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# Dominant Cognitive Strategy in Aphantasia

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DOMINANT COGNITIVE STRATEGY IN APHANTASIA

by

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ABSTRACT

Dominant Cognitive Strategy in Aphantasia

by

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Those with aphantasia, reduced or absent visual imagery, are limited in the number of strategies available to represent information and solve problems. The current study examined how the dominant cognitive strategy (dominant cognitive strategy), the primary way of representing information, of an individual with aphantasia impacts performance on several tasks. Specifically, a spatial imagery strategy and mental rotation task (mental rotation task), an object imagery strategy and object memory task (object memory task), and a verbal strategy and a paired word task (paired word task) were used to explore the predictability of dominant cognitive strategy on task performance. A secondary aim of the study was to examine the impact of aphantasia on object specific information by comparing those with aphantasia and typical imagery ability on the object memory task. The results of the study did not reveal any significant differences in performance on the object memory task and were only partially supportive of dominant cognitive strategy predicting task performance.

(51 pages)

# PUBLIC ABSTRACT


Dominant Cognitive Stragey in Aphantasia

Sarah Pope

The purpose of this research was to explore the impact on thinking when an individual is not able to "see with a mind's eye." This is known as aphantasia and is the reduction or absence of visual imagery, which can have large impacts on problem solving and remembering one's own past. The current study examines these impacts by exploring the different ways in which thinking may occur, verbal-analytical, visual imagery, spatial imagery, and how a one's dominant thinking strategy affects performance on a paired word task, a mental rotation task, and an object memory task. Comparing those with typical imagery abilities and those with aphantasia revealed large differences in visual and verbal thinking between those with and without typical imagery abilities, but no differences within the spatial imagery thinking strategy appeared between the two groups. In order to determine if thinking strategy predicts performance on an associated task (verbal-analytical and the paired word task, object imagery and the object memory task, and spatial imagery and the mental rotation task) regression models were used. The analyses revealed only a marginal predicting value for the spatial imagery subscale and the mental rotation task, and no predicting value for the object imagery and verbal-analytical subscales. Results corroborate past research indicating that spatial imagery skills remain intact for those with aphantasia and add to the current literature that aphantasiacs prefer to use verbal thinking strategies over visual ones. However, ceiling effects on the object memory task limited interpretation of the statistical results.

Furthermore, the questionnaire used to assess types of thinking has questionable validity. Future research will focus clarifying the different types of thinking and exploring the developmental trajectory of those with aphantasia and the impact on education.

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# CHAPTER I

# INTRODUCTION

## Visual imagery

Mental imagery is the internal experience of sensory information without the presence of a physical stimulus and has been found in each sensory modality including visual, auditory, haptic, olfactory, gustatory, and kinesthetic (Dance et al., 2022; Kosslyn, 1980; Nanay, 2021). Recently, individual variation in visual imagery ability has been a focus of mental imagery and cognitive science research. The common usage of visual imagery in the processes of remembering one's past, thinking about the future, and problem solving are likely the reason for the proliferation in visual imagery research (Blomkvist, 2021).

Autobiographical memory includes memories of one's own past and is enhanced by mental imagery, which allows for the person to relive core aspects of an autobiographical memory, such as the sensory information and emotions associated with the memory. Furthermore, visual imagery has been implicated as a core cognitive process in autobiographical memory retrieval. For example, Vannucci and colleagues (2016) compared voluntary and involuntary autobiographical memory retrieval between those with an object imagery dominant strategy (High-OI) and individuals who did not have an object imagery dominant strategy (Low-OI). During the involuntary phase, participants wrote down any thoughts or ideas that popped into their head while performing a mundane target search task (Vannucci et al., 2016). The results suggested that the High-OI group had more voluntary and involuntary autobiographical memory's, quicker response times, and reported more memory details than the Low-OI group (Vannucci et al., 2016).

The impact of visual imagery on episodic memory is also evident as it relates to the process of prospection. Indeed, activation in overlapping brain areas have been found between autobiographical memory and future thinking, particularly within the visuospatial regions of the cortex during construction of event representations (Addis et al., 2007). It is further suggested by Conti and Irish (2021) that construction of future events relies on sensory information previously experienced, and that individual differences in the ability to use visual imagery in reexperiencing that sensory information accounts for the wide variety of representations that are seen in future thinking.

Beyond reminiscing on past experiences and planning for future ones, visual mental imagery has been shown to be a useful tool when engaging with information and problem solving. When given instructions to use visual imagery, adults solve more math problems correctly than those with non-imagery instructions (Singh & Pande, 2007). Kunzendorf and Reynolds (2005) found similar results with a group of college students on a geometric figure rotation task with similar instructions. They also found that those students who rated their visual imagery as more vivid performed better than those who rated their visual imagery as less vivid. It is worth mentioning that this study did not account for the distinction between object imagery and spatial imagery, and instead treated visual imagery as a unitary construct. Still, the impact on episodic memories, future thinking, and problem-solving due to individual differences in vividness of visual imagery has gained increasing attention, particularly with recent examination of aphantasia.

## Aphantasia

Aphantasia is described as the reduced or absent ability to form visual mental images (Zeman et al., 2015; Pearson, 2019), and has been implicated in a range of cognitive problems from poor verbal short term memory performance to a severely deficient autobiographical memory (Monzel et al., 2021). Though the impact of aphantasia has been explicitly documented, the theory behind aphantasia has not been so completely explored.

### *Theories of Aphantasia*

Expanding on studies that have shown some involuntary imagery (e.g., dreams) in aphantasiacs, Nanay (2021) posits that aphantasia is the lack of conscious visual imagery. Nanay claims that sensory trace studies provide evidence for unconscious perception, and if imagery is perception without an external trigger, then it could be assumed that mental imagery may also have unconscious processes as well. Nanay's theory does not account for performance on objective measures of visual imagery ability, such as binocular rivalry tasks. These tasks often use Gabor patches (see Figure 1 for an example of binocular rivalry and Gabor patches) presented to each eye that are different in color and orientation. Previous priming of one image increases the chance of perceiving that image during the binocular rivalry phase; however, this priming is not found in those with aphantasia (Keogh & Pearson, 2018).

The reverse visual hierarchy theory argues that visual imagery can be thought of as visual perception in reverse (Pearson, 2019). Whereas perception starts with an external stimulus that is processed in lower brain areas (visual cortex) prior to being processed in higher level brain areas (prefrontal cortex), visual imagery starts with processing a concept in higher level brain regions prior to being processed in lower brain areas, where it is then perceived as a visual image. The theory is supported by neuroscientific evidence (Kosslyn et al., 1993; Ganis et al., 2004) that shows overlapping brain area activation for visual perception and visual imagery. Moreover, the theory incorporates research on the connectivity and directionality between frontal and posterior regions of the cortex as well as the excitability in the visual cortices to explain the individual variation in visual imagery experience.

Dijkstra et al. (2017) used dynamic causal modeling of selected brain regions of interests and found that perception was driven by bottom-up connectivity from the early occipital cortex to the intraparietal sulcus, fusiform gyrus, and inferior frontal gyrus. However, top-down connectivity (intraparietal sulcus, fusiform gyrus, and fusiform gyrus to the early occipital cortex) was also found during perception. This reciprocal connectivity during perception provides an account of predictive modeling by the higher brain areas (i.e., intraparietal sulcus, fusiform gyrus, and fusiform gyrus) that is then updated with incoming information from the lower brain regions (i.e., early occipital cortex; Dijkstra et al., 2017). Visual imagery, on the other hand, was only associated with an increase in top-down connectivity (intraparietal sulcus, fusiform gyrus, and fusiform gyrus to the early occipital cortex). When the connections between these regions are strong, they lead to more vivid imagery; likewise, when the connections between higher brain regions and lower ones are weak, decreased imagery ability is likely (Dijkstra et al., 2017).

The reverse hierarchy theory also explains imagery ability in terms of cortical excitability within the visual cortex. Lower visual cortical excitability has been associated with stronger imagery abilities; Keogh et al. (2020) found that those with lower visual cortex excitability has more vivid visual imagery than those with higher excitability, though some participants showed the opposite pattern. Activity in the frontal lobe was positively associated with visual imagery (higher frontal excitability = more vivid imagery). In other words, those with aphantasia appear to have a visual cortex that is easily excited, meaning that those neurons are not able to be used for visualizing.

The above theories are founded on the assumption that aphantasia is a deficit with symptoms such as severely deficient autobiographical memory. Blomkvist (2022), however, has suggested the counter. Using the constructive episodic simulation hypothesis (CESH) as a foundation, Blomkvist argues that aphantasia is a symptom of a greater problem that exists within at least one process of the episodic memory system.

According to the CESH theory, the episodic memory system relies on memory indices, which provide the instructions for accessing sensory specific information. Blomkvist argues that these memory indices could be the source of symptoms seen within aphantasia. Those with aphantasia are still able to perceive, but are unable to retrieve, visual information (Blomkvist, 2022). This suggests that aphantasia could be the result of corrupted memory indices that make the directions of visual information difficult to access, a breakdown in the process of retrieving visual information, or an inability to reconstruct that information into a meaningful experience.

**Dominant cognitive strategy**

Dominant cognitive strategy is the primary way of acquiring and processing information (Ausburn & Ausburn, 1978). Some attempts at measuring dominant cognitive strategy have fallen short. For example, the *Visualizer-Verbalizer* dimension of cognitive strategy proposed two primary ways of processing information: visual imagery and verbal-analytical (Pavio, 1971). However, as pointed out by Blazhenkova and Kozhevnikov (2009), this dimension was not founded on any cognitive theory, leading to a variety of ways to operationalize the differences in visualizer and verbalizer thinkers.

Furthermore, the visualizer-verbalizer dichotomy failed to incorporate the two distinct subsystems of visual imagery (object and spatial), and the characteristics of these two systems as qualitatively distinct. Object imagery deals with the appearance of objects and scenes through color, texture, and shape, while spatial imagery processes spatial relationships, movements, and transformation of objects and scenes (e.g., mental rotations and scanning a visualized scene; Blazhenkova & Kozhevnikov, 2009). The two processes are also known as the ventral and dorsal pathways, respectively.

Along with the two distinct imagery subsystems, dominant cognitive strategy also encompasses a verbal-analytical dimension – one’s ability and tendency to process and use verbal representations over an object or spatial imagery strategy. Given that those with aphantasia are not able to use the object imagery strategy, they may rely on either or both a spatial and verbal strategy. However, previous research has primarily focused on examining aphantasiacs’ spatial processing, which has limited the understanding of how cognition is different without visual imagery ability.

Though dominant cognitive strategy is the primary and consistent way of processing, maintaining, and retrieving information, a task that requires a strategy other than the individual's dominant one may result in the individual using a compensatory strategy to help solve the problem. This is of particular importance, as those with aphantasia do not have the option to engage with the object imagery strategy. Thus, it is important to differentiate between task-related cognitive strategy and one's dominant cognitive strategy; however, studies examining strategy in aphantasia have primarily focused on task-related strategy (e.g., Keogh et al., 2021).

## The Current Study

Previous research on aphantasia and cognitive strategy have primarily focused on assessing task-related strategy. Moreover, research examining object memory in aphantasia has primarily used spatial visuals (i.e., oriented lines, Gabor patches, and spatial arrays of objects; examples of these can be seen in Figure 1). The current study examined these literature gaps through two separate aims.

## Aims and Hypotheses

Aim 1 was to determine the extent to which dominant cognitive strategy predicts performance on related tasks in a group of aphantasiacs, and included two hypotheses:

1.1 Participants identified as being aphantasiac will not endorse the object imagery cognitive strategy at the same rate as those with typical imagery abilities.

1.2 One's dominant cognitive strategy will predict performance on a related task.

The second aim of the study was to quantify the long-term memory deficit for object-specific information of individuals identified as having aphantasia. This aim includes one hypothesis:

2.1 Aphantasiacs will perform worse on the object memory task compared to controls with typical imagery ability.

# CHAPTER II

# METHOD

## Procedure

All survey and behavioral data were collected online through the Multisensory Cognition Lab via the platforms Qualtrics and Pavlovia, respectively. Participants completed the study in two phases. The first phase took approximately 20 minutes and included electronically signing the informed consent, answering demographic questions, and completing the Vividness of Visual Imagery Questionnaire (Marks, 1970), which was used to place participants in either the control group (VVIQ $\geq$ 32) or the aphantasia group (VVIQ $\leq$ 31). During the second phase, participants completed the Object-Spatial Imagery and Verbal Questionnaire (OSIVQ; Blazhenkova & Kozhevnikov, 2009) followed by the object memory task, paired word task, mental rotation task, and Raven's progressive matrices task (Raven, 2003). The counterbalanced order of these tasks can be found in Table 1. The second phase of the study lasted around 45 minutes, and the time between the two phases varied as participants were able to complete the study on their own time after receiving the study instructions.

## Participants

To account for attrition and incomplete data, the proposed sample size was 120 participants in each group ($N$ = 240). General recruitment took place via posting social media graphics to Facebook, Twitter, and Instagram. Though general recruitment probably captured some aphantasiacs, specific recruitment also included posting to an aphantasia sub-reddit and the Aphantasia Network. All participants were directed to Qualtrics to complete the study via the same link, and the place where the link was posted (Twitter or Reddit) is not recorded. To filter potential scams and robot submissions, all responses were reviewed for patterns typically seen by robotic attempts to receive study incentives, such as not following question directions, incomplete information, and suspicious email addresses (Qualtrics, 2023). Further review included sending each submission an email asking them to verify their date of birth, which was then cross-referenced with the age they entered on the initial survey.

Currently there has been a total of 470 study submissions, and 89 participants have officially been verified and assigned a participant ID. Of the 89 participants officially recruited, 46 have completed both phases of the study. Several participants were excluded for incomplete behavioral data (i.e., did not complete the object memory task), not meeting study eligibility (English as a first language, normal or corrected to normal hearing and vision, no previous neurological illness), and/or not meeting the 50$^{th}$ percentile on the Raven's progressive matrices task, resulting in a total sample size at 32 participants. The 50$^{th}$ percentile of the Raven's progressive matrices task was used as a cut off for eligibility to account for results due to lower-than-average intelligence. 52.78% of the total sample identified as women (men = 41.67%, non-binary = 5.56%), and most of the sample did not report any neurogenetic disorders (66.67%). Additionally, 88.89% of the sample had some college education or higher. For a complete summary of demographics by group, please see Table 2.

**Materials**

*Vividness in Visual Imagery Questionnaire* The Vividness in Visual Imagery Questionnaire (VVIQ) was used to assess subjective vividness of visual imagery. The VVIQ is a 16 item self-report questionnaire that asks participants to form mental images of various scenes and objects and then rate their experiences on a 5-point Likert scale, ranging 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*; Marks, 1974). Scores of 32 or higher indicate that the participant has greatly diminished or absent imagery. Previous studies have found good convergent and divergent construct validity, as well as acceptable internal consistency (i.e., α = .91; Campos, 2011). Furthermore, this self-report measure has been correlated with objective measures of imagery ability (Pearson et al., 2008).

*Object-Spatial Imagery and Verbal Questionnaire*. The OSIVQ is a self-report measure that is meant to assesses three cognitive strategies (object imagery, spatial imagery, and verbal-analytical), one of which is theorized to be dominant over the others. The questionnaire includes three subscales, one for each strategy, with 15 questions using a 5-point Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*) with 3 (*unsure*) as a neutral choice. Each subscale is meant to be evaluated independently of the other subscales, rather than combining subscale scores (Blazhenkova & Kozhevnikov, 2009).

Though Blazhenkova and Kozhevnikov (2009) reported adequate predictive validity, acceptable confirmatory factor analysis, and adequate internal consistencies of α = .74, α = .83, and α = .79 for the object, spatial, and verbal subscales, respectively, the validation of the scale raises a few concerns. For one, the object imagery strategy was only validated by the VVIQ. Contrastingly, the spatial imagery and verbal-analytical subscales were validated with at least one behavioral measure. Of similar concern is that the spatial imagery subscale was only validated with behavioral tasks and was not compared to any equivalent subjective measures of spatial imagery ability. Although the VVIQ has been validated with other objective measures of visual imagery (Pearson et al., 2008) and the spatial scale was correlated with behavioral measures, these validation concerns should be taken into account when interpreting the analyses below.

*Object Memory Task.* To test group differences in object memory, participants were shown 10 consecutive images of difficult-to-describe objects, followed by a short (~ 60 seconds) distracting video. After answering a question about the video, participants were shown the 10 original images along with 10 new distractor images. Participants then used a computer mouse to click on the 10 original images, and the number of correctly selected images and response times were used as performance measures (see Figure 2 for an example of this and the other tasks).

The images of objects used in this study were originally created by Horst and Hout (2014) and are part of a larger database known as the Novel Object and Unusual Name Database. Validation of the database examined participant ratings of familiarity (how familiar or novel the object is), name-ability (the degree to which adults give the same name to a given object,), and object properties (e.g., color and texture saliency).

*Mental Rotation Task.* This task was adapted from the stimuli dataset validation study by Ganis and Kievit (2015). Participants viewed two 3-D geometric shapes side by side and indicated if the two shapes were the same or different by pressing the b and n keys, respectively. Across two blocks of 48 trials each, stimuli were presented in one of four orientations (0, 50, 100, and 150 degrees), and participants had up to 7500ms to provide an answer. The stimuli were validated through examining response time and error rates as the angle of the rotation increased. The authors reported significant increases in response times ($F(3,159) = 160.81$, $p < .0001$, $\eta^2 = .75$) and error rates ($F(3,159) = 160.81$, $p < .0001$, $\eta^2 = .75$) as the orientation of each object increased.

*Paired Word Task*. This task was meant to test an individual's short-term memory ability and was adapted from a task created by Monzel et al. (2021), in which participants heard a list of words and then reported the words that contained a target letter. The words chosen originated from a list of 40,000 words that were rated on their concreteness and were randomly paired with each other until 30 same and 30 different pairs were created. All words chosen had a minimum concrete rating of 4.5 out 5 and did not contain more than two syllables.

The paired word task asked participants to focus on a fixation cross and listen to 10 pairs of concrete words, some of which start with the same letter and some that do not (i.e., crown-clamp and coin-boy). The list was followed by a static image of a triangle that switched colors every .2 seconds for 5.6 seconds. The purpose of this delay period was to disrupt any potential use of an object imagery strategy. Participants completed three blocks of the paired word task with breaks between each block.

*Raven's Progressive Matrices*. The Raven's progressive matrices is a non-verbal mental ability test that measures pattern recognition and problem solving. Though this test has been correlated with Spearman's G, it should be taken into consideration that this test does not account for verbal reasoning and may only be useful in examining the mental rotation task. This task was used to match control and experimental groups for further task performance comparison, as well as to account for responses that may have been due to lower-than-average intelligence. Participants were presented with stimuli of patterns with a cutout in the pattern and were asked to correctly select the cutout piece that would complete the pattern. Stimuli were presented in 5 blocks with 12 trials each. Each block starts out easy and gets progressively more difficult as the trials continue (Raven, 2003).

# CHAPTER III

# DATA ANALYSES

## Task Scoring

Proportions of correct and possible correct responses were calculated to score each task. To account for differences in number of same and different pairs between trials, paired word task scores were calculated by finding the proportion of correctly reported pairs for each block, adding those proportions together and dividing by the total number of blocks. D prime has been calculated for the object memory task and the paired word task.

## Aim 1

Prior to any statistical testing, the data was examined for normality and homogeneity of variance. Testing for normality requires the comparison of theoretical residual errors and the actual residual errors found in the data, and homogeneity of variance compares the distribution of data between the control and experimental group. The normality and homogeneity of variance violations of the object imagery subscale indicated the need for nonparametric statistical analysis for Hypothesis 1.1. A Wilcox Signed Rank Test was chosen to compare the object imagery strategy endorsement of the control and aphantasia groups. For hypothesis 1.2, correlations were calculated and analyzed between the dominant cognitive strategy and associated tasks. A simple linear regression was then used to examine the predictability of each dominant cognitive strategy (object-imagery, spatial-imagery, verbal-analytical) on performance for each task (object memory task, mental rotation task, and paired word task).

**Aim 2**

Due to assumption violations of the object imagery strategy and ceiling effects observed in the object memory task, the relationship between the object imagery strategy and performance on the object memory task was examined by splitting the data into two groups: high-object memory task and low-object memory task. These groups were then compared on their object imagery strategy endorsement. Using the split data for the object memory task, hypothesis 2.1 was explored by comparing the proportion of aphantasiacs and controls in the high-object memory task group and the low-object memory task group. Additional analyses used the Wilcox test to examine the relationship between object imagery strategy endorsement and object memory task group. Reaction time was also considered in group difference analyses.

**Power Analysis**

An a priori analysis suggested that 200 participants were needed for comparison on the object memory task with a medium effect size of 0.4 and power of .80. However, to account for attrition and missing data, the proposed sample size was 240. As recruitment is ongoing, a second power analysis was conducted on the current dataset. With an effect size of 0.41, the current power for the study is .31. The low power and effect size for the results of hypothesis 2.1 should prompt caution when interpreting the results of this study.

# CHAPTER IV

# RESULTS

## Descriptive Statistics

The total sample's mean VVIQ score was 31.22 (18.57), with the means of the control and aphantasia groups being 53.92 (10.07) and 18.39 (2.28), respectively. Endorsement of the spatial imagery strategy was similar across groups (total sample: $M$ = 2.20, SD = 1.15). The mean endorsement for the object imagery and verbal-analytical scales, however, differed across groups. The mean score for the aphantasia group on the object imagery and verbal-analytical subscales was $M$ = 1.46 (0.36) and $M$ = 3.38 (0.47), respectively. The control group however had a mean object imagery endorsement of $M$ = 3.5 (0.86) and a mean verbal analytical score of $M$ = 2.81 (3.79). For the full summary of the survey and behavioral data, please see Tables 3 and 4, respectively.

## Normality and Homogeneity of Variance

Normality for the VVIQ and each of the subscales of the OSIVQ were examined via density plots, QQ plots, and the Shapiro-Wilks test of normality. Both the VVIQ and the object imagery subscale were found to not be normally distributed, $W = .78$, $p < .001$; $W = .82$, $p < .001$, respectively. This finding echoed the results of the OSIVQ validation study (Blazhenkova & Kozhevnikov, 2009). The non-normality was not surprising as this study was examining two groups who differ on the vividness of their visual imagery. Plots and results of the Shapiro-Wilks test for the VVIQ and OSIVQ subscales can be found in Figure 3 and Table 4. The object memory task ($W = .84$, $p < .001$) and the mental rotation task (*W* = .79, $p < .001$) were also found to not be normally distributed in the current sample. Normality plots and statistical results can be found in Figure 3 and Table 4 in the Appendix.

Homogeneity of variances was tested next, with a particular focus on those measures that were not normally distributed (VVIQ, object imagery subscale, the object memory task, and the mental rotation task). Only the VVIQ and the object imagery subscale violated the homogeneity of variance assumption (please see Table 5 for statistical results).

**Hypothesis 1.1**

The one tailed Wilcox Signed Rank Test revealed a significant difference in object imagery strategy endorsement between the two groups. The aphantasia group was found to endorse the object imagery strategy significantly less than the control group, $W = 9$, $p < .001$, thus leading to rejection of the null hypothesis. Group endorsement for the verbal-analytical subscale also showed significant differences, $t(34) = 3.49$, $p = .001$. Mean endorsement for each dominant cognitive strategy by group is presented in Table 3 and t-test results can be found in Table 6.

**Hypothesis 1.2**

Correlations (see Table 7) were examined to determine relationships among dominant cognitive strategy and related tasks. Positive, yet nonsignificant, correlations emerged between the object imagery strategy and number of correctly identified objects ($r = .12$) and response time ($r = .19$), on the object memory task. Surprisingly, a nonsignificant negative correlation emerged between response times (*r* = -.11) and performance (*r* = -.14) on the paired word task and the verbal-analytical strategy. After calculating D prime, the correlations between the strategies and tasks decreased the strength of the relationship (-0.05 for the object memory task and object imagery strategy and -.08 for the paired word task and the verbal strategy. The spatial imagery strategy was weakly correlated with performance on the mental rotation task, *r* = .34, *p* = .04, but was not significantly correlated with mental rotation task response time (*r* = .-04).

Only one regression analysis was performed, as only the spatial imagery strategy produced a significant correlation with its associated task. The regression analysis revealed that about 12% of the variation in mental rotation task performance scores was accounted for by spatial imagery strategy endorsement. Intelligence, as measured by the Raven's progressive matrices, emerged as a unique predictor for the mental rotation task, more so than the spatial scale, with 29% of the variance in scores being accounted for by Raven's progressive matrices scores.

**Hypothesis 2.1**

Ceiling effects were determined to have skewed the data, with 55.56% of the total sample and 52.17% of the aphantasia group scoring 26 and higher. The median (24) was used to split the data into two groups: high object memory task (*N* = 25) and low object memory task (*N* = 11). 56% of the high object memory task group and 81.82% of the low object memory task group were aphantasiac. The Wilcox Rank Sum Test was used to examine the difference in sample group (control vs aphantasiac) and object memory task group (high and low). The results revealed a marginally non-significant result, *W* = 114, *p*

= .07. The average response time of the aphantasia group (*M* = 24.36 seconds) and the control group (*M* = 28.04 seconds) did not differ significantly, *p* = .28.

In an effort to explore the relationship between the OSIVQ and VVIQ, the data was scanned for participants who scored low on both measures and participants who had a low OSIVQ and high VVIQ (or vice versa). The first group (consistent scores between VVIQ and OSIVQ) were kept in their same group. Those with inconsistent scores across the questionnaires (2 aphantasiacs scored high on the OSIVQ, and 2 controls scored low on the OSIVQ) were removed from the analysis. The results did not differ largely from the original analysis, though this could be the result of a small sample size.

**Effect Sizes**

Though the significance of the t-tests discussed above was disappointing, examination of effect sizes through Hedges G offers some hope for future analyses. For one, the response times for the paired word and object memory tasks have a moderate effect size (0.42 and 0.40, respectively). A moderate effect size for the object memory task also shows a moderate effect size of 0.40. These effect sizes indicate that there is some difference between those with aphantasia and typical imagery abilities, and a higher sample size will help to tease these effects apart.

# CHAPTER V

# DISCUSSION

As predicted, hypothesis 1.1 was supported by the results of the independent samples t-test. The object imagery strategy is characterized by using visual images to solve problems and represent different thoughts in everyday life. As aphantasia is marked by the inability to voluntarily generate visual images, it is unsurprising that none of the aphantasiacs endorsed the object imagery strategy as their dominant cognitive strategy. According to Pavio's dual hypothesis, if possible, information will be represented both visually and verbally, and as those with aphantasia do not have the ability to represent information visually, it was expected that they would prefer a verbal strategy of information representation more so than typical imagers.

Indeed, the results indicated that those with aphantasia endorsed the verbal dominant cognitive strategy more than twice as much as the object imagery scale, and about 79% of the aphantasia group endorsed the verbal strategy as their dominant one. Contrastingly, about 85% of the control group endorsed the object imagery strategy as their dominant strategy, yet the difference in mean endorsement for the object imagery and verbal strategies was much closer than seen in the aphantasia group. These results provide corroborating evidence to recent studies indicating that those with aphantasia engage with different types of representations in significantly different ways than those with typical imagery abilities.

In contrast, the significant results of hypothesis 1.1 did not fully extend to hypothesis 1.2. The only dominant cognitive strategy that was mildly predictive of task performance, but not response time, was the spatial imagery strategy on the mental rotation task. Raven's progressive matrices was positively associated with scores on the mental rotation task, which is not surprising, as both the mental rotation task and the matrices test probe pattern recognition and spatial understanding. This is supported by the finding that Raven's progressive matrices was not correlated with either the paired word task or the object memory task (See Table 8); for this reason, Raven's matrices test was not used as a covariate when exploring the predictive value of the OSIVQ subscales. Neither the verbal-analytical strategy nor the object imagery strategy was associated with performance or response time on the paired word task and object memory task, respectively.

Furthermore, the mental rotation task used here measures spatial imagery abilities, but including another task that examines spatial imagery memory could help to tease apart differences in spatial thinking. For this task, participants would answer questions about their spatial abilities and memories, followed by two mental rotation tasks: the one used in the study and one that taps into spatial memory. The second task would include observing a single geometric figure, followed by interstimulus duration of about 3 seconds, followed by a presentation either a different rotation of the same figure or the same figure presented in the same rotation.

These findings are similar to what was reported in the validation study of the OSIVQ (Blazhenkova & Kozhevnikov, 2009). The results of the validation study only revealed a moderate correlation between the spatial imagery strategy and spatial processing tasks. The current study found a similar relationship with the mental rotation task. The lack of a difference between the control and aphantasia groups supports past research indicating that the dorsal pathway is not impacted in those with aphantasia

(Keogh & Pearson, 2017). However, it is concerning that the spatial imagery subscale has repeatedly been shown to be only minorly predictive of a task that is considered a valid tool in measuring spatial imagery ability (Blazhenkova & Kozhevnikov, 2009).

Surprisingly, the paired word task was negatively associated with the verbal-analytical strategy, suggesting that the task was not an appropriate measure of one's verbal ability or memory. This result is not due to ceiling or floor effects, as can be seen in Figure 5. Though this task was not effective at measuring verbal short term memory, it is important to note that the verbal-analytical subscale of the OSIVQ did not have strong relationships with the measures of verbal ability. In fact, only one of three measures had a minor relationship with the verbal-analytical subscale. The lack of validation of both the task and measure of verbal thinking impedes the ability to interpret the data in a meaningful way, however the current study's limitations (e.g., sample size and low power) also have an impact on the interpretation of results.

The validation of the object imagery scale did not use a behavior task, so it is difficult to compare the results of this study to how well the scale predicts object imagery related thinking. Despite this, some conclusions can be drawn between aphantasiacs and controls. For one, there are more aphantasiacs in the low-object memory task group, suggesting that when performance is poor, the individual is more likely to be aphantasiac.

Response time has been considered an indicator of cognitive effort (Robinson et al., 1997). Though there was not a significant response time difference between the two groups, the aphantasiac group had a slower average response time on evert task compared to the control group. One explanation for this is that those with visual imagery ability can use whichever strategy is most efficient for the given task leading to faster response times. The aphantasiacs, on the other hand, are limited in the strategies available to them; as a result, they may be combining more than one strategy to compensate for the lack of an object-imagery strategy, leading to slower response times.

This may be that the strategy employed to remember the objects was more cognitively demanding than the visual strategy that is likely employed by the control group. It could also be the case that aphantasiacs are using multiple strategies to remember the information.

## Limitations and Future Directions

The current study has several limitations worth discussing. For one, the validation of several measures used in this study is questionable; this is due to the original nature of the paired word task and object memory task and the low validity of the OSIVQ. Another limitation is that the study has not recruited the full sample and the group sizes vary drastically, both leading to a lower power than needed to detect meaningful differences. Lastly, the generalizability of these results is limited as participants were conveniently sampled.

As discussed in the results section, moderate ceiling effects were observed for the object memory task. One reason for the ceiling effects seen in the object memory task could be due to the ease of the task. Future studies will include increasing the stimulus set as well as adopting a change detection analysis. This task would use the same stimuli, with some of the objects presented in a variety of color. The first modification to the task will help to detect any capacity differences between aphantasiacs and those with typical imagery abilities, and the second will help to decipher any deficits in the details of object information.

Yet another limitation is that the tasks used here utilized experimental stimuli, but the self-report questionnaires use real-world examples, which reduces the ecological validity of the results. To date, the only ecological validation of how well the OSIVQ and VVIQ predict real-life behavior has been with career and college major choices, which shows that those with visual imagery tend to focus in visual art areas more so than aphantasiacs (Zeman et al., 2020). Examination into how aphantasiacs interact with verbal, spatial, and object strategies in real-life tasks has been extremely limited. There was one study, however, that measured object and spatial memory by having participants view real-life pictures of different rooms (bedroom, kitchen, etc.). The results revealed that those with aphantasia had fewer pictorial details in their drawings than those with typical visual imagery. The current research has largely focused on the object information processing deficit in aphantasia, and future research should explore how verbal real-life information processing is impacted by a lack of visual imagery.

The impact of this study is more theoretical than applicable. Still, examination of how individuals process and represent information is an important area of research within cognitive psychology. Getting at the core of information processing could lead to advancements in educational practices and even therapeutic ones, and as visual imagery is a common mnemonic tool used in these two fields, it is worth exploring the subsequent cognitive effects of not having voluntary visual imagery.

Prior to exploring this topic in more depth, the exact constructs that the OSIVQ, or any other cognitive strategy questionnaire, are measuring must be determined. An initial exploration of the items by subscale (object-imagery, spatial-imagery, and verbal-analytical) revealed that the items are not consistent in the composition of the statements. For example, some items use phrasing that indicate the participant should evaluate their skills in the given strategy ("My verbal skills are excellent," "My images are very vivid and photographic," "I can easily imagine and mentally rotate three-dimensional geometric figures"). Other items appear to ask about the individual's preferences of how information is presented ("I would rather have a verbal description of an object or person than a picture," "I enjoy pictures with bright colors and unusual shapes", "Architecture interests me more than painting"). The last theme that appeared were those items that indicated some type of habit or automatic thinking ("I am always aware of sentence structure," "Sometimes my images are so vivid and persistent that it is difficult to ignore them," "My images are more schematic than colorful and pictorial")

Considering the different ways in which the items on the OSIVQ are framed, I propose that the questionnaire may be measuring two different forms of cognitive strategy: automatic and intentional. Automatic, or passive, strategies are those that an individual naturally engages in without any intentional effort, and intentional, or active, strategies are those that an individual purposely engages with the intention of reaching a goal, like solving a problem. Currently, examination into how passive and active engagement in cognitive strategies impacts performance on tasks and academic achievement is scarce. Some research has found instructions on a visual search task that emphasis either active (directing attention to target) or passive (letting the target simply appear) impacts performance, with participants performing better on passive strategy trials compared to active strategy trials (Enns et al., 2006). The authors argue that these results suggest that passive strategies engage automatic processes, which are thought to be quicker than more active top-down control processes. The results did not consider the modality in which an individual may automatically process information, such as an object-imagery strategy.

The OSIVQ construct inconsistency and the results from Enns et al (2006) prompts further exploration into how passive or automatic cognitive strategies differ from active or intentional cognitive strategies in terms of problem-solving performance. Future examination into cognitive strategy should establish a more appropriate questionnaire that accounts for the differences between automatic and intentional cognitive strategy.

Future aims for this research could go in a couple of different directions. One direction is to further explore how information is represented by those without visual imagery using more appropriate and valid methods. For example, exploring the different ways of representing information should include investigating more than visual, spatial, and verbal representations, as information can be represented in a variety of modalities, such as kinesthetically.

Another direction would be to explore the applicability of visual imagery in development. There have been some suggestions that math performance is augmented by the use of visual imagery (Gray et al., 2000). There is also needed research on the developmental impacts of aphantasia. Those without visual imagery are using differential strategies to solve problems, and exploring the factors that influence one strategy over another is a worthy endeavor.

In conclusion, though not all results were significant, supporting evidence was found for previously published results on aphantasia. It is not surprising that those with aphantasia endorse a verbal strategy over a visual one, yet it remains unknown what exact strategy is being used and how that impacts performance on problem solving. In the future, I plan on exploring the educational impact of aphantasia, specifically within mathematical ability.

*Table 1*

*Counterbalance Order of Tasks*

| Order 1 | Order 2 | Order 3 | Order 4 |
|---|---|---|---|
| MRT | PWT | RPM | OMT |
| PWT | RPM | OMT | MRT |
| RPM | OMT | MRT | PWT |
| OMT | MRT | PWT | RPM |

*Note. The counterbalance order is presented above. After the 4th participant, the order restarts, so that participant 005 would be assigned to Order 1, 006 assigned to Order 2, and so on. MRT = mental rotation task; PWT = paired word task; RPM = Raven's Progressive Matrices; OMT = object memory task.*

*Table 2*

*Demographic Summary Statistics*

| Characteristic | Total (*N* = 36) | | Aphantasia (*N* = 23) | | Control (*N* = 13) | |
|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | mean | SD |
| Age | 41 | 14.47 | 46 | 14.21 | 32 | 10 |
| | n | % | n | % | n | % |
| Gender | | | | | | |
| Woman | 19 | 52.78 | 12 | 52.17 | 7 | 53.85 |
| Man | 15 | 41.67 | 10 | 43.48 | 5 | 38.46 |
| Non-Binary | 2 | 5.56 | 1 | 4.35 | 1 | 7.69 |
| NeuroGenetic | | | | | | |
| None | 24 | 66.67 | 14 | 60.87 | 10 | 76.92 |
| ADHD/ADD | 7 | 19.44 | 6 | 26.09 | 1 | 7.69 |
| Autism | 2 | 5.56 | 1 | 4.35 | 1 | 7.69 |
| Dual | 3 | 8.33 | 2 | 8.7 | 1 | 7.69 |
| Education | | | | | | |
| High School | 4 | 11.11 | 3 | 13.04 | 1 | 7.69 |
| Some college | 7 | 19.44 | 3 | 13.04 | 4 | 30.77 |
| Associates | 1 | 2.78 | 0 | 0 | 1 | 7.69 |
| Bachelors | 12 | 33.33 | 8 | 34.78 | 4 | 30.77 |
| Masters+ | 12 | 33.33 | 9 | 39.13 | 3 | 23.08 |

*Table 3*

*Summary Statistics for Surveys*

| | VVIQ | | | OSIVQ_OI | | | OSIVQ_SI | | | OSIVQ_VA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Aph | Control | Total | Aph | Control | Total | Aph | Control | Total | Aph | Control |
| Mean | 31.22 | 18.39 | 53.92 | 2.2 | 1.46 | 3.5 | 2.85 | 2.86 | 2.84 | 3.17 | 3.38 | 2.81 |
| Median | 20.5 | 16 | 53 | 1.6 | 1.33 | 3.67 | 2.87 | 2.87 | 2.73 | 3 | 3.47 | 2.87 |
| Minimum | 16 | 16 | 38 | 1 | 1 | 1.5 | 1.6 | 1.8 | 1.6 | 1.93 | 2.53 | 1.93 |
| Maximum | 68 | 29 | 68 | 4.75 | 2.5 | 4.75 | 4.2 | 2.5 | 4.2 | 4.07 | 4.07 | 3.79 |
| SD | 18.57 | 4.05 | 10.07 | 1.15 | 0.36 | 0.86 | 0.65 | 0.59 | 0.78 | 0.54 | 0.47 | 0.45 |
| Kurtosis | 2.03 | 4.75 | 1.79 | 2.1 | 4.48 | 3.48 | 2.22 | 2.24 | 1.98 | 2.15 | 1.72 | 3.47 |
| Skewness | 0.79 | 1.7 | -0.09 | 0.8 | 1.41 | -0.99 | 0.03 | -0.1 | 0.18 | -0.13 | -0.34 | 0.15 |

*Note. VVIQ = Vividness of Visual Imagery Questionnaire; OSIVQ_OI = object imagery subscale of the Object-Spatial Imagery and Verbal Questionnaire; OSIVQ_SI = spatial imagery subscale of the Object-Spatial Imagery and Verbal Questionnaire; OSIVQ_VA = verbal-*

*Table 4*

*Summary Statistics for Behavioral Tasks*

| | RPM | | | OMT | | | MRT | | | PWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Aph | Control | Total | Aph | Control | Total | Aph | Control | Total | Aph | Control |
| Response Time | 17.57 | 16.71 | 19.09 | 25.69 | 24.36 | 28.04 | 3.74 | 3.8 | 3.64 | 24.7 | 21.13 | 31.01 |
| Mean | 0.84 | 0.83 | 0.85 | 24.92 | 24.13 | 26.31 | 0.92 | 0.93 | 0.92 | 0.35 | 0.33 | 0.37 |
| Median | 0.85 | 0.84 | 0.85 | 26 | 26 | 27 | 0.95 | 0.95 | 0.95 | 0.36 | 0.34 | 0.37 |
| Minimum | 0.67 | 0.67 | 0.7 | 7 | 7 | 19 | 0.73 | 0.73 | 0.74 | 0.05 | 0.05 | 0.17 |
| Maximum | 0.97 | 0.95 | 0.97 | 30 | 30 | 30 | 1 | 0.98 | 1 | 0.75 | 0.75 | 0.61 |
| SD | 0.07 | 0.07 | .0.8 | 4.81 | 5.36 | 3.38 | 0.07 | 0.06 | 0.08 | 0.17 | 0.17 | 0.13 |
| Kurtosis | 2.73 | 2.93 | 2.31 | 6.57 | 5.57 | 2.91 | 4.65 | 7.28 | 2.64 | 2.64 | 2.54 | 2.12 |
| Skewness | -0.29 | -0.51 | -0.28 | -1.7 | -1.57 | -0.87 | -1.6 | -2.2 | -0.99 | 0.36 | 0.5 | 0.08 |

*Note. RPM = Raven's Progressive Matrices; OMT = object memory task; MRT = mental rotation task; PWT = paired word task.*

*Table 5*

*Shapiro-Wilks Normality Test*

| | *W* | Sig |
|---|---|---|
| VVIQ | 0.78 | 0.00*** |
| DCS_OI | 0.82 | 0.00*** |
| DCS_SI | 0.98 | 0.71 |
| DCS_VA | 0.95 | 0.06 |
| OMT | 0.84 | 0.00*** |
| MRT | 0.79 | 0.00*** |
| PWT | 0.97 | 0.55 |
| RPM | 0.98 | 0.86 |

*Note. The above results show normality violations for the VVIQ, OSIVQ object imagery subscale, object memory task, and the mental rotation task.*

*** p < .01; *** p < .001*

*Table 6*

*Levene's Test of Homogeneity of Variances*

| | *F* | df1 | df2 | Sig. |
|---|---|---|---|---|
| VVIQ | 17.73 | 1 | 34 | 0.00*** |
| DCS_OI | 6.34 | 1 | 34 | 0.02** |
| DCS_SI | 1.04 | 1 | 34 | 0.31 |
| DCS_VA | 2.4 | 1 | 34 | 0.13 |
| OMT | 1.54 | 1 | 34 | 0.22 |
| MRT | 3.31 | 1 | 34 | 0.07 |
| PWT | 2 | 1 | 34 | 0.17 |
| RPM | 0.6 | 1 | 34 | 0.44 |

*Note. The above results show homogeneity of variance violations for the VVIQ and OSIVQ object imagery subscale.*

*** p < .01; *** p < .001*

*Table 7*

*Results of the Two Sample T-Test*

| | Aphantasia | Control | | | | Confidence Interval | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *M* | *t* | *df* | Sig | Lower | Upper | *Hedge's G* |
| DCS_SI | 2.86 | 2.84 | 0.1 | 34 | 0.92 | -0.44 | 0.49 | 0.03 |
| DCS_VA | 3.38 | 2.81 | 3.49 | 34 | 0.001 | 0.24 | 0.89 | 1.23 |
| MRT | 0.93 | 0.92 | 0.58 | 34 | 0.57 | -0.03 | 0.06 | 0.15 |
| MRT RT | 3.8 | 3.64 | 0.22 | 34 | 0.83 | -1.33 | 1.65 | 0.1 |
| PWT | 0.33 | 0.37 | -0.55 | 34 | 0.58 | -0.16 | 0.09 | 0.25 |
| PWT Prime | 0.67 | 1.06 | -0.7 | 34 | 0.25 | inf | 0.59 | 0.25 |
| PWT RT | 21.13 | 31.01 | -1.18 | 34 | 0.25 | -26.9 | 7.14 | 0.42 |
| RPM | 0.83 | 0.85 | -1.11 | 34 | 0.27 | -0.08 | 0.85 | 0.27 |
| RPM RT | 16.71 | 19.09 | -0.69 | 34 | 0.49 | -9.38 | 4.62 | 0.22 |

*Wilcoxon Rank Sum Test*

| | *M* | *M* | W | Sig | Hedge's G |
|---|---|---|---|---|---|
| DCS_OI | 1.46 | 3.50 | 9.00 | 0.00 | 2.26 |
| OMT | 24.23 | 26.31 | 111.50 | 0.11 | 0.46 |
| OMT Prime | -0.20 | -0.41 | 192.50 | 0.83 | 0.4 |
| OMT_DIS | 2.22 | -0.40 | 176.50 | 0.82 | 0.2 |
| OMT RT | 24.36 | -0.40 | 131.00 | 0.28 | 0.4 |

*Note. Presented above are the t-test results comparing the control and aphantasia group on the OSIVQ and behavioral tasks. Due to normality and HOV violations a Wilcox Rank Sum test was used to examine differences in the object imagery subscale and object memory task between controls and aphantasiacs. Hedge's G and D' have also been added.*

*Table 8*

*Correlations of Test Variables*

| | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. VVIQ | 1 | | | | | | | | | | | | | |
| 2.Object | 0.85*** | 1 | | | | | | | | | | | | |
| 3.Spatial | -0.04 | -0.27 | 1 | | | | | | | | | | | |
| 4.Verbal | -0.13 | -0.18 | 0.12 | 1 | | | | | | | | | | |
| 5. OMT | 0.09 | 0.1 | -0.03 | -0.25 | 1 | | | | | | | | | |
| 6. OMT Dis | 0.01 | -0.09 | 0.15 | 0.01 | -0.2 | 1 | | | | | | | | |
| 7. OMT_RT | 0.16 | 0.19 | 0.22 | 0.01 | 0.2 | -0.04 | 1 | | | | | | | |
| 8.OMT D' | -0.17 | -0.05 | -0.01 | 0.08 | -0.16 | -0.18 | 0.15 | 1 | | | | | | |
| 9. MRT | -0.1 | -0.26 | 0.34 | 0.07 | 0.08 | 0.08 | -0.03 | 0.1 | 1 | | | | | |
| 10. MRT_RT | -0.05 | 0.11 | -0.04 | -0.05 | -0.24 | 0 | 0.2 | 0.28 | -0.26 | 1 | | | | |
| 11. RPM | 0.1 | 0.05 | 0.01 | 0.08 | 0.3 | -0.1 | -0.01 | 0.02 | 0.53*** | -0.07 | 1 | | | |
| 12. RPM_RT | 0.14 | -0.02 | 0.37* | -0.11 | -0.14 | 0.16 | 0.55*** | -0.2 | 0.13 | -0.01 | 0.03 | 1 | | |
| 13.PWT D' | 0.09 | 0.11 | 0.11 | -0.08 | 0.08 | -0.22 | 0.07 | 0.33* | -0.15 | 0.13 | 0.17 | 0.01 | 1 | |
| 14. PWT | 0.05 | 0.18 | -0.03 | -0.13 | 0.16 | -0.28 | 0.04 | 0.24 | -0.21 | 0.35* | 0.15 | -0.26 | 0.65*** | 1 |
| 15. PWT_RT | 0.2 | 0.23 | 0.17 | -0.1 | 0.27 | -0.25 | 0.6*** | 0.15 | -0.03 | -0.01 | 0.18 | 0.24 | 0.27 | 0.45** |

*Note. OMT Dis = Number of distractors selected; RT = response time.*

**** p < .001*

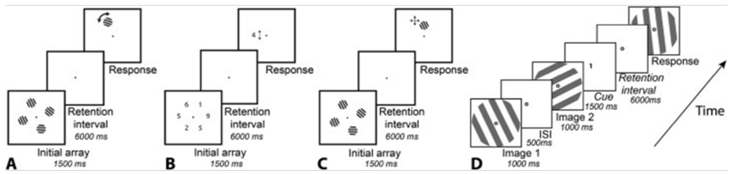
*** p < .01*

** p < .05*

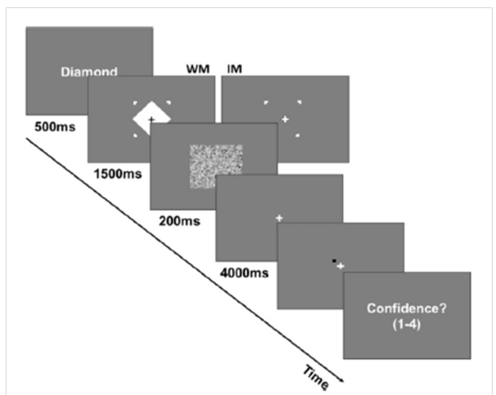
*Figure 1*

*Examples of Spatial Tasks in Aphantasia Research*

A



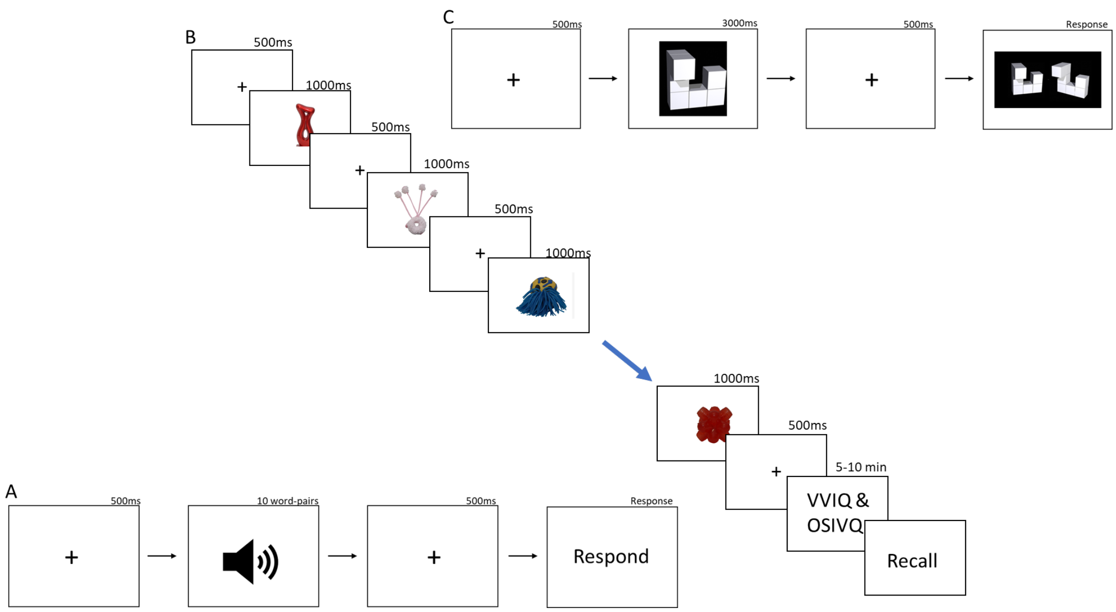

B




*Note.* *Both* ***A.*** *Keogh et al. (2021) and* ***B.*** *Jacobs et al. (2008) are common tasks within aphantasia research, but because these tasks use largely spatial information, understanding the different cognitive strategies those with aphantasia use is limited.*

*Figure 3*

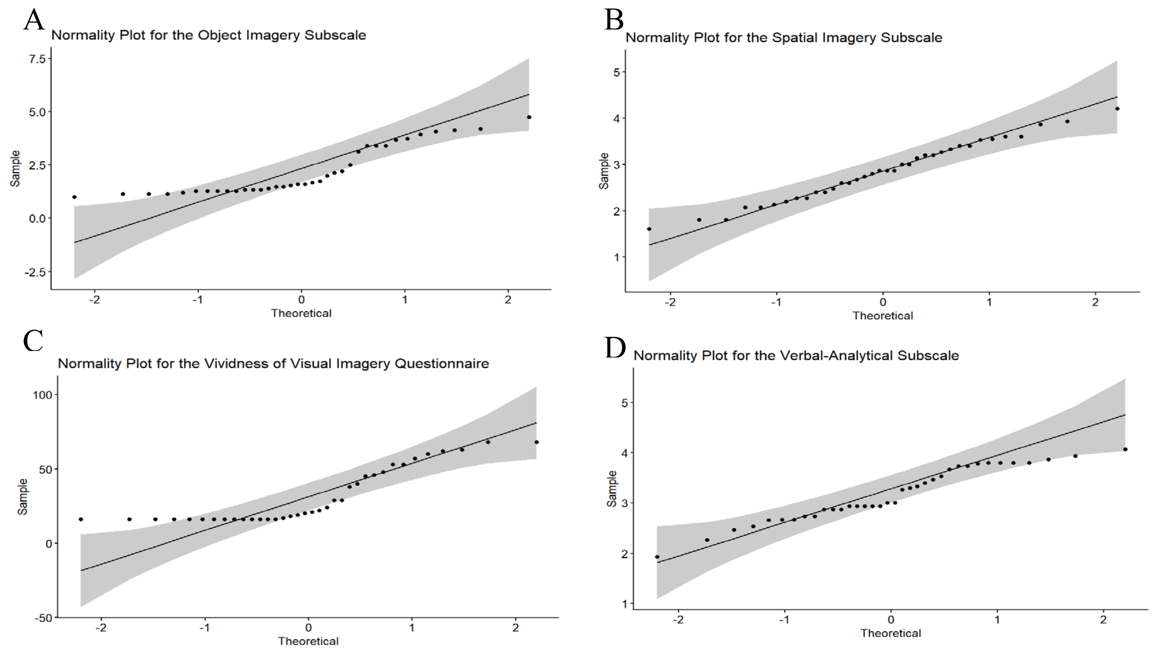
*Task Sequence*




*Note.* ***A.*** *Task sequence for the paired word task. After a short appearance of a fixation cross, participants will hear 10 pairs of words, some of which will have the same beginning letter. During the Response time, participants will have unlimited time to enter via keyboard all the pairs that started with the same letter.* ***B.*** *The object memory task will present 10 objects sequentially for one second at a time. After the 10 objects have been presented, participants will complete the self-report questionnaires; after the VVIQ and OSIVQ, participants will recall by selecting, in order, 10 out of 13 presented objects.* ***C.*** *The mental rotation task will present one 3-D geometric shape for three seconds. Participants will then respond by indicating if the two objects presented after the second fixation cross are the same or different.*

*Figure 5*

Normality Plots for Survey Data




*Note.* *The normality plots above show the comparison between the sampled data and the theoretical normal distribution. The more the data diverge from the theoretical regression line, the more the data violate the normality assumption. The graphs above show large normality violations for the OSIVQ object imagery and verbal analytical subscales, as well as for the VVIQ. The spatial imagery subscale of the OSIVQ did not show any normality violations.*

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