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Face detection dissociates from face identification

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Running Head: Face detection and identification

Abstract

We describe three experiments in which viewers complete face detection tasks as well as standard measures of unfamiliar face identification. In the first two studies, participants view pareidolic images of objects (Experiment 1) or cloud scenes (Experiment 2), and their propensity to see faces in these scenes is measured. In neither case is performance significantly associated with identification, as measured by the Cambridge Face Memory or Glasgow Face Matching Tests. In Experiment 3 we show participants real faces in cluttered scenes. Viewers' ability to detect these faces is unrelated to their identification performance. We conclude that face detection dissociates from face identification.

Key word: Face recognition, face detection

Introduction

Despite the very large literature on face perception, there is rather little known about the processes underlying *face detection.* So, while there is considerable cumulative evidence about how we judge the identity, age, sex or attractiveness of a face, the initial process of detecting the face in a visual scene remains little-studied (for example see major reviews of face processing such as Calder, Rhodes, Johnson & Haxby, 2011; Bruce & Young, 2012). This dearth of psychological research contrasts sharply with computer-based face detection, which is a highly active field (e.g. see Viola & Jones, 2004; Zhu & Ramanan, 2012).

The face detection research that does exist has demonstrated a number of interesting findings. Faces are detected very fast (Crouzet, Kirchner & Thorpe, 2010; Crouzet & Thorpe, 2011) and highly accurately in natural scenes (Burton & Bindemann, 2009). The process is enhanced by colour (Bindemann & Burton, 2009), and detection ('is there a face present?') dissociates from categorisation ('is a centrally-presented stimulus a face or not?') (Bindemann & Lewis, 2013). Furthermore, detection is tuned to some extent to our own species – in that human faces are detected more efficiently than monkey faces (Simpson, Buchin, Werner, Worrell & Jakobsen, 2014).

In this paper we ask whether face detection is related to face identification. There is now considerable evidence that people differ widely in their ability to identify faces (Yovel, Wilmer & Duchaine, 2014) and there has been extensive study of high performers, or 'super-recognisers' (Russell, Duchaine & Nakayama, 2009; Bobak & Hancock, 2016; Robertson, Noyes, Dowsett, Jenkins & Burton, 2016) and poor performers, or those with developmental prosopagnosia (Duchaine & Nakayama, 2005; Behrmann & Avidan, 2005). Between these two extremes, there is a full range of abilities on standardised face identification tasks such as the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and the Glasgow Face Matching Test (Burton, White & McNeill, 2010). There is increasingly strong evidence that these individual differences are highly heritable (Shakeshaft & Plomin, 2015; Zhu et al, 2010; Wilmer et al, 2010).

Why might processes involved in face *detection* be associated with those underlying face *identification*? Faces are known to be a strong attentional cue in drawing visual attention

(Langton, Law, Burton & Schweinberger, 2008; Theeuwes & van der Stigchel, 2006). However, this attention capture is not mandatory: it can be modulated by top-down influences such as instructions and expectations (Bindemann, Burton, Langton, Schweinberger & Doherty, 2007). We do not presently know the extent of individual differences in face detection performance, but it seems possible that any such differences could reflect underlying differences in viewers' interest in faces, or in people generally. For example, some clinical groups lacking sociability also show deficits in processing faces, either for affect or identity (e.g. Marsh & Blair, 2008; Weigelt, Koldewyn & Kanwisher, 2012).

Across the broader population, it is not so clear whether differences in general sociability predict face perception, though there is some evidence that extraverts show better recognition of facial identity (Li et al, 2010) and facial emotion (Canli, Sivers, Whitfield, Gotlib & Gabrieli, 2002). Whether such differences would be observable in face detection tasks remains to be seen.

In the studies below we present three experiments using an individual differences approach to examine any link between face detection and identification. We ask participants to complete standard unfamiliar face identification tasks, as well as tasks that reflect face detection. In the first two experiments we measure people's *propensity* to detect faces in scenes by presenting pareidolic images and asking them to report whether they detect faces or not. We ask whether viewers who are prone to see faces in non-face stimuli are particularly good at facial identity tasks. In Experiment 3 we measure people's ability to detect real faces in photographic scenes, and again compare this to their ability on an identity task. To anticipate the results, we consistently fail to find any reliable association between detection and identification performance, leading us to conclude that these abilities are independent.

Experiment 1

In this experiment we showed participants pareidolic images, i.e. non-face images in which viewers often see faces (see Figure 1). We expected some individual variability in the extent to which viewers would "detect" the faces in these images, and this can be compared to variability in standard face identification tests. There is good evidence that illusory perception of faces is related to top down processes involved in real face processing. For example, Liu et al (2014) showed participants visual noise, but led them to expect to see faces

or letters within this visual noise. When participants reported "seeing" a face, this was associated with activation in the fusiform face area (FFA), a brain region known to be associated with face perception. Furthermore, Takahashi & Watanabe (2013) demonstrate that pareidolic images show face-like attentional-cueing properties, *only* when they are perceived as faces.

Previous studies have not reported details of individual differences in pareidolia, but, there is some evidence for population differences. Pareidolic processing is thought to arise in early childhood (8-10 months old; Kato & Mugitani, 2015), while children with ASD show reduced sensitivity to these images (Guillon et al, 2016). It therefore seems appropriate to use pareidolic images to test viewers' face detection sensitivity.

Method

Participants

Forty participants (36 female) with a mean age of 20 years (SD = 2, Range = 18-26) were recruited from the University of York, Department of Psychology. All participants were naïve to the purpose of the study and received a course credit or monetary payment for their participation.

Stimuli and Apparatus

Face Detection Task: Pareidolic Objects

FIGURE 1: The image on the left shows a cardboard box which gives rise to the pareidolic representation of a face. The image of the cardboard box on the right shares many of the characteristic of the pareidolic image, but it does not elicit the perception of a face. For copyright reasons we cannot present the pareidolic stimuli used in Experiment 1, however, the images shown above are a good approximation to those used in the task. Images used under CC BY-SA 3.0 licence (Left: photographer: Alexander Gee 2011; post author: Bostwickenator; Right photographer and post author: HornM201).

Fifty pareidolic object images (e.g. houses, cars, fruit, office stationary) were selected from online websites with content specifically related to this phenomenon. Fifty additional images of everyday objects that did not elicit the perception of a face were selected from an internet image search. The foil set was selected such that the objects would retain the same type of images in the pareidolic set but that there configuration within the image did not lead to the perception of a face. See Figure 1 for examples. Four independent raters confirmed that each of the images in the pareidolic set elicited the perception of a face, while each foil image did not. The images were re-sized to a width of 600 pixels, equating to 15.9^{o} of visual angle at the viewing distance used in these experiments. We also used a colour-block mask of size 1000 x 1000 pixels, as described below. All of the stimuli were presented on a 12 inch Hewlett Packard laptop using E-Prime 2.0.

Face Identity Task 1: The Glasgow Face Matching Test (GFMT)

The GFMT (short version) consists of 40 pairs of unfamiliar faces, half of which are same identity 'match' pairs and half of which are different identity 'mismatch' pairs. Each

face image in the set is front facing in pose, neutral in expression, and standardised to a width of 350 pixels (see Burton, White & McNeill. 2010). Viewers are shown each of these pairs in turn, and respond 'same person' or 'different people' to each pair.

Face Identity Task 2: The Cambridge Face Memory Test (CFMT)

The Cambridge Face Memory Test (Duchaine & Nakayama, 2006a) is a 72 item recognition memory task which is split into three sections. In section one, participants are told to learn a target face; they are then presented with a three-alternative forced choice task in which they have to pick out the identical face image. This process is repeated for each of six target faces and each of three target face orientations (left facing, forward facing, right facing). In section two the three-AFC test is retained, with participants now having to identify novel instances of each target face. Section three is identical to section two, with the exception that the test images have had visual noise added to them in order to make the task more challenging.

Procedure

The pareidolic face detection task was completed first for all participants, followed by the GFMT and CFMT in counterbalanced order. This ensured that participants came to the pareidolia task fresh, i.e. without having spent the previous thirty minutes looking at faces. For each of the 100 images in the pareidolia task, participants were asked whether the image elicited the perception of a face or not, and responded by button press. Each trial began with a 500ms fixation cross, followed by the task image for one second, after which the colour-block mask was displayed for one second. Participants had a two second response window that began from the moment the task image appeared on screen. A 1500ms blank screen was displayed between each trial. Following completion of this task, participants immediately took the two identification tests.

Results and Discussion

One participant, who performed at chance level on the CFMT and 3 SD's below the mean on the detection task, was removed from the analysis.

For the face detection task, the mean hit rate was 94% (SD = 5%; Range = 80-100%) and the mean false alarm rate 4% (SD = 5%; Range = 0-22%). Across participants, mean detection sensitivity (d') was 3.55 (SD = 0.53) with a response criterion (*c*) of 0.12 (SD = 0.31). The mean accuracy rate for the GFMT was 78% (SD = 12%; Range = 50-97%) with

an almost identical accuracy rate found for the CFMT (M = 77%; SD = 13%; Range = 42-99%). Table 1 shows correlations between the three tests.

	Face detection (pareidolia) d'	Face ID CFMT	Face ID GFMT
Face detection (pareidolia) d'	-	0.19	0.10
Face ID: CFMT		-	0.47**
Face ID: GFMT			-

Table 1: Correlations (Pearson's r) between tests. N = 39, ** $p < 0.01$

These results show high levels of association between the two tests on unfamiliar face identity processing, but neither ID task is associated with face detection. This pattern suggests a dissociation between identity and detection tasks. However, previous research using pairwise face matching has shown that performance on match and mismatch trials is uncorrelated (Megreya & Burton, 2007). For this reason, we also correlated face detection with GFMT match and mismatch trials separately. Table 2 shows these correlations. The results confirm the lack of association between components of the matching task, but confirm that neither component of identity is related to face detection.

	Face detection (pareidolia) d'	GFMT Match trials	GFMT Mismatch trials
Face detection (pareidolia) d'	-	0.04	0.05
GFMT Match Trials		-	0.03
GFMT Mismatch Trials			-

Table 2: Correlations (Pearson's r) between detection and components of the GFMT. All NS.

These results are consistent with a dissociation between face detection and face identification. However, the null result may, in principle, arise due to lack of power. Our tests had reasonable power: with 40 participants, and $\alpha = 0.5$, power to detect a moderate correlation of .4 is .83 (one-tailed) or .74 (two-tailed), (Altman, Machin, Bryant & Gardner, 2013). While the observed correlations were much lower, we should also note that there is a relatively constricted range of detection scores. Performance on the pareidolic objects test is near ceiling (high d' with relatively small SD), which could account for the

poor levels of correlation with other tasks. For these reasons, we seek converging evidence on the relationship between recognition and detection using a different procedure. In the next experiment, we use a different test of pareidolic face image detection, which gives rise to lower face detection rates.

Experiment 2

This experiment provides an extension of Experiment 1 by comparing face detection and identification tasks. In this study we introduce a new face detection task using pareidolic images of cloud formations. 'Seeing faces in clouds' is a well-known example of pareidolia, and the ready availability of many examples (through web image search) makes this a convenient class of stimuli for developing a novel task. Alongside this new face detection task, we use a single measure of identification in Experiment 2, the GFMT. Since the two identity measures correlated highly in the previous experiment, we chose to use only one of them – the matching task – in this experiment.

Method

Participants

Forty participants (32 female) with a mean age of 22 years (SD = 3, Range = 18-26) were recruited from the University of York Department of Psychology. All participants were naïve to the purpose of the study and received a course credit or monetary payment for their participation.

Stimuli: Pareidolic Clouds

FIGURE 2: The image on the left shows a cloud scene which gives rise to the pareidolic representation of a face. The image of the cloud scene on the right shares many of the same characteristic but does not elicit the perception of a face. Images used under CC-BY-NC-ND 2.0 and CC BY-SA 3.0 licences, respectively. Photographer and post authors: left, Dana & Curios Tangles; right, Chevy111.

Fifty pareidolic cloud images were selected using online websites which had content specifically related to this phenomenon, and Google Image searches (search terms: 'faces in clouds', 'cloud faces', 'person in clouds', 'cloud people'). An example can be seen in Figure 2. Fifty additional images of cloud scenes that did not elicit the perception of a face were also selected from an internet image search. All images were natural photographs, and none had been artificially manipulated to make them look like faces. To select these images we asked four independent raters to confirm whether each of the cloud scenes we had picked for the pareidolic set did indeed elicit the perception of a face. As the cloud scenes are more variable and subjective than the pareidolic objects used in Experiment 1, we placed a red circle around the area of the scene in which we believed a face could be detected. (This highlighting device was used for stimulus selection only, not in the experimental task, below). We refined the pareidolic set until each rater agreed that a face could be detected in the circled area of the scene. Similarly, for the non-pareidolic set of cloud scenes, each rater agreed that none of the images in the final set led to their perception of a face. The images were re-sized to a width of 600. All of the stimuli were presented on a 12 inch Hewlett Packard laptop using E-Prime 2.0.

Procedure

All participants completed the face detection task, followed by the GFMT. During the detection task, participants were told that an image of a cloud scene would appear onscreen on each trial, and that they should press '1' if the image elicited the perception of a face or press '3' if it did not. Each trial began with a 500ms fixation cross followed by the task image which remained onscreen until response. As we anticipated that the cloud task would be harder than the task in Experiment 1, this experiment was self-paced in order to avoid floor effects. The colour-block mask again followed the task display and it remained onscreen for 1s before a 1500ms blank screen and then the next trial.

Results and Discussion

For the cloud face detection task, the mean hit rate was 69% (SD = 11%; Range = 48-94%) and the mean false alarm rate 13% (SD = 13%; Range = 0-66%). Across participants, mean detection sensitivity (d') was 1.86 (SD = 0.49) with a response criterion (*c*) of 0.39 (SD = 0.43). So, this task produces fewer pareidolic experiences than the task used in Experiment 1, and there is a good range of responses here (e.g. hit rate range: 80-100% in Experiment 1; 48-94% in Experiment 2). The mean accuracy rate for the GFMT face identity task was 77% (SD = 10%; Range = 55-95%).

Once again, there was no reliable correlation between the face detection and GFMT, the face ID task (r = -.06, N = 40, p = 0.73). Furthermore, there was no correlation between detection and either of the two GFMT components (match: r = -.09, N = 40, p = 0.56; mismatch: r = .01, N = 40, p = 0.97). This adds to the evidence that face detection and identification are unrelated phenomena – a replication of Experiment 1 using a different procedure. While Experiment 2 had the same power as Experiment 1, the correlation sizes were even smaller – giving no hint of a reliable association. In the next experiment we extend these findings be replacing the pareidolic image task with a test of real detection.

Experiment 3

Experiments 1 and 2 showed no relationship between viewers' propensity to see faces in non-face scenes and their abilities on unfamiliar face identification. We take this as evidence supporting the idea of a dissociation between face detection and identification. However, we

have not so far taken a direct measure of face detection. In this final experiment we replace the pareidolia tasks with a measure of real face detection in cluttered scenes.

Method

Participants

Forty participants (33 female) with a mean age of 21 years (SD = 3, Range = 18-31) were recruited from the University of York Department of Psychology. All participants were naïve to the purpose of the study and received a course credit or monetary payment for their participation.

Stimuli: Face Detection

Two hundred and forty images of indoor scenes were used in this experiment, in half of which a face was embedded (for an example, see Figure 3, an image was taken from Bindemann & Lewis, 2013, and Bindemann & Burton, 2009). Faces were front-facing photos of young Caucasian adults showing neutral expression. They were standardised to a size of 1000 (width) x 750 (height) pixels. The faces occupied a relatively small area of the cluttered scenes (between 0.08% and 1.73% of the total image area) but were not of a fixed size, to avoid strategic search.

Figure 3: An example image containing a face (to the left of the third shelf down).

Procedure

Participants again completed the face detection task first and the GFMT second. For the face detection task, participants were instructed that on each trial they would be presented with an image of an everyday scene. They were told that on some trials a face photo would be present in the scene and that they should press '1' if they saw a face and '2' if they did not. Each trial began with a fixation cross for 500ms, followed by the indoor scene for 200ms. The colour block mask was presented for 1000 followed by a 1500ms blank display between trials. There was a two second response window which began with the presentation of the scene image. The participants were told that as the task image presentation time was brief and accuracy was emphasised over speed of response.

Results

For the face detection task, the mean hit rate was 64% (SD = 10%; Range = 42-84%) and mean false alarm rate 19% (SD = 16%; Range = 2-72%). Across participants, mean detection sensitivity (d') was 1.36 (SD = 0.51) with a response criterion (*c*) of 0.30 (SD = 0.37). The mean accuracy rate for the GFMT face identity task was 80% (SD = 10%; Range

= 57-97%). There was no reliable association between face detection (d') and GFMT scores, $r = .18$, N = 40, $p = 0.28$. As in previous studies, there was no correlation between detection and either of the two GFMT components (match: $r = .11$, N = 40, $p = 0.49$; mismatch: $r = .13$, N = 40, $p = 0.44$). Once again, this provides support for the idea that identification and detection of faces are dissociable.

General Discussion

Across three experiments we have consistently failed to find significant associations between detection and identification tasks. This lack of association holds across three different measures of face detection – two pareidolic image tasks measuring viewers' propensity to see faces in scenes, and a direct measure of detection performance. So, while experiments such as these, with moderate power, can never conclusively rule-out an association, the converging evidence from three different types of measure suggest that detection and identification are either unrelated, or very weakly related. These experiments therefore provide evidence against the idea that individual variation in face tasks reflects a more fundamental 'interest in people'– or at least if it does, such a dimension does not affect early face detection processes.

The lack of association between face detection and face identification tasks is consistent with evidence from psychophysiological sources. For example, the well-studied N170 ERP component is known to show sensitivity to faces (Bentin, Allison, Puce, Perez & McCarthy, 1996), and is often held to be associated with structural coding (Eimer & McCarthy, 1999). However, this component is typically unaffected by the familiarity of a face (Bentin & Deouell, 2000; Rossion et al, 1999). Instead, a later component, the N250r, is typically reported as the earliest indicator of a face's familiarity (Schweinberger, Pickering, Jentzsch, Burton & Kaufmann, 2002). If these component-based effects reflect a sequential processing of facial information, of the type often invoked in functional models of face recognition (e.g. Bruce & Young, 1986) then our results may simply reflect the order in which facial information becomes available for use. So, faces are detected first, and then processed for identity, with no top-down influence on these early processes. Across a large range of perceptual tasks, there is now considerable debate about the extent to which perceptual and cognitive processes interact (for example see Firestone & Scholl, 2014; Goldstone, de Leeuw & Landy, 2015). However, in the domain of face detection and recognition, we have found no evidence for mutual influence.

The literature on developmental prosopagnosia (DP) is also informative here. One potential cause of DP is a failure of the face detection system, held to be innate in some accounts (Morton & Johnson, 1991). If face detection is poor, then later processes may not receive information necessary for fine-tuning the *recognition* system (Johnson, 2005). There has therefore been some attempt to establish whether people with DP have particular problems with detection. However, the evidence suggests that there is very wide diversity. Studies with adults (Garrido, Duchaine & Nakayama, 2008) and children (Dalrimple & Duchaine), using various different face detection tasks, show that some cases of DP are associated with detection problems and some are not. These results are consistent with the dissociation reported here for neurotypical participants.

In the experiments above, we have concentrated exclusively on unfamiliar faces, even though we have used *identity* tasks – the CFMT and GFMT. There is growing evidence that there are actually strong dissociations between familiar and unfamiliar face processing on some tasks (Megreya & Burton, 2006; Johnston & Edmonds, 2009). It would be interesting to establish whether there might be an association between detection of familiar faces, and individual differences in familiar face identification - and such an association cannot be ruled-out on the basis of the experiments described here. However, it does seem clear from these experiments that, for unfamiliar faces, no association exists between detection and identification.

References

Altman, D., Machin, D., Bryant, T., & Gardner, M. (Eds.). (2013). *Statistics with confidence: confidence intervals and statistical guidelines*. John Wiley & Sons.

Behrmann, M., & Avidan, G. (2005). Congenital prosopagnosia: face-blind from birth. *Trends in cognitive sciences*, *9*(4), 180-187.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of cognitive neuroscience*, *8*(6), 551-565.

Bentin, S., & Deouell, L. Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology*, *17*(1-3), 35-55.

Bindemann, M., & Burton, A. M. (2009). The role of color in human face detection. *Cognitive Science*, *33*(6), 1144-1156.

Bindemann, M., Burton, A. M., Langton, S. R., Schweinberger, S. R., & Doherty, M. J. (2007). The control of attention to faces. *Journal of vision*, *7*(10), 15-15.

Bindemann, M. & Lewis, M.B., (2013). Face detection differs from categorization: Evidence from visual search in natural scenes. *Psychonomic Bulletin & Review*, 20(6), 1140–1145.

Bobak, A. K., Hancock, P. J., & Bate, S. (2016). Super‐recognisers in Action: Evidence from Face‐matching and Face Memory Tasks. *Applied Cognitive Psychology*, *30*(1), 81-91.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British journal of psychology*, *77*(3), 305-327.

Bruce, V. & Young, A. (2012). *Face perception*. London: Psychology Press.

Burton, A. M., & Bindemann, M. (2009). The role of view in human face detection. *Vision Research*, *49*(15), 2026-2036.

Burton, A. M., White, D., & McNeill, A. (2010). The Glasgow Face Matching Test. *Behavior Research Methods*, *42*(1), 286-291.

Calder, A., Rhodes, G., Johnson, M., & Haxby, J. (Eds.). (2011). *Oxford Handbook of Face Perception*. OUP Oxford.

Canli, T., Sivers, H., Whitfield, S. L., Gotlib, I. H., & Gabrieli, J. D. (2002). Amygdala response to happy faces as a function of extraversion. *Science*, *296*(5576), 2191-2191.

Crouzet, S. M., Kirchner, H., & Thorpe, S. J. (2010). Fast saccades toward faces: face detection in just 100 ms. *Journal of vision*, *10*(4), 16-16.

Crouzet, S. M., & Thorpe, S. J. (2011). Low-level cues and ultra-fast face detection. *Frontiers in psychology*, *2*, 342.

Dalrymple, K. A., & Duchaine, B. (2016). Impaired face detection may explain some but not all cases of developmental prosopagnosia. *Developmental Science*, *19*(3), 440–451.

Duchaine, B., & Nakayama, K. (2005). Dissociations of face and object recognition in developmental prosopagnosia. *Journal of Cognitive Neuroscience*, *17*(2), 249-261.

Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia*, *44*(4), 576-585.

Eimer, M., & McCarthy, R. A. (1999). Prosopagnosia and structural encoding of faces: Evidence from event‐related potentials. *Neuroreport*, *10*(2), 255-259.

Firestone, C., & Scholl, B. J. (2014). "Top-down" effects where none should be found the El Greco fallacy in perception research. *Psychological science*, *25*(1), 38-46.

Garrido, L., Duchaine, B., & Nakayama, K. (2008). Face detection in normal and prosopagnosic individuals. *Journal of Neuropsychology*, *2*(1), 119–140.

Goldstone, R. L., de Leeuw, J. R., & Landy, D. H. (2015). Fitting perception in and to cognition. *Cognition*, *135*, 24-29.

Guillon, Q., Rogé, B., Afzali, M. H., Baduel, S., Kruck, J., & Hadjikhani, N. (2016). Intact perception but abnormal orientation towards face-like objects in young children with ASD. *Scientific Reports*, *6*.

Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews Neuroscience*, *6*(10), 766-774.

Johnston, R. A., & Edmonds, A. J. (2009). Familiar and unfamiliar face recognition: A review. *Memory*, *17*(5), 577-596.

Kato, M., & Mugitani, R. (2015)**.** Pareidolia in infants. *PloS one*, *10*(2), e0118539.

Langton, S. R., Law, A. S., Burton, A. M., & Schweinberger, S. R. (2008). Attention capture by faces. *Cognition*, *107*(1), 330-342.

Li, J., Tian, M., Fang, H., Xu, M., Li, H., & Liu, J. (2010). Extraversion predicts individual differences in face recognition. *Communicative & integrative biology*, *3*(4), 295-298.

Liu, J., Li, J., Feng, L., Li, L., Tian, J., & Lee, K. (2014). Seeing Jesus in toast: Neural and behavioral correlates of face pareidolia. *Cortex*, *53*(1), 60–77.

Marsh, A. A., & Blair, R. J. R. (2008). Deficits in facial affect recognition among antisocial populations: a meta-analysis. *Neuroscience & Biobehavioral Reviews*, *32*(3), 454-465.

Megreya, A. M., & Burton, A. M. (2006). Unfamiliar faces are not faces: Evidence from a matching task. *Memory & Cognition*, *34*(4), 865-876.

Megreya, A. M., & Burton, A. M. (2007). Hits and false positives in face matching: A familiarity-based dissociation. *Perception & Psychophysics*, *69*(7), 1175.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: a two-process theory of infant face recognition. *Psychological review*, *98*(2), 164-181.

Robertson, D. J., Noyes, E., Dowsett, A., Jenkins, R., & A. Mike Burton. (2016). Face Recognition by Metropolitan Police Super-recognisers. *PLoS ONE 11(2)*: e0150036.

Russell, R., Duchaine, B., & Nakayama, K. (2009). Super-recognizers: People with extraordinary face recognition ability. *Psychonomic Bulletin & Review*, *16*(2), 252-257.

Schweinberger, S. R., Pickering, E. C., Jentzsch, I., Burton, A. M., & Kaufmann, J. M. (2002). Event-related brain potential evidence for a response of inferior temporal cortex to familiar face repetitions. *Cognitive Brain Research*, *14*(3), 398-409.

Shakeshaft, N. G., & Plomin, R. (2015). Genetic specificity of face recognition. *Proceedings of the National Academy of Sciences*, *112*(41), 12887-12892.

Simpson, E. A., Buchin, Z., Werner, K., Worrell, R., & Jakobsen, K. V. (2014). Finding faces among faces: human faces are located more quickly and accurately than other primate and mammal faces. *Attention, Perception, & Psychophysics*, *76*(8), 2175-2183.

Takahashi, K., & Watanabe, K. (2013). Gaze cueing by pareidolia faces. *i-Perception*, *4*(8), 490-492.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition*, *13*(6), 657-665.

Viola, P., & Jones, M. J. (2004). Robust real-time face detection. *International journal of computer vision*, *57*(2), 137-154.

Weigelt, S., Koldewyn, K., & Kanwisher, N. (2012). Face identity recognition in autism spectrum disorders: a review of behavioral studies. *Neuroscience & Biobehavioral Reviews*, *36*(3), 1060-1084.

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., Nakayama, K., & Duchaine, B. (2010). Human face recognition ability is specific and highly heritable. *Proceedings of the National Academy of Sciences, 107*(11), 5238-5241.

Yovel, G., Wilmer, J. B., & Duchaine, B. (2014). What can individual differences reveal about face processing? *Frontiers in human neuroscience*, *8*.

Zhu, X., & Ramanan, D. (2012, June). Face detection, pose estimation, and landmark localization in the wild. In *Computer Vision and Pattern Recognition (CVPR), 2012 IEEE Conference on* (pp. 2879-2886). IEEE.

Zhu, Q., Song, Y., Hu, S., Li, X., Tian, M., Zhen, Z., Dong, Q., Kanwisher, N., & Liu, J. (2010). Heritability of the specific cognitive ability of face perception. *Current Biology, 20*, 137-142.