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General and specific factors in the processing of faces

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ABSTRACT

The ability to recognize faces varies considerably between individuals, but does performance co-vary for tests of different aspects of face processing? For 397 participants (of whom the majority were university students) we obtained scores on the Mooney Face Test, Glasgow Face Matching Test (GFMT), Cambridge Face Memory Test (CFMT) and Composite Face Test. Overall performance was significantly correlated for each pair of tests, and we suggest the term *f* for the factor underlying this pattern of positive correlations. However, there were large variations in the amount of variance shared by individual tests: The GFMT and CFMT are strongly related, whereas the GFMT and the Mooney test tap largely independent abilities. We do not replicate a frequently reported relationship between holistic processing (from the Composite test) and face recognition (from the CFMT)—indeed, holistic processing does not correlate with any of our tests. We report associations of performance with digit ratio and autism-spectrum quotient (AQ), and from our genome-wide association study we include a list of suggestive genetic associations with performance on the four face tests, as well as with *f*.

1. Introduction

Face recognition is singularly important for human social interaction (Bruce & Young, 2012), but not everyone is equally good at recognizing faces. Indeed, there are large individual differences: Some people cannot recognize faces at all, while others remember practically every face they see (Burton, White, & McNeill, 2010; Duchaine, Germine, & Nakayama, 2007; Russell, Duchaine, & Nakayama, 2009). In some situations, quantifying the ability to detect, discriminate and recognize faces is of great practical value—for example, in the screening of border-control officers (Burton & Jenkins, 2011). However, in the history of understanding perceptual and cognitive processes, the measurement of individual differences has led also to theoretical insights. Thus Peterzell and Teller (2000) used a covariance analysis to identify sub-channels within the visual system that are specific to particular spatial frequency bands; and in the specific case of face processing, studies of individual differences have shown that there is remarkably little overlap between general intelligence and the specific ability to recognize faces (Shakeshaft & Plomin, 2015; Wilmer, Germine, & Nakayama, 2014).

Several tests have been developed to measure the ability to detect faces or to remember them, but no single test assesses all aspects of face processing. We here ask to what extent different measures co-vary. For a large sample of healthy participants, we established the distribution of individual performance on four well-established tests of face processing: The Mooney Face Test, the Glasgow Face Matching Test, the Cambridge Face Memory Test, and the Composite Face Test.

The stimuli of the classical *Mooney Face Test* consist of seemingly unrelated patches of pure black and pure white, which, without apparent conscious effort on the viewer's part, suddenly arrange themselves to form the percept of a face (Mooney, 1957a, 1957b). This process of organization is referred to as *closure*. The objective of the Mooney test is to detect the face, and the test is considered a test of face detection and of *holistic processing*—the processing of faces as a whole as opposed to processing of individual features separately.

The *Glasgow Face Matching Test* (GFMT) measures discrimination between unfamiliar faces. Participants are shown two photographs of faces and asked to indicate whether they are of the same person, or of different persons (Burton et al., 2010). Contrary

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to intuition, performance is far from perfect and there are marked individual differences.

The *Cambridge Face Memory Test* (CFMT) is widely used to assess face recognition ability and is often administered via the Internet (Duchaine & Nakayama, 2006; Wilmer et al., 2010). Individuals with prosopagnosia show significantly lower performance than controls (Duchaine & Nakayama, 2006), and performance is highly heritable (Wilmer et al., 2010).

The *Composite Face Test* is often-used but unstandardized: Many researchers have created their own version (Richler, Cheung, & Gauthier, 2011; Richler & Gauthier, 2014; Rossion, 2013; Young, Hellawell, & Hay, 1987). In the Composite test, the participant makes a same/different judgment between the top half of the 'study' face and the top half of the subsequently presented 'target' face, while ignoring the bottom halves. Face stimuli are created by combining a top half and a bottom half, either of the same face or of different faces; the two halves are either aligned or misaligned. On a given trial, both—or either—the top and the bottom half of each face may differ between the study face and the target face, or may be the same. The test is designed to tap into holistic processing: The bottom half should influence the perception of the top half in the aligned conditions, since then all the features cohere in a Gestalt; and if the top halves are the same but the bottom halves differ, this holistic process would interfere with making a correct judgment.

All four tests previously have been compared to other tests, though not necessarily to one another. Foreman (1991) tested 127 participants on a visual-search task, the Mooney test, and two other tests of closure (the Gollin Incomplete Figures Test and the Poppelreuter test), but found no significant correlation in performance between the Mooney test and any of the other tests. This suggests that Mooney performance is independent of visual-search efficiency, and that the Mooney test does not tap the same processes as the two other tests of closure.

Burton et al. (2010) compared the Glasgow Face Matching Test to three measures of visual processing in a sample of 300 participants. GFMT performance correlated significantly and moderately strongly with matching of familiar line drawings of figures ($r = 0.42$, $p < 0.001$), and significantly but less strongly with recognition memory for faces ($r = 0.29$, $p < 0.001$). There was no significant correlation with visual short-term memory for objects ($r = 0.05$, $p > 0.05$).

Bowles et al., 2009 report a significant and strong correlation ($r = -0.61$, $p < 0.001$, $N = 124$) between the Cambridge Face Memory Test and the Cambridge Face Perception Test, which asks participants to sort a row of faces from "most similar" to "most dissimilar" in comparison to a target face; the correlation is negative because the measure of the latter test is the number of errors, rather than number correct, as is the case for the former). Wilmer et al., 2012, 2014 report a significant and sizeable correlation between the CFMT and a Famous Faces Test ($r = 0.52$, $N = 1219$), but only relatively low correlations between the CFMT and two other memory tests: The Abstract Art Memory Test ($r = 0.26$, $N = 1469$) and a Verbal Paired-Associates Memory Test ($r = 0.18$, $N = 1469$). It is on the basis of these—and other—results, that Wilmer and colleagues argue that face recognition is an independent skill, exhibiting high correlations with other tasks of face processing, but low correlations with other abilities, such as general memory.

Several studies have investigated the relationship between face recognition and holistic processing, but results are mixed: Some report a positive correlation—either strong (DeGutis, Wilmer, Mercado, & Cohan, 2013; Richler et al., 2011) or moderate (Wang, Li, Fang, Tian, & Liu, 2012)—whereas others observe no significant correlation (Konar, Bennett, & Sekuler, 2010). The interpretation of these studies is complicated by differences in both methodology and data analysis (DeGutis et al., 2013; Richler & Gauthier, 2014; Rossion, 2013).

In the present study, a large cohort of participants completed four tests that measure different aspects of face processing. The tests were selected to reliably assess as many different aspects of face processing as possible, while keeping our online test battery sufficiently brief as to encourage a high rate of participation and completion. Additionally, we hold genetic and phenotypic data for our participants from their previous visits to our lab. Face recognition previously has been shown to be strongly heritable (Shakeshaft & Plomin, 2015; Wilmer et al., 2010), to be impaired in people with autism (e.g. Weigelt, Koldewyn, & Kanwisher, 2012), and to be related to digit ratio (Leow & Davis, 2012). We are in a position to report results from a genome-wide association study (GWAS) that we conducted on participants' performance on our four face tests. We also report results from correlations of performance on our four tests with both autism-spectrum quotient and digit ratio.

2. Methods

2.1. Participants

Our 397 participants (252 female) were a subset of a cohort of 1060 who had previously completed a battery of perceptual tests in our laboratory as part of the PERGENIC project (Goodbourn et al., 2012; Lawrance-Owen et al., 2013; Verhallen et al., 2014). Participants were healthy young adults between the ages of 18 and 42 ($M = 24$ years, $SD = 4.3$), all of European descent. When tested on their original visit to the laboratory, 97% of the present cohort had a (corrected) visual acuity of 0.2 logMAR or better. The majority were students at the University of Cambridge. Participants took part in order to have a chance of winning a Kindle 3G or Amazon vouchers worth £120, the winner being chosen randomly from all who completed the four tests. Ethical permission for the study was given by the Cambridge University Psychology Ethics Committee, and work was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Participants gave informed consent before testing began.

2.2. Materials

The Mooney test was classically designed to be administered by personal interview; in the current study we use our online, three-alternative forced-choice (3AFC) version of the Mooney test (Verhallen et al., 2014). The test uses the original forty Mooney (1957a) faces, but each face is paired with two custom-made distractors. The position of the target image was random and 3AFC stimuli remained on screen until participants made a response by pressing the keys 1, 2 or 3 on their keyboard. The first trial, of forty in total, was a practice trial with feedback.

The shortened version of the Glasgow Face Matching Test was administered according to the original procedure (Burton et al., 2010): For forty trials participants had to indicate whether two photographs were of the same person or of different persons, by pressing the keys L or A on their keyboard, respectively. Each greyscale photograph was cropped tightly around the external outline of the face, ears and hair, and was presented on a white background. Stimuli remained on screen until participants made a response. In line with the original procedure there was no practice trial.

The Cambridge Face Memory Test was administered according to the original procedure (Duchaine & Nakayama, 2006): The first of three sections introduced six different faces for memorization, each presented for three seconds, followed by three 3AFC tests