.963	.047	.815	1.000	.022	−9.816	<.001
	Aphantasic	3168	.952	.963	.043	.815	1.000			
MCT tactile (acc)	Non-aphantasic	6270	.900	.901	.067	.707	1.000	.023	−41.443	<.001
	Aphantasic	3168	.956	.951	.048	.848	1.000			

Table 2
Descriptive statistics for the mental imagery measures (individual means) as a function of aphantasia.

Variable	Group	*N*	Mean	Median	*SD*	Minimum	Maximum	*d*	*t*	*p*
VVIQ_total	Non-aphantasic	95	50.853	51.000	12.434	25.000	78.000	3.34	18.851	<.001
	Aphantasic	48	16.771	16.000	1.859	16.000	23.000			
MCT overall (sec)	Non-aphantasic	95	1.781	1.631	.508	1.042	2.984	−.131	−.737	.462
	Aphantasic	48	1.845	1.778	.438	1.112	2.898			
MCT visual (sec)	Non-aphantasic	95	1.675	1.584	.502	.963	2.996	−.160	−.901	.369
	Aphantasic	48	1.754	1.677	.469	.985	2.891			
MCT auditory (sec)	Non-aphantasic	95	1.767	1.644	.534	1.029	4.011	−.178	−1.005	.317
	Aphantasic	48	1.858	1.771	.457	1.126	2.722			
MCT tactile (sec)	Non-aphantasic	95	1.905	1.782	.578	1.010	3.741	−.027	−.153	.879
	Aphantasic	48	1.920	1.837	.472	1.185	3.157			
MCT overall (acc)	Non-aphantasic	95	.930	.941	.040	.809	1.000	−.775	−4.377	<.001
	Aphantasic	48	.960	.971	.033	.868	1.000			
MCT visual (acc)	Non-aphantasic	95	.945	.955	.057	.727	1.000	−.541	−3.058	.003
	Aphantasic	48	.973	1.000	.038	.864	1.000			
MCT auditory (acc)	Non-aphantasic	95	.942	.963	.048	.815	1.000	−.212	−1.200	.232
	Aphantasic	48	.952	.963	.044	.815	1.000			
MCT tactile (acc)	Non-aphantasic	95	.900	.901	.067	.707	1.000	−.897	−5.066	<.001
	Aphantasic	48	.956	.951	.048	.848	1.000			
PSIQ total	Non-aphantasic	95	245.558	248.000	55.320	91.000	346.000	3.337	3.337	<.001
	Aphantasic	46	75.087	67.000	40.857	35.000	185.000			
PSIQ_vision	Non-aphantasic	95	35.032	36.000	9.628	5.000	50.000	2.009	2.009	<.001
	Aphantasic	46	14.674	11.000	11.120	5.000	45.000			
PSIQ_sound	Non-aphantasic	95	38.221	38.000	9.106	10.000	50.000	2.701	2.701	<.001
	Aphantasic	46	12.109	5.000	10.742	5.000	42.000			
PSIQ_smell	Non-aphantasic	95	32.884	34.000	9.525	9.000	50.000	3.221	3.221	<.001
	Aphantasic	46	6.870	5.000	3.462	5.000	19.000			
PSIQ_taste	Non-aphantasic	95	33.463	33.000	10.504	10.000	50.000	2.751	2.751	<.001
	Aphantasic	46	7.739	5.000	6.294	5.000	39.000			
PSIQ_touch	Non-aphantasic	95	37.368	37.000	8.913	5.000	50.000	3.568	3.568	<.001
	Aphantasic	46	8.478	5.000	6.047	5.000	31.000			
PSIQ_bodily	Non-aphantasic	95	33.558	34.000	8.747	7.000	50.000	2.794	2.794	<.001
	Aphantasic	46	10.543	7.500	7.058	5.000	35.000			
PSIQ_feeling	Non-aphantasic	95	35.032	36.000	9.628	5.000	50.000	2.009	2.009	<.001
	Aphantasic	46	14.674	11.000	11.120	5.000	45.000			

3.2. Robustness checks

Before modelling the effects of aphantasia and modality, robustness checks were performed. Individual response latency variance on the MCT was calculated and compared between groups. It was found that the aphantasic sample showed greater variance in MCT response latency, $M = 1.845$ ($SD = .433$) vs. $M = 1.781$ ($SD = .505$), $t(9436) = 6.032$, $p < .001$. However, closer inspection of boxplots identified a number of non-aphantasic participants with unexpectedly high variances of greater than 2.5sec, with none of the highest five, and only four of the 16 longest-variance responders being aphantasic, despite comparable response accuracies, $M = 93.658$ %, $t(141) = .384$, $p = .702$. The analysis for MCT data reported in Table 2 were now repeated, excluding these 16 responses. The corresponding *t*-tests revealed hypothesis-conforming tendencies towards advantages for non-aphantasic participants' response latencies for overall ($p = .080$) and visual items ($p = .065$), with these being statistically significant for auditory ($p = .027$), but not tactile items ($p = .429$).

3.3. Modality and group interactions

Next, mixed-effects regressions were conducted, namely linear mixed models for response latency and generalized linear mixed models for response accuracy using the software JASP. These included random intercepts for individual MCT items and individual participants and tests for main effects for aphantasia and MCT modality, and their interaction. Additionally, in initial models key covariates that arise due to group differences on background variables were included, namely age, gender, and education. However, these key variates were not statistically significant, so are not reported further.

Beginning with response latency, the model indicated a significant effect for modality ($p = .008$), but not for aphantasia ($p > .540$) or their interaction ($p > .292$). However, as found earlier, there were some non-aphantasic participants who showed unexpectedly large variance on the MCT accompanied with high skewness and kurtosis. Accordingly, the model in Table 3 was re-run, without these participants. Additionally, to better account for the skew in the data, participants individual MCT response latencies at an item level were capped at 1SD above their individual mean, instead of the pre-registered 3SD. This resulted in capping 2.9 % of the data at the individual's mean plus one standard deviation. This reduced the skewness from 3.462 to 1.733 and the kurtosis from 20.538 to 2.699. The model for response latency was re-run and appears in Tables 3 and 4.

As can be seen in Table 3, there are significant effects for modality and the interaction between aphantasia and modality, with the aphantasic difference being close to significant ($p = .096$). Compared to the aphantasics, the non-aphantasics appeared to show the greatest response latency advantage in the auditory modality in Table 4.

Turning to response accuracy, the generalized mixed effects models are presented in Tables 5 and 6. All main effects and interactions were significant. The contrasts in Table 6 indicate that the advantage in response accuracy for the aphantasic participants was in the visual and tactile modalities.

3.4. Balanced Integration Score

Given the contrasting findings thus far, whereby aphantasics were slower but more accurate, an *ad hoc* analysis using the Balanced Integration Score (BIS), which provides a single score designed to partial out speed-accuracy trade-offs (Liesefeld and Janczyk, 2019), was conducted. A linear mixed model, identical to that in Table 3 but with BIS instead of response latency was conducted, finding a significant effect of modality ($p = .005$), and the interaction with aphantasia X modality ($p < .001$), but not for the aphantasia dummy variable ($p = .612$).

Because the BIS was not normally distributed (skewness = −2.288, kurtosis = 6.108), an exploratory Bayesian 2 X 3 ANOVA was run on item level data. The analysis indicated that the model with just modality alone was best, with the model containing both modality and aphantasia along with their interaction being marginally worse, $BF_M = 1.754$, with the model with the two main effects being less likely still, $BF_M = 22.445$. However, the analysis of effects indicated that there was only weak evidence in favour of including the aphantasia factor ($P_{include} = .381$, criterion $P_{include} \geq .600$, $P_{exclude} = .619$, criterion $P_{exclude} \geq .400$), reasonable evidence for the modality × aphantasia interaction ($P_{include} = .353$, against criterion $P_{include} \geq .200$, $P_{exclude} = .647$, criterion $P_{exclude} \geq .800$), with overwhelming evidence for retaining modality ($P_{include} = 1.000$, against criterion $P_{include} \geq .600$, $P_{exclude} = .000$, criterion $P_{exclude} \geq .400$). Given the theoretical interest in the full factorial model from the linear mixed model, this is plotted in Fig. 1 and the pattern of findings depicted there mirrored that of the linear mixed model. As Fig. 1 shows, there is a clear advantage for the visual, followed by the auditory and then tactile modalities. Visual inspection reveals a slight advantage for aphantasic participants in the tactile modality, with the contrast being statistically significant, $Z = 2.018$, $p = .044$.

Table 3
ANOVA summary of fixed effects for MCT response latency as a function of aphantasia and MCT modality.

Effect	*df*	*F*	*P*
Aphantasic group	1, 125.18	2.819	.096
MCT modality	2, 63.87	5.609	.006
Aphantasic group X Modality	2, 8188.00	3.305	.037
	1, 125.18	2.819	

Note. Model terms tested with Satterthwaite testMethod. The following variables are used as random effects grouping factors: 'date', 'MCT_Item_Num'.

3.5. Strategies during MCT

To investigate differences in how the aphantasic and non-aphantasic samples solved the MCT, independent samples *t*-tests were conducted and these, along with descriptive statistics, appear in Table 7. As can be seen in Table 7 and consistent with the third hypothesis, the aphantasic participants reported less imagery during the MCT, and also relied less on gut feeling, thought less about what the objects were like, and experienced fewer imagery sensations.

Next, an explorative mixed-effects regression was conducted investigating the role of MCT strategies on performance. An exploratory correlational analysis revealed that the experience of visual/auditory/tactile imagery during the MCT items were highly correlated, *rs* $\geq .790$, $p < .001$, so these were aggregated into a single variable. Separate models were run as a function of aphantasia on MCT accuracy/speed, including the predictors use of (a) facts, (b) gut feeling, (c) thinking about the objects, and (d) imagery. For the non-aphantasic sample, thinking about the objects was significantly related to more accurate performance, $\chi^2(1) = 16.924$, $p < .001$, but none of the other factors were, *ps* $> .235$. None of the predictors related significantly to response latency. For the aphantasic sample, none of the predictors related significantly to response latency or accuracy.

Next, we analysed the open-responses to the question of how participants solved the MCT task. After reading through the responses blind to aphantasic status, responses were coded into five categories: (a) participants "imagined" the response or equivalent, e.g., thinking about the sound that an object made; (b) using propositional logic to reason about the stimuli; (c) answering based on memory or experience, (d) reflective responding, e.g., "I just knew …", and (e) non-informative/empty/not codable. Responses could contain more than one assignment. A summary of the responses and coding is presented in the Supplementary Table. Aphantasic participants mentioned using propositions 49 % of the time, whereas 8 % of non-aphantasics reported doing this. In contrast, 71 % of non-aphantasics used imagery, whereas 16 % of aphantasics were coded as using imagery, however, four of the seven aphantasics that reported using imagery did not mention "imagine" directly, but rather "thought about the sounds" indicating contemplating a sensory aspect. For the remaining categories, responses were more even between groups with 30 % and 16 % of aphantasics mentioning using experience and responding instinctively, whereas this was 25 % and 13 % of non-aphantasics respectively.

4. Discussion

The primary purpose of the current study was to test the ability of aphantasics to make mental multimodal comparisons, using the MCT that was *a priori* expected to be solved optimally using mental imagery (Suggate, 2024). Consistent with previous research and the first hypothesis, lower performance on the VVIQ was associated with lower performance on the PSIQ (Andrade et al., 2014). Aphantasic participants self-reported extremely low levels of imagery across all modalities of the PSIQ, suggesting a general deficit in mental imagery (Hinwar and Lambert, 2021; Monzel et al., 2022).

Findings on the second hypothesis revealed a mixed and differentiated picture. There was consistent evidence that non-aphantasic participants had shorter response latencies on the MCT, with this difference being generally not statistically significant. Specifically, there appeared to be some non-aphantasic responders with an unexpectedly large response latency variance, while showing normal accuracy. Controlling for these differences resulted in tendencies for aphantasics to indeed be slower, with this difference being most pronounced in the auditory modality. However, contrary to our second hypothesis, the aphantasic participants showed a large advantage in response accuracy on the MCT,

Table 4
Contrasts on MCT response latency for the significant main effect of modality from the linear mixed model in Table 3.

				95 % Confidence interval		Contrast	
Aphantasia group	Modality	Estimate	*SE*	Lower	Upper	*z*	*p*
Non-aphantasic	Visual	1.506	.059	1.391	1.621	−1.546	.122
Aphantasic	Visual	1.612	.070	1.475	1.749		
Non-aphantasic	Auditory	1.588	.055	1.480	1.696	−2.275	.023
Aphantasic	Auditory	1.742	.067	1.611	1.872		
Non-aphantasic	Tactile	1.739	.060	1.620	1.857	−1.026	.305
Aphantasic	Tactile	1.809	.071	1.669	1.949		

Table 5
ANOVA summary of fixed effects for MCT response accuracy as a function of aphantasia and MCT modality.

Effect	*df*	χ^2	*p*
Intercept	1	133.078	<.001
Aphantasic group	1	21.424	<.001
MCT modality	2	9.774	.008
Aphantasia group X MCT modality	2	11.160	.004

Note. MCT = Mental Comparisons Task. Generalized linear mixed model with binomial family and logit link function. Model terms tested with likelihood ratio tests testMethod. The following variable is used as random effects grouping factors: 'Participant', 'MCT item'.

$d = .775$, median difference 3.0 %. The analyses using BIS scores to account for what appeared to be a group difference in speed-accuracy, found mostly that MCT modality effects superseded other differences. However, the pattern of findings including the significant modality × aphantasia interaction was consistent with aphantasics having an advantage on tactile items, although more research is needed to confirm this difference.

Turning to strategy usage, there was clear evidence that aphantasic participants experienced and solved the MCT differently. Aphantasics reported extremely low levels of visual, auditory, and tactile imagery during the MCT, as expected. Aphantasics relied less on gut feeling, suggesting that they approached the task in a more analytical way. In the open-response questions, there was a clear difference in the use of propositional like strategies to solve the task for the aphantasics, with a large majority of the non-aphantasics actively using mental imagery. Methodologically, there was perhaps some ambiguity in the “thinking about” item, as this correlated strongly with imagery experience during the MCT, $r(139) = .424, p < .001$, suggesting that some participants may have understood “thinking” pictorially (e.g., think of a sound/picture/smell often means “imagine a sound/picture/smell”). Also, there was a general ceiling effect for both groups for the item “using facts” to solve the MCT, which may explain why this variable was not a significant predictor of MCT performance. Drawing these strands together, non-aphantasic participants relied more on imagery and gut-feeling, which may have been less accurate strategies than the propositional analysis aphantasics appeared to use.

Against the fourth hypothesis, aphantasics also exhibited a modality effect (Suggate, 2024), particularly on response latency and BIS scores. Indeed, across all MCT indices, the pattern pointed towards visual comparisons being better than auditory, and in turn, tactile. There was also some evidence that aphantasics were slower on the auditory items for the MCT (see Table 4). These modality differences are important for both the MCT's claim to measure mental imagery and for the existence of mental imagery in aphantasia, so they will now be considered in more detail.

Beginning with the MCT's claim to measure mental imagery, this task was designed to invite participants to construct sensory simulations of external stimuli, in particular requiring image generation, maintenance and inspection (Suggate, 2024). The best evidence that the MCT measures mental imagery comes from two arguments, one empirical and one intuitive: (a) the self-report items here suggest that non-aphantasic participants generally report using mental imagery and in previous research on a similar task, greater vivid imagery for individual items indicated faster response latencies (Liu and Bartolomeo, 2023), and (b) solving the task requires making object comparisons that, over the

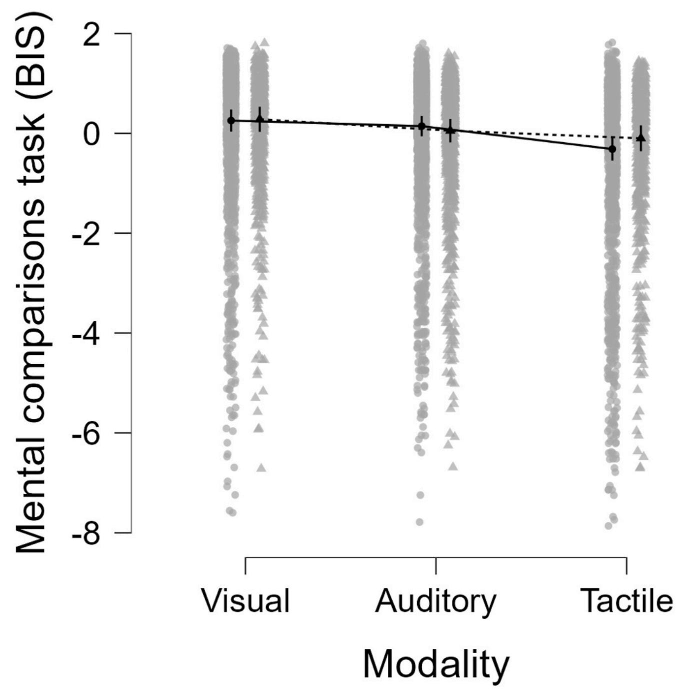

Fig. 1. Interaction between mental comparisons task (MCT) response accuracy and aphantasia group using the Balanced Integration Score (BIS).

Table 6
Contrasts on MCT response accuracy from the generalized linear mixed model in Table 4.

				95 % Confidence interval			
Aphantasia group	Modality	Estimate	*SE*	Lower	Upper	*z*	*p*
Non-aphantasic	Visual	.982	.006	.966	.990	2.649	.008
Aphantasic	Visual	.994	.003	.986	.997		
Non-aphantasic	Auditory	.983	.005	.970	.991	.897	.370
Aphantasic	Auditory	.986	.005	.974	.993		
Non-aphantasic	Tactile	.933	.020	.883	.963	3.056	.002
Aphantasic	Tactile	.974	.009	.950	.987		

Table 7
Aphantasic vs. Non-Aphantasic Strategies During Mental Comparisons.

	Group	*N*	*M*	*SD*	*t*	*p*	*d*
Facts	Aphantasic	44	4.41	.948	.442	.659	.078
	Non-aphantasic	95	4.34	.870			
Gut feeling	Aphantasic	44	2.43	1.265	−2.108	.037	−.388
	Non-aphantasic	95	2.94	1.335			
Think about …	Aphantasic	44	3.25	1.449	−6.277	<.001	−1.141
	Non-aphantasic	95	4.46	.823			
Visual sensations	Aphantasic	44	1.02	.151	−13.511	<.001	−2.467
	Non-aphantasic	95	3.18	1.052			
Auditory sensations	Aphantasic	44	1.30	.594	−8.984	<.001	−1.634
	Non-aphantasic	95	3.01	1.198			
Tactile sensations	Aphantasic	44	1.14	.409	−8.623	<.001	−1.572
	Non-aphantasic	95	2.73	1.189			

course of 68 items, have unlikely been learned propositionally, rendering a sensory simulation a parsimonious and intuitive account. Thereby, the MCT continues in the tradition of viewing mental imagery as a "shadow" (Kosslyn, 2010) or "echo" (Phillips, 2025) of perception, relying on the assumption that the task involves mental simulations that have parallels in perception.

But to what extent do mental comparisons involve shadows of perception? There is good evidence that lexical information activates corresponding sensorimotor processing (e.g., Pexman et al., 2019; Pulvermuller, 2005; Siakaluk et al., 2008; Suggate and Stoeger, 2017), hence it seems reasonable to assume that sensory images could be invoked by the MCT. Data from simple response times to visual, auditory, and tactile stimuli have found that tactile stimuli evoke the quickest responses (Langner et al., 2012), which is further reinforced with the finding that audiotactile stimuli elicit a crossmodal superiority to audiovisual or visuotactile stimuli (Fujisaki and Nishida, 2009). However, it is difficult to ensure that the visual, tactile, and audio stimuli used in these studies are equally stimulating. Additionally, as suggested by the claim that the primary visual cortex may not be responsible for mental imagery (Spagna et al., 2021), response timings in this initial perceptual layer are unlikely to be directly relevant for the MCT. Instead, it may be more fruitful to look beyond perceptual to higher-order and semantic processing of perceptual stimuli. Consistent with the current findings, it has been found that visual lexemes are rated as having greater perceptual strength than auditory, and, in turn, tactile words (Lynott et al., 2020; Speed and Brysbaert, 2022). Further corresponding to the MCT modality effect, evidence suggests that response latencies on a lexical decision task (word vs. pseudoword) were shorter for visual, followed by auditory, and then tactile stimuli (Speed and Majid, 2017). In light of this alternate possibility, whereby a non-imagery account could explain the obtained modality effect, we would likely have formulated hypothesis 4 differently if we were pre-registering this study again.

Accordingly, the current findings appear consistent with participants solving the MCT by using sensory information encoded with the lexical information inherent in the items presented in the MCT. This makes it likely that the MCT measures the ability to form sensory representations of external stimuli, however, is this sufficient to warrant calling it a measure of mental imagery? According to a classic definition of mental imagery, whereby this reflects the conscious experience of perceptual phenomenon in their physical absence (Kosslyn et al., 2010), then the MCT could be considered a measure of mental imagery only for those participants that reported experiencing mental imagery during the task. The danger of this conservative interpretation is that it relegates all behavioural measures of mental imagery behind self-report scales, because then the adopted criterion for mental imagery is introspective access to the experience of mental imagery. Adopting such a definition would exclude behavioural measures in the binocular rivalry tasks and arguably confine the field to a continued overreliance on the VVIQ (Blomkvist and Marks, 2023; Phillips, 2025).

If the MCT does capture a kind of mental imagery, and assuming some do not experience mental imagery, then the aphantasic performance needs explaining, whereby these participants showed the same modality effect as non-aphantasics. One explanation is that some kind of mental imagery is preserved in aphantasia, as suggested by Phillips (2025). Phillips points out that a significant proportion of aphantasics report experiencing at least flashes of imagery, suggesting that the VVIQ and other tasks have not always targeted imagery with sufficient breadth and sensitivity. Further, Phillips (2025) argues for at least two kinds of mental imagery, a visual-object and spatial kind. Indeed, in the current study, the advantage that aphantasics showed for tactile mental comparisons supports the idea that this imagery modality was at least preserved, if not better.

It remains to be considered how the MCT is solved if participants do not experience imagery during this task, or do not report using an imagery strategy. One idea is that the MCT items are stored in semantic space arranged according to sensory properties (Viberg, 1984). For instance, *moss*, *sponge*, and *wool* may be more strongly associated with the word *soft* and are, in contrast to *trumpet* and *mirror*, distal to the concept *shiny*. Indeed, neuroimaging research indicates that the occipitotemporal cortex represents semantic information during mental imagery tasks (Mitchell and Cusack, 2016), whilst semantic categories presented auditorily can activate the visual cortex (Pollicina et al., 2025). This research fits in with the proposal that semantic information is also processed during visual imagery tasks (Spagna et al., 2021; Winlove et al., 2018). This associative explanation has the advantage of explaining how even non-aphantasic participants appear to solve the MCT, or at least some items, without conscious imagery. Further, this explanation avoids the need for a cumbersome deductive strategy (e.g., a violin is metal, therefore hard, wool is fibrous, therefore soft) which would presumably result in greater differences in response latencies between those using an imagery versus associative strategy. It is also noteworthy that the analyses on strategy did not predict MCT task performance.

However, this associative account is arguably not without its conceptual challenges. First, in order to solve the MCT both here and in previous work on similar tasks (Liu and Bartolomeo, 2023; Moyer, 1973), this idea would require that the items are stored with a sufficient perceptual resolution or probabilistic weighting to enable the rapid processing observed. The consequence of this high resolution perceptual associative network is then to produce behaviour consistent with the MCT being solved using mental imagery, that is, using actual mental comparisons. Therefore, functionally, it might be asked at a behavioural level what the differences between such subtle lexical processing of perceptual properties and mental imagery is? If the main difference is introspective access then, as reasoned above, there would appear to be little purpose in developing non self-report measures of mental imagery because these would only be considered mental imagery if voluntary or conscious experience of imagery is invoked.

Perhaps, an associative perceptual high-resolution semantic network exists, and is common to all participants, but that in aphantasic participants it does not result in mental imagery (see also Brogaard and Gatzia, 2017; Krempel and Monzel, 2024; Nanay, 2021). Indeed, recent findings indicate that aphantasics can process semantic information during imagery tasks, but show reduced functional connectivity between fronto-parietal areas and the fusiform imagery node (Liu et al., 2025). This would be consistent with the idea that aphantasia is a partial deficit in mental imagery (Phillips, 2025), or at any rate connecting perceptual-like images to semantic information. If the MCT is assumed to be a measure of mental imagery, then the excellent performance of the aphantasics would be consistent with the idea that people with aphantasia may be able to use some form of unconscious imagery (Chang et al., 2025; Scholz et al., 2025). However, until more is known about the processes involved in solving the MCT and definitions around mental imagery, such a conclusion must be treated with caution.

4.1. Limitations

It is important to note that the participants in this study were recruited via different methods (i.e., Prolific, Eye's Mind Database, and University students). Further, without random assignment being possible, it is conceivable that sampling error explains the findings.

Additionally, the MCT accuracy scores were high, although not strongly skewed, resulting in some degree of ceiling effects. It is likely that lower accuracy scores would have resulted in greater effects between groups on this variable, due to less attenuated variance. In contrast to the eBIP (Liu and Bartolomeo, 2023), the MCT presented the property stimulus first, followed by the items, one after the other. One advantage of this approach is that it is perhaps less taxing on working memory, making the MCT amenable for use on children. One potential concern is that participants then may guess some items before the second item is presented. Although in some cases this may well be possible, we designed the task such that 50 % of the correct responses were the second presented stimulus and to not be consistently guessable based on the first stimulus. Further, the MCT strategy questions were placed at the end of the experiment, forcing participants to make a general judgment about how they solved all 68 items, across three modalities, some time after completing the MCT, which may have introduced bias.

Although we found modality effects in MCT responses, we cannot rule out that this was due to items being more difficult to imagine, or mentally compare, in one modality over another. Previous research has tried to account for the number of syllables and frequency with which the MCT items appear in language (Suggate, 2024), to rule out inherent differences in solvability across items and modalities. This analysis could be extended to include other properties, such as concreteness, abstractness, perceptual strength, embodiment, or semantic associates. However, the MCT involves an emergent and relative comparison between two target stimuli and a perceptual modality. One word (e.g., train) can theoretically belong in a visual and an auditory modality (e.g., “louder” and “longer”), which means that item difficulty cannot easily be modelled on single parameters, but would likely require a range of ratings.

The MCT was administered aurally in previous research (e.g., Suggate and Lenhard, 2022; Suggate, 2024) whereas here the stimuli were presented as text. Examining the obtained response latencies here, these were slower than in previous research (around 1.8 vs. 1.4sec). We speculate that this has to do with the presentation – in the auditory version participants are presented the stimuli at a slower rate, likely meaning that the participants have time to create an image in response to the first stimulus before the second is presented. This may have had two effects, firstly reducing any bottleneck effect, and secondly, encouraging more imagery generation. Further, by presenting the MCT items visually, this may have reduced modality switching costs for the visual MCT items, presumably for participants solving the task using visual mental imagery. However, speaking against this idea is the finding that the modality effects across all items were similar here to previous research (Suggate, 2024), accordingly, it is likely that the visual presentation sped up the task administration, but resulted in slightly higher response latencies.

4.2. Implications and future research

The main implication of this research is that lacking conscious mental imagery does not mean that performance in comparing visual, auditory, and tactile objects mentally is impaired, regardless of whether this happens via imagistic or via associative lexical simulations – or some other approach. Aphantasics appeared to err on the side of caution, responding more accurately but slower, which when accounted for using the BIS, resulted in very similar performance. However, in support of the idea that aphantasics may have intact imagery in non-visual modalities (Phillips, 2025), they showed slightly better performance on MCT tactile items. Accordingly, the current study, by virtue of using a task that can be used across different modalities, expands the study of visual imagery to the auditory and tactile domains – using the same paradigm.

Can the MCT be considered a measure of mental imagery that can be added to the emerging range of behavioural measures? There is currently no simple answer to this question. If the MCT is conceptualised as a measure of skill at making sensorimotor representations of objects in their physical absence, across all participants, then yes. The rapid response latencies for what, on average, can be reasonably expected to be novel stimulus pairs, along with the existence of the predicted modality effects suggest that participants performed perceptual like mental comparisons. If mental imagery is defined as requiring conscious experience, then the answer is mixed, because only some participants used mental imagery strategies and reported mental imagery during the MCT.

Future research should validate the MCT against other tasks, such as mental rotation, the eBIP, or binocular rivalry. A simple addition to the current study involving a semantic decision task on the MCT items would test our supposition that the MCT modality effect follows semantic processing of perceptual modalities (i.e., vision > auditory > tactile). Alternatively, aphantasics with comparative deficits in only one imagery modality (e.g., visual vs. auditory) could be recruited to test for corresponding modality effects on the MCT. Neuroimaging work also would provide validation of the processes involved in solving the MCT. Additionally, future research should examine other sensory modalities using the MCT, in addition to the three investigated here. Examples include gustatory, olfactory, and interoceptive modalities. Studies might also investigate cross-modal effects by selecting items that have multimodal versus amodal and single-modality perceptual strength (Lynott et al., 2020).

Earlier we referred to one explanation of the findings whereby unconscious mental imagery remains intact for aphantasic participants. To test this, a priming task could be used to expose participants to perceptual stimuli that are either concordant or discordant with MCT items. If the priming stimuli similarly affected MCT responses in the aphantasic participants, it might be inferred that both groups had similar unconscious imagery processes. This would also have the advantage in not relying on self-report to determine underlying simulation processes. Finally, a task such as the MCT, which can be used on preschool children (Suggate and Martzog, 2020), could be used to study the development of mental imagery – particularly as a function of aphantasia (e.g., is it congenital or acquired?).

5. Conclusion

The current study is the harbinger of good news – aphantasic participants can out-perform controls at making mental comparisons, in terms of accuracy, and seemingly also in the tactile modality, despite being a little slower and experiencing deficits in self-reported mental imagery. This adds to the body of work finding limited performance differences on behavioural measures of mental imagery (Phillips, 2025) and may help explain why aphantasics can still be high achievers in numerous domains (Zeman et al., 2020), enjoy reading (Williams and Suggate, 2024), and normally live unimpaired lives (Monzel et al., 2023). Nevertheless, a key concern of the current study remains, that as expressed by the author of the VVIQ (Blomkvist and Marks, 2023), overreliance on this as the only diagnostic instrument for aphantasia is potentially problematic. We urge future research to continue to search for accessible and easy to use approaches to measure objective, behavioural, and multimodal mental imagery performance in aphantasic participants also.

CRediT authorship contribution statement

Sebastian P. Suggate: Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Fraser Milton:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Conceptualization. **Jeremy Tree:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Conceptualization.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2026.109373.

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