Individuals with aphantasia show independent impairments in face perception and face memory, but not face matching

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Abstract

Some individuals with aphantasia, an absent or reduced ability to form visual imagery, report face recognition difficulties, and studies have shown aphantasics exhibit impaired face recognition performance on the Cambridge Face Memory Test. While this impaired performance may be due to poor face memory, it may instead, or in addition, be due to difficulties in other face processing domains (such as face perception or face matching). The Cambridge Face Memory Test, Oxford Face Matching Test and a novel analysis strategy were used to obtain independent measures of face memory, face matching and face perception from 34 individuals with aphantasia and an age-matched control group. Results showed that individuals with aphantasia exhibit impairments in face memory and face perception, but not face matching. This study therefore provides information about the specific face processing mechanisms that may be impaired in aphantasia.

Aphantasia is a term used to describe absent or reduced conscious visual imagery (Monzel et al., 2022; Zeman et al., 2015), and this reduced visual imagery is thought to lead to a variety of consequent psychological atypicalities (Bainbridge et al., 2021; Kay et al., 2022; Keogh & Pearson, 2018; Pounder et al., 2022; Wicken et al., 2021). The consequences of reduced visual imagery are not always as might be intuited, for example while some aspects of memory seem to be impaired in individuals with aphantasia (henceforth 'aphantasics'; Bainbridge et al., 2021; Dance et al., 2023; Zeman et al., 2020), aphantasics perform as well as individuals with typical visual imagery ('typical imagers') on working memory tasks, including tasks thought to involve visual imagery (Pounder et al., 2022; Reeder et al., 2024). Additionally, while visual perception itself is suggested to be unimpaired in aphantasia (Bainbridge et al., 2021; Keogh & Pearson, 2018), aphantasic participants show longer response times, and are less confident, on a number of perceptual tasks (Liu & Bartolomeo, 2023; Liu et al, 2025).

In an attempt to characterise cognitive difficulties associated with aphantasia, several studies have used self-report data from aphantasic individuals (Dawes et al., 2020; Watkins, 2018; Zeman et al., 2020). Findings from these studies have revealed that a large proportion of individuals with aphantasia report difficulties in face recognition (though it is worth noting that not all individuals with aphantasia report poor face recognition (Zeman et al., 2020)). On the Prosopagnosia Index (PI-20; Shah et al., 2015), a self-report measure of face recognition difficulties, participants with aphantasia score significantly higher than typical imagers (Milton et al., 2021), indicating worse self-reported face recognition ability. In addition, it has previously been shown that nearly half of aphantasic participants report PI-20 scores above the threshold indicating possible prosopagnosia (42% in Dance et al., 2023), and it is documented that some

individuals with prosopagnosia report reduced vividness of visual imagery (Grüter et al., 2009; Tree, 2011; Svart & Starrfelt, 2022).

Studies that have been conducted with aphantasic individuals using objective tests of face recognition have produced somewhat mixed results. For example, no difference in performance was observed between individuals with and without aphantasia on the famous face recognition task, which requires participants to identify the face of a well-known individual amongst four distractor faces (Milton et al., 2021). Tests using famous face stimuli have been criticised as being susceptible to noise induced by differing levels of semantic information available to participants about the famous individuals (Keogh et al., 2021; Milton et al., 2021; Rizzo et al., 2002), and so it is interesting that two studies which have used the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) have found impaired face recognition in aphantasia (Dance et al., 2023; Monzel et al., 2023). The CFMT requires participants to identify a pre-learned (but otherwise unknown) target face among two distractor faces. While both studies using the CFMT conclude that aphantasia is associated with poor face recognition ability, it remains unclear which specific processes are driving these results. This is because face recognition tasks such as the CFMT are not '*process-pure',* as several processes contribute to face recognition performance.

To clarify, although all face recognition tasks (including the CFMT) require good face memory, successful performance on the task is also dependent upon (at least) two additional processes. First, accurate face perception is required to store in memory a veridical representation of the target face that can be recognised from different angles and under different lighting conditions, and to represent the target and any foil faces accurately when recognition is tested. Second, to establish whether the facial representation stored in memory *matches* each of

the target and foil faces during recognition, face matching - the psychological decision-making process whereby one decides whether two facial images are of the same or different facial identities – is required. Traditional face matching tasks (such as the Glasgow Face Matching Task, GFMT, (Burton et al., 2010) cannot provide a pure measure of face matching as performance on these tasks is also governed by face perception ability. In order to determine which, if any, face processes are impaired in aphantasia, an objective and independent assessment of face perception, matching and memory is required.

Independent measures of face perception, face memory and face matching can be derived using a combination of the Oxford Face Matching Test (OFMT; Stantić et al., 2022a) and the CFMT. In the OFMT, participants make two independent responses after being presented with two face images, from either the same person, or different people. Participants are required to rate the perceptual similarity of the two faces, and are also required to decide whether the two face images are from the same or different people. An objective index of how perceptually similar two faces are is obtained from three leading face recognition algorithms, the average of which is used as a measure of the degree of similarity between the presented faces (see Stantic et al., 2022a for methodological details of algorithms used). This algorithmic measure can then be compared to a participant's similarity rating to provide an index of face perception ('deviation score'), which is independent of their face matching responses. The deviation score is derived by calculating the average absolute difference between the algorithmic and the participant's similarity ratings across all test trials (for details, see Stantic et al., 2022b and Stantic et al., 2023). Subsequently, an independent measure of face matching can be obtained by statistically controlling for face perception ability in face matching performance. And finally, an independent measure of face memory can be obtained by regressing both face perception and face matching

onto face memory scores (from the CFMT), with any variance not explained by face perception and face matching used as an index of face memory (Stantić et al., 2022b).

This approach using the OFMT and CFMT has been used to derive independent estimates of these face processes within a range of clinical and non-clinical populations. For example, individuals with autism show difficulties with face recognition, which is underpinned by difficulties with face memory and face perception, but not face matching (Stantić et al., 2023). Individuals who are 'super-recognisers' (who have an extraordinary ability to recognise faces, (Russell et al., 2009) exhibit superior face perception, face matching and face memory (Stantic, Pounder, et al., 2024), while conversely, individuals with developmental prosopagnosia exhibit impairments in all of these processes (Stantić et al., 2022b).

There is growing evidence that individuals with aphantasia do not form a homogenous group, however, with claims that some aphantasia subtypes are characterised by prosopagnosia and autism and some not (Dance et al., 2022; Milton et al., 2021). The extent to which the face recognition difficulties in aphantasia are similar to those experienced in developmental prosopagnosia or autism remain unclear. For instance, it is not known whether people with aphantasia experience impairments on all three sub-processes of face recognition **(**Dance et al., 2023), as do individuals with prosopagnosia, or two sub-processes, such as in autism, or only one. Given that previous literature was unable to assess face matching, memory and perception independently, specific *apriori* hypotheses are unjustified. Even with respect to face perception, despite previous work indicating that visual perception is unimpaired in aphantasia, perceptual decisions were slower in this group. If perception (rather than decision-making) is slower in aphantasic individuals, then it is possible that face perception could be impaired in this group on behavioural tasks.

In summary, previous studies document that people with aphantasia report difficulties with face recognition. No studies have yet investigated the specific face processes that may be impaired in aphantasia. Here, we recruit a group of participants with aphantasia and an age-matched group of individuals with typical visual imagery and typical face processing abilities. We use the OFMT and CFMT to derive independent measures of face perception, face matching, and face memory.

Methods

Participants

Thirty-nine individuals with self-identified congenital aphantasia (Vividness of Visual Imagery Questionnaire, VVIQ, scores ≤ 25) were recruited from social media platforms across Facebook and Reddit, as well as the authors' own databases. Forty-two participants with typical imagery (VVIQ scores > 35) were recruited from Prolific. At present, there is no agreed VVIQ threshold for defining groups based on self-reported imagery, and published studies have used thresholds ranging from the minimum VVIQ score of 16, indicating no reported visual imagery, to scores in the low-to-mid 30s, indicating very weak or absent imagery. We used VVIQ cut-off values consistent with our previous studies (Bainbridge et al., 2021; Pounder et al., 2024; Pounder et al., 2022). This approach is relatively conservative for the aphantasic group, because participants were required to score ≤ 25, and it also created a separation between the aphantasic and typical-imagery control groups by requiring controls to score > 35. Five self-identified aphantasic participants were excluded as their scores were above this cut-off. The remaining 34 aphantasic participants (VVIQ ≤ 25; 20 female, 12 male, 2 other) had a mean age of 42.68 years

(SD = 13.70). On the VVIQ, aphantasic participants scored a mean of 17.09 (SD = 2.34). One control participant was excluded as their score (35) was below the control cut-off, resulting in 41 participants with typical imagery (VVIQ > 35; 27 female, 14 male), with mean age of 39.51 years (SD = 2.00). An independent t-test [t(34.17) = 1.34, p = .19, d = -.34] showed no differences in age between the groups. On the VVIQ, control participants scored a mean of 59.66 (SD = 8.01).

All experimental protocols were approved by the Central University Research Ethics Committee, University of Oxford. All methods used in this study were carried out in accordance with the tenets of the Declaration of Helsinki.

Procedure

In a randomised order, participants completed the OFMT (Stantic et al., 2022a) and the CFMT (Duchaine & Nakayama, 2006). Subsequently, participants completed the visual acuity task (Hetherington, 1973, see below), followed by three questionnaires in a randomised order: the PI-20 (Shah et al., 2015) which assesses self-perceived face recognition ability, the Autism Spectrum Quotient (28-item version; AQ-28, Hoekstra et al., 2011) which measures autism traits in adults, and the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) which measures the vividness of one's visual imagery.

Autism Spectrum Quotient (AQ-28; Hoekstra et al., 2011)

The AQ-28 is a self-report measure used to assess the degree of autistic traits in adults, and comprises 28 questions. For both versions, each item has four response options ('definitely agree', 'slightly agree', 'slightly disagree' and 'definitely disagree') and participants select one

response per item. In the AQ-28, responses are scored from 1 (definitely agree) to 4 (definitely disagree). The total score is derived by summing the scores of all items, with some items reverse-scored. Higher scores indicate more autistic traits. Scores greater than approximately 80 on the AQ-28 are thought to be clinically-relevant (Hoekstra et al., 2011).

The 20-item Prosopagnosia Index (PI-20; Shah et al., 2015)

The PI-20 (Shah et al., 2015) is a self-report measure of face recognition ability. It consists of 20 items where participants rate their difficulties with recognising faces in everyday scenarios (e.g. *'When I was at school I struggled to recognize my classmates'*) on a Likert scale (ranging from: 1 = strongly disagree to 5 = strongly agree). Five questions are reverse scored. The scores from all items are summed to derive a total score and the maximum score achievable is 100. A higher score indicates greater face recognition difficulty, with participants scoring over 75 considered likely to have prosopagnosia (Shah et al., 2015, though note that this threshold may be considered too high, with several authors recommending a threshold of 65 and above; DeGutis et al., 2023; Burns et al., 2023; Epihova & Astle, 2024).

Oxford Face Matching Test (OFMT; Stantić et al., 2022a)

The OFMT is comprised of 200 face pairs: 100 pairs that match (i.e., are different photos of the same individual's face) and 100 pairs that are mismatched (i.e. are photos of different individuals' faces). Each face pair is presented for 1600ms, and participants are first asked to determine whether the faces are of the same person or different individuals, with a maximum matching score of 200 over all trials. Second, participants are asked to provide a perceptual similarity rating for each face pair on a scale ranging from 0 to 100. The face pairs in the OFMT

are constructed to have overlapping similarity distributions, meaning that two images of the same person can appear perceptually very different, while two images of different individuals can appear perceptually very similar. Additionally, the task includes 12 attention check trials specifically created to be answered correctly by individuals even with severe face processing impairments. Participants who responded incorrectly to two or more of these trials were excluded from the study. The OFMT is available to researchers on the Gorilla Open Material repository (see Gorilla Open Materials repository: https://gorilla.sc/openmaterials/134286).

Cambridge Face Memory Task (CFMT; Duchaine & Nakayama, 2006)

The CFMT (Duchaine & Nakayama, 2006) comprises 72 trials. Initially, participants learn six faces and are subsequently tested on three-alternative-forced-choice trials that contain two novel face images, and one face image from a previously learned identity. The task is divided into three stages of increasing difficulty, the first 18 trials are presented with no changes to viewpoint or lighting, the following 30 trials have alterations to viewpoint and lighting and the last 24 trials have alterations to viewpoint and lighting plus the addition of visual noise. The maximum score is 72, with **participants scoring below 42** considered likely to have prosopagnosia (Duchaine & Nakayama, 2006).

Visual acuity task (Hetherington, 1973)

The task is comprised of 9 rows of 9 letters, with each row of letters descending in size. Participants are asked to maintain the same distance from the screen as during the other tasks and type out each row of letters one-by-one and stop when the letters are no longer visible. The

number of rows, plus the accuracy of the letters provided as a proportion of the total number of letters, is reported.

Analysis strategy

The analysis approach for this study has been used to investigate the independent contributions of face perception, face matching and face memory in autism, developmental prosopagnosia and super-recognisers (Stantić et al., 2023; Stantić et al., 2022b; Stantić, Pounder et al., 2024). In brief, an independent measure of face *perception* can be obtained by comparing participants' similarity ratings of face pairs in the OFMT, with the similarity rating derived from the average of three facial recognition algorithms, to generate an average absolute deviation from algorithmically-provided similarity for each participant (termed the Deviation score; see Stantić et al., 2022b for further information). This value represents the difference between a participant's similarity score and the average similarity score provided by the algorithms. Face *matching* scores, independent of face perception, can be obtained by regressing deviation scores from OFMT matching accuracy scores across participants. Similarly, face *memory*, independent of both face perception and face matching, can be obtained by regressing CFMT accuracy scores on Deviation scores and OFMT matching accuracy scores.

Group comparisons (i.e. Aphantasic vs Control) were analysed with independent t-tests or the non-parametric equivalent, the Mann Whitney test, when normality assumptions were violated. Fisher's exact tests were used for between-group comparisons of the number of participants meeting categorical cut-offs. All statistical analyses were performed using SPSS Statistics Version 28 (with the exception of the between-groups independent t-test for the AQ-28 and Mann-Whitney for the PI-20, which were undertaken in JASP). All analyses used a

significance level of $p < .05$, and all p-values are two-tailed. All data, **including data from excluded participants with a column indicating inclusion/exclusion status**, are available at https://osf.io/f9jtr/. No part of the study procedures or analysis was preregistered, although the analysis approach is identical to those reported in (Stantić et al., 2023; Stantić et al., 2022b).

Results

Group Comparisons – Standard Test Scores and Questionnaires

PI-20

An independent samples t-test revealed a significant group difference in PI-20 scores [$t(73) = 5.59$, $p < .001$, $d = 1.30$] with aphantasic participants scoring higher ($M = 60.53$, $SD = 19.20$) than the control group of typical imagers ($M = 41.44$, $SD = 9.55$). None of the control group scored over 75 on the PI-20 (the threshold for moderate prosopagnosia), while in the aphantasic sample, 9/34 (26.5%) participants ($M = 85.56$, $SD = 8.49$) scored > 75 on the PI-20. Using the more liberal PI-20 threshold of ≥ 65, 14/34 (41.2%) aphantasic participants and 1/41 (2.4%) control participants met the cut-off.

AQ-28

An independent t-test showed no significant group difference in AQ-28 scores [$t(73) = 1.89$, $p = .063$, $d = .44$], with control participants ($M = 64.17$, $SD = 9.32$) scoring lower on the AQ-28 than aphantasic participants ($M = 68.53$, $SD = 10.68$) on average.

OFMT: Matching Performance

At the group level, an independent t-test showed no significant difference in OFMT matching accuracy [$t(73) = 1.26$, $p = .21$, $d = .29$] between aphantasic (M = 74.5 %, SD = 6%) and control (M = 76%, SD = 7%) participants.

OFMT: Algorithmic Deviation

An independent samples t-test revealed a significant difference in deviation scores [$t(73) = 2.74$, $p = .008$, $d = -.64$] with aphantasic participants (M = 24.63, SD = 3.36) having higher deviation scores (i.e., rating faces more differently from algorithmic similarity scores) compared to control participants (M = 22.55, SD = 3.19).

CFMT

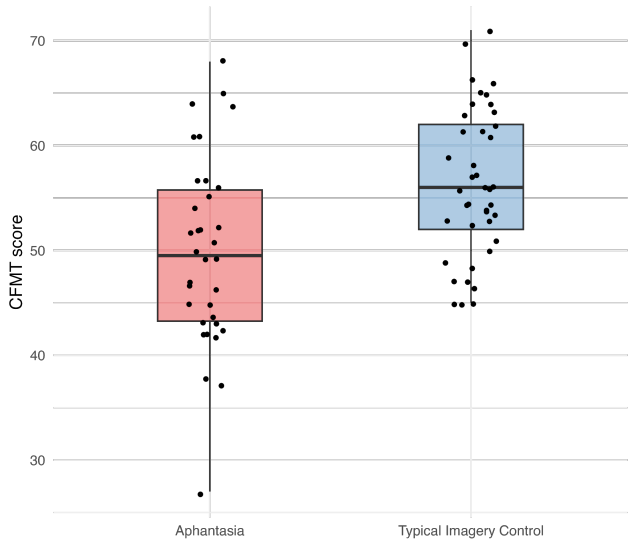
At the group level, an independent t-test showed a significant difference in CFMT accuracy scores [$t(73) = 3.44$, $p < .001$, $d = .80$], with aphantasic participants (M = 49.97, SD = 9.03) less accurate than control participants (M = 56.37, SD = 7.06).

Using the combined criterion of PI-20 ≥65 and CFMT <42, 3/34 (8.8%) aphantasic participants and 0/41 (0%) control participants met both thresholds. The same 3/34 (8.8%) aphantasic participants and 0/41 (0%) control participants met the combined criterion when the more conservative PI-20 threshold of > 75 was used. This group difference was, therefore, not statistically significant using the Fisher's exact test for either PI-20 threshold (both p = .089).

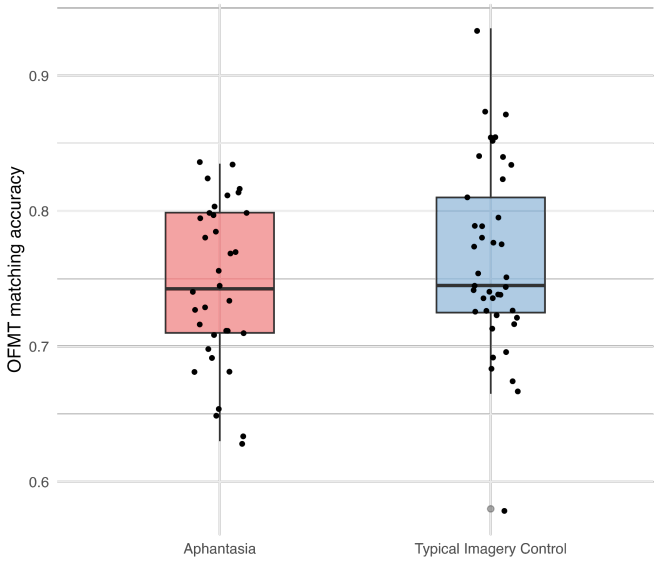
Visual Acuity

A Mann-Whitney test showed no difference in the number of rows completed in the visual acuity task (U = 529, p = .06, $r = .22$) between aphantasic participants (median = 5 lines completed, range: 2 - 7) and control participants (median = 5 lines completed, range: 2 - 6).

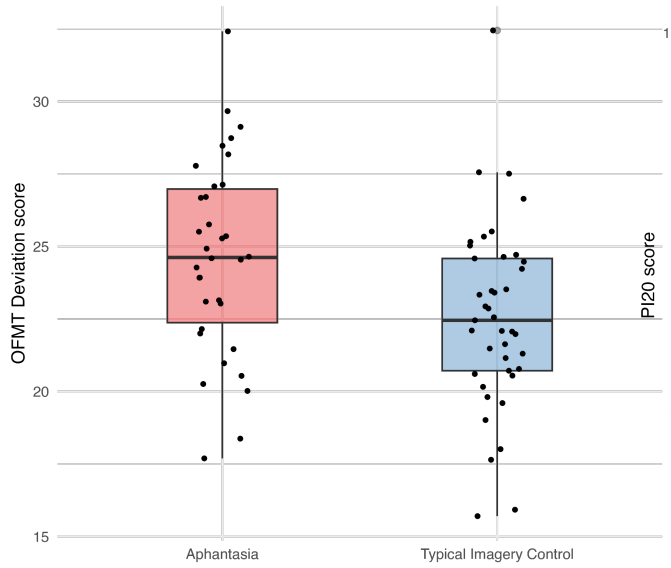
a)


CFMT score
70
60
50
40
30
Aphantasia
Typical Imagery Control

(b)


OFMT matching accuracy
0.9
0.8
0.7
0.6
Aphantasia
Typical Imagery Control

c)


OFMT Deviation score
30
25
20
15
Aphantasia
Typical Imagery Control

(d)

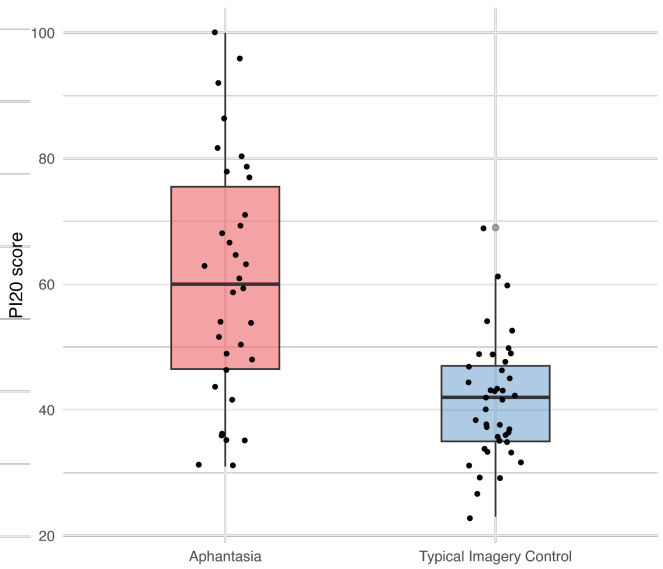

PI20 score
100
80
60
40
20
Aphantasia
Typical Imagery Control

Figure 1: Raw scores for (a) CFMT performance, (b) OFMT matching performance (accuracy), (c) OFMT deviation score and (d) PI-20 score for participants with aphantasia and the typical imagery control group. Significant group differences indicated poorer CFMT performance, higher (poorer) OFMT deviation scores, and higher (poorer) PI-20 scores in the aphantasic group compared with the control group; OFMT matching accuracy did not differ significantly between groups.

Group (Aphantasic vs Control), Deviation scores (measure of face perception), and their interaction were entered into a regression to predict OFMT matching accuracy. Deviation scores were a significant predictor ($\beta = -.78$, $t = -9.56$, $p < .001$) of OFMT matching accuracy, suggesting that face perception abilities are related to OFMT matching performance. Group was not a significant predictor of OFMT matching accuracy ($\beta = -.09$, $t = -1.10$, $p = .28$), indicating that face matching was not worse in the group of participants with aphantasia after accounting for face perception ability. The interaction between Group and Deviation scores was also not a significant predictor ($\beta = -.05$, $t = -.68$, $p = .50$), suggesting that the relationship between face perception and OFMT matching performance did not vary as a function of group.

Face Memory, Controlling for Face Perception and Face Matching

Group (Aphantasic vs Control), Deviation scores, Face Matching (OFMT accuracy) and the interactions between Deviation scores and Group, and Face Matching and Group, were entered into regressions predicting CFMT scores. Results showed no significant independent contributions of face matching ($\beta = .27$, $t = 1.79$, $p = .08$) or face perception (as measured by Deviation scores; $\beta = -.26$, $t = -1.68$, $p = .10$) to CFMT scores. Group was a significant predictor

(β = .25, t = 2.50, p = .02), indicating that face memory was worse in participants with aphantasia even after controlling for face perception and face matching. The two interactions were not significant predictors, indicating the relationships between face memory and face perception, and face memory and face matching, did not vary as a function of group (Group x Deviation scores: β = -.05, t = -0.33, p = .74; Group x Face Matching: β = -.17, t = -1.09, p = .28).

Discussion

This study examined the face processing abilities of individuals with aphantasia across behavioural tasks and via self-report. The aim was to understand the sub-processes that may underlie aphantasics' self-reported difficulties in face recognition (Zeman et al., 2020). We investigated whether a specific sub-process, or a combination of several sub-processes (face matching, face memory, and face perception), were impaired in aphantasia.

Approximately 25% of the aphantasic group reported PI-20 scores above the conservative threshold of >75, and as a whole they reported significantly higher PI-20 scores than the typical imager control group (in line with previous findings, Milton et al., 2021). Using the more liberal PI-20 threshold of ≥ 65, 14/34 (41.2%) aphantasic participants and 1/41 (2.4%) control participants met the cut-off. The results of the PI-20, therefore, provide evidence consistent with previous studies suggesting that, on average, aphantasic individuals perceive themselves to have face-processing difficulties. When PI-20 and CFMT cut-offs were considered together, the same pattern was observed using either PI-20 threshold: 3/34 (8.8%) aphantasic participants and 0/41 (0%) control participants met the combined criteria of PI-20 ≥ 65 and CFMT < 42, and the same 3/34 (8.8%) aphantasic participants and 0/41 (0%) control participants met the combined criteria

of PI-20 > 75 and CFMT < 42. This group difference was not statistically significant for either combined criterion.

On the behavioural tasks, compared to the control group, aphantasic participants performed less accurately on the CFMT, and were worse at judging the perceptual similarity of the face pairs on the OFMT. In contrast, there were no differences between aphantasic participants and the control group in face matching accuracy, both before and after controlling for face perception ability. When face matching and face perception were controlled for, the aphantasic group showed worse face memory than the control group. Overall, these results indicate that individuals with aphantasia show impaired face memory and face perception, in the presence of intact face matching. This pattern is consistent with that observed in autistic individuals (Stantić et al., 2023), and distinct from that observed in individuals with developmental prosopagnosia who showed impairments in face perception, matching and memory (Stantić et al., 2022b).

Aphantasic participants were less accurate on the CFMT compared to control participants with typical imagery, which is consistent with previous literature which has documented aphantasics' reduced performance on this task (Dance et al., 2023; Monzel et al., 2023). While this pattern of results is similar to individuals with prosopagnosia, who also perform poorly on the CFMT (Duchaine & Nakayama, 2006), it should be noted that only 3/34 (8.8%) aphantasic participants scored below the standard threshold of 42 on the CFMT, which would suggest they have prosopagnosia. Thus, while aphantasic participants exhibited reduced performance on the CFMT compared to typical imagers, their performance was not severe enough to classify the group as prosopagnosic using this test (see Monzel et al., 2023).

Results show that, on average, face perception is impaired in aphantasia (in the absence of an impairment in visual acuity). Given previous findings of intact visual perception in aphantasia (Keogh & Pearson, 2018; Bainbridge et al., 2021) this result may appear surprising, but one potential explanation is that the requirement to process stimuli as complex as two faces in a relatively short time may have exceeded a reduced perceptual capacity in aphantasia that previous experimental tasks did not. This explanation is bolstered by previous findings of slower perceptual decisions in aphantasic individuals (Liu & Bartolomeo, 2023), which could indicate a reduced perceptual ability.

A second potential explanation is that face perception, as defined here, *requires* some visual imagery. It is possible that building a 3-D representation of a face from a 2-D photograph in order to account for changes of viewpoint and lighting requires visual imagery, although it is also possible that face perception may be accomplished by non-visual spatial processing, or even non-conscious visual imagery. The same applies to face memory – it is possible that face memory *requires* the ability to generate a visual image of a learned face, or it may be the case that any visual images generated by typical imagers during face memory are epiphenomenal with respect to face memory performance. These possibilities are central to the question of whether face perception and memory is an additional difficulty seen in those with aphantasia, or whether conscious visual imagery is a necessary part of these processes, meaning that *by definition* individuals with aphantasia should experience difficulties with them.

In conclusion, this study derived independent measures of face perception, face matching, and face memory in a sample of aphantasic participants and an age-matched typical-imagery control group. Results show that individuals with aphantasia exhibit impaired face memory and face perception, but not face matching.

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