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ORIGINAL ARTICLE

Objects that induce face pareidolia are prioritized by the visual system

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Abstract

The human visual system has evolved specialized neural mechanisms to rapidly detect faces. Its broad tuning for facial features is thought to underlie the illusory perception of faces in inanimate objects, a phenomenon called *face pareidolia*. Recent studies on face pareidolia suggest that the mechanisms underlying face processing, at least at the early stages of visual encoding, may treat objects that resemble faces as real faces; prioritizing their detection. In our study, we used breaking continuous flash suppression (b-CFS) to examine whether the human visual system prioritizes the detection of objects that induce face pareidolia over stimuli matched for object content. Similar to previous b-CFS results using real face stimuli, we found that participants detected the objects with pareidolia faces faster than object-matched control stimuli. Given that face pareidolia has been more frequently reported amongst individuals prone to hallucinations, we also explored whether this rapid prioritization is intact in individuals with schizophrenia, and found evidence suggesting that it was. Our findings suggest that face pareidolia engages a broadly tuned mechanism that facilitates rapid face detection. This may involve the proposed fast subcortical pathway that operates outside of visual awareness.

KEYWORDS
continuous flash suppression, face perception, pareidolia, schizophrenia, vision

BACKGROUND

Humans have evolved specialized neural mechanisms to sensitively detect faces and evaluate the important social signals they convey (Harries & Perrett, 1991; Haxby et al., 1999, 2002; Kanwisher et al., 1997; Perrett et al., 1985). This perceptual sensitivity has supported human evolution, by allowing us to communicate with conspecifics and rapidly detect face cues (e.g., fearful expressions) which signal threat (e.g., predators) in our environment (Öhman, 2009; Öhman et al., 2001; Pascalis & Kelly, 2009; Sander et al., 2007). Recent studies show that our sensitivity for face information may also extend to illusory faces in inanimate objects (see Figure 1a for examples); a phenomenon known as face pareidolia (Palmer & Clifford, 2020; Partos et al., 2016; Wardle et al., 2017a, 2017b; Zhou & Meng, 2020). Research on face pareidolia indicates that the detection of what has been referred to as 'false positive' faces may be a by-product of an error-prone face detection mechanism that favours sensitivity over specificity (Palmer & Clifford, 2020; Taubert et al., 2018, 2019; Wardle et al., 2017a). Indeed, it has been shown that within the first 200 ms after stimulus onset, brain responses to objects that induce face pareidolia are distinguishable from responses elicited by objects sharing similar visual information and semantic identity (Hadjikhani et al., 2009; Wardle et al., 2017b). Interestingly, these early signals seem to be more similar to those brain responses conveying information about real faces and driven by low-level visual features, such as high-contrast and low-spatial frequency components of face configuration (Wardle et al., 2017b). Also, results from recent gaze cueing and cross-adaptation studies indicate that sensory mechanisms recruited for viewing human faces may overlap with those recruited for viewing pareidolia faces (Alais et al., 2021; Palmer & Clifford, 2020; Takahashi & Watanabe, 2013). Together, these findings suggest that the mechanisms involved in the early stages of visual processing might treat face pareidolia stimuli like real faces.

There is growing evidence that the initial stages of face detection rely on a rapid subcortical pathway relaying coarse visual information to the amygdala via the superior colliculus and pulvinar (Johnson, 2005; McFadyen et al., 2017, 2020; Morris et al., 1999; Senju & Johnson, 2009). This

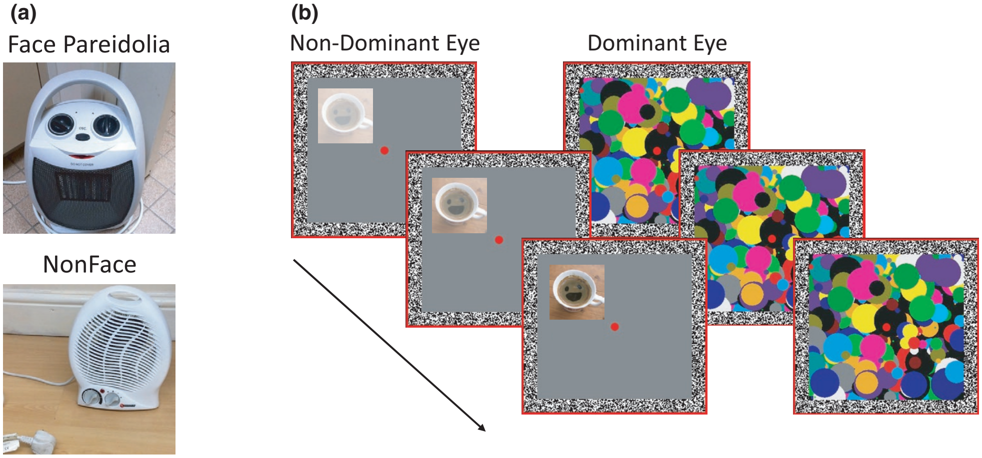

FIGURE 1 (a) Example of matched stimuli for objects with and without illusory face features. The full stimulus set is available on the Open Science Framework (https://osf.io/9g4rz) and exemplars shown here are adapted from Wardle et al. (2020) with permission under a Creative Commons Attribution 4.0 License. (b) A schematic representation of an example trial. Under continuous flash suppression (CFS), separate stimuli are presented to each eye. A target stimulus is presented to the non-dominant eye and is rendered invisible for several seconds by a high-contrast mask presented to the dominant eye. The target stimulus is temporarily suppressed by the mask from visual awareness. Masks (dominant eye) were updated at 10 Hz. When the target stimulus became visible to the participant, they were required to quickly and accurately press a button to indicate whether it appeared on the left or right side of fixation. The time taken for observers to detect the target stimulus under these conditions (i.e., 'suppression time') was taken as an index of stimulus potency in accessing conscious awareness pathway is proposed to underpin the rapid detection and orienting responses to face stimuli, and is thought to operate reflexively and outside of conscious awareness. In a recent study by Taubert et al. (2018), it was shown that bilateral lesions to the amygdala in rhesus monkeys eliminate a robust and automatic looking preference for real faces and face pareidolia stimuli, suggesting an involvement of the amygdala and possible recruitment of the fast broadly tuned subcortical route in face pareidolia (Taubert et al., 2018). Currently, however, no research has shown evidence for face pareidolia recruiting this pathway in humans.

The primary aim of the current study was to test whether face pareidolia implicates the involvement of a broadly tuned, rapid face detection mechanism using a direct behavioural measure. Specifically, we used breaking continuous flash suppression (b-CFS; see Figure 1) to examine whether face pareidolia stimuli were prioritized over other stimuli matched for object content and visual features (Tsuchiya & Koch, 2005). B-CFS is a method argued to probe the earliest preconscious stages of visual processing, including the rapid subcortical face detection pathway (Yang et al., 2007). Previous studies using b-CFS have shown that real faces gain privileged access to visual awareness and are detected faster than other objects (Caruana et al., 2019; Stein et al., 2016). Face inversion effects are also observed under b-CFS, whereby the upright canonical view is detected faster than its inverted counterpart (Caruana et al., 2019; Stein et al., 2016). In this study, we used this same approach, but substituted real face stimuli with face pareidolia stimuli (Figure 1b). We predicted that recruitment of early face detection mechanisms for face pareidolia stimuli would result in faster awareness of these stimuli compared to control images matched for object content.

A second, exploratory, aim of this study was to determine whether this b-CFS paradigm could be used to probe behavioural markers of hallucination proneness at the earliest stages of visual processing. Existing face pareidolia research in humans indicates significant individual differences in this phenomenon (Smailes et al., 2020; Zhou & Meng, 2020). In particular, links have been made between face pareidolia and proneness to experiencing hallucinations—particularly in patients diagnosed with Parkinson's disease with Lewy body dementia (Akdeniz et al., 2020; Uchiyama et al., 2012; Yokoi et al., 2014). In these studies, patients have exhibited the experience of visual hallucinations, including intensified experiences of pareidolic illusions, when assessed using both behavioural and electrophysiological measures.

However, while differences in reporting pareidolia might indeed reflect variation in the perceptual experience of visual stimuli (as is typically implied from these studies), it is also possible that cognitive biases underlie differences in reporting whether or not an illusory face is present. For instance, individuals more susceptible to hallucinations might have a stronger tendency to report seeing a face when they are uncertain and forced to guess, while other individuals may exert a more conservative bias. So far, no research disentangles perceptual bias from cognitive bias when examining individual differences in face pareidolia. To this end, our exploratory study examined whether differences exist between healthy adults and individuals with schizophrenia. Schizophrenia is a condition known to significantly increase hallucination susceptibility (David et al., 2011; Dudley et al., 2018; Mueser et al., 1990) with an 80% prevalence rate (Lim et al., 2016). Whilst auditory hallucinations are most common, up to 62% of individuals with schizophrenia experience visual hallucinations (Baethge et al., 2005; Bracha et al., 1989; Delespaul et al., 2002). Furthermore, an estimated 70% of patients experiencing auditory hallucinations also experience visual hallucinations—suggesting that a common mechanism underlies aberrant perceptual experiences that manifest across sensory modalities (Gauntlett-Gilbert & Kuipers, 2003). As such, our prediction was that if the proposed link between face pareidolia and hallucination proneness is based on a perceptual bias, we would find differences in the processing of face pareidolia stimuli under b-CFS between groups. This might manifest as a larger stimulus effect in patients with schizophrenia than controls (i.e., relatively faster suppression times for face pareidolia stimuli compared to non-face stimuli). Because b-CFS probes early stages of perception and does not require participants to report the features of the stimulus, the use of this method specifically eliminates potential influences of cognitive bias on the participant's report (Caruana et al., 2019; Caruana & Seymour, 2021; Caruana et al., 2019; Seymour et al., 2016).

METHOD

Ethical statement

The methods of this study were approved by the local Human Research Ethics Committee (reference number: 5201200021) and were performed in accordance with this approval and the Declaration of Helsinki. All participants received payment for their time and provided written and informed consent before participating.

Participants

Twenty-four healthy adult individuals (14 M/10F) participated in this study ($M_{\text{Age}} = 42.92$; $SD = 16.13$). In addition, we tested a sample of 17 outpatients diagnosed with schizophrenia or schizoaffective disorder (8 M/9F), recruited from the Australian Schizophrenia Research Bank (https://www.neura.edu.au/discovery-portal/asrb/). Eligibility criteria for both groups of participants included: (1) no history of neurological disease or injury resulting in a concussion or being unconscious for more than 1 hour; (2) no history of substance abuse (as per DSM-V criteria); (3) 8 years or more of formal education; and (4) normal or corrected-to-normal vision. Healthy controls were screened using an interview protocol based on the affective, psychotic and substance abuse screening modules from the Structural Clinical Interview for Axis 1 Disorders previously outlined under DSM-IV (SCID-1; First et al., 2002). All patients were diagnosed by a clinical psychologist or psychiatrist before being recruited into the study. See Table S1 for an additional summary of patient characteristics. Whilst the primary focus of the study was to examine face pareidolia in healthy adults, our second aim was to determine whether there were any differences in the processing of face pareidolia under CFS conditions in individuals with schizophrenia. Thus, for valid direct group comparisons, we used only a subset of our healthy adult sample to obtain two groups of 17 participants matched on age (patients $M = 53.50$, $SD = 7.90$; control $M = 50.20$, $SD = 12.10$; $t(32) = 0.94$, $p = .355$, $BF_{10} = .462$;) and premorbid intelligence (NART; Nelson & Willison, 1991; patients $M = 106.00$, $SD = 8.95$; control $M = 106.00$, $SD = 10.5$; $t(32) = 0.16$, $p = .875$, $BF_{10} = .332$).

Target stimuli

We presented stimuli previously selected and verified in related research (see Figure 1 for examples; original stimulus set also available on the Open Science Framework https://osf.io/9g4rz). In total, we presented a stimulus set of 112 images. These comprised 56 colour images of natural examples of illusory faces in inanimate objects collected from the Internet. For each pareidolia image, a photograph of a similar object without an illusory face was sourced and cropped to match the first image as closely as possible. This ensured we had a control (non-face) stimulus set that was matched in terms of object category and visual features as much as possible. These stimuli were presented either in the upright or inverted orientation depending on trial type.

b-CFS Approach

Given the current debate surrounding b-CFS and its ability to provide evidence for unconscious processes, we paid close attention to addressing the three criteria set out by Moors et al. (2019) in our methodology. First, we ensured our stimulus conditions were matched as best as possible for low-level visual features. Previous research using GIST and Graph-Based Visual Saliency modelling of these stimuli has shown that illusory face stimuli are on average far less similar in visual properties to each other than to their matched non-face objects (Wardle et al., 2020). Second, we attempt to replicate a reliable b-CFS finding of face prioritization, using different stimuli. Third, we sought the most parsimonious explanation of our data.

CFS Set-up

Participants viewed dichoptic displays on a Samsung SynchMaster SA950 HD LED monitor (60 × 34 cm, 100 Hz), through a mirror stereoscope while their head was stabilized in a chin rest 70 cm from the screen. Two red frames (12° × 12°) were displayed side by side on the screen, separated by 8 degrees of visual angle. This ensured that the left and right frames were only visible to the left and right eye, respectively. Fusion contours (random noise pixels; width 0.5°) were also presented within each of the frames to facilitate binocular fusion. Prior to running the experiment, we ensured that participants perceived a single fused frame when viewing the screen binocularly and that only one frame could be seen when viewing the screen monocularly with each eye.

Participants were required to maintain fixation of a black point (0.2°) in the centre of the fused frame for the duration of the experiment. On any given trial, either a pareidolia or control stimulus (3° × 3°) appeared on a grey background at an eccentricity of 1 degree of visual angle in the upright or inverted orientation. In total, participants were presented with 448 trials; 56 pareidolia images and 56 control images presented four times each, twice in the upright orientation and twice inverted. All target stimuli were presented to participants' non-dominant eye, confirmed using the near convergence test (Rice et al., 2008) in order to prolonged suppression and therefore optimized the detection of group differences.

Procedure

Trials began with the presentation of the two red frames and fusion contours and a central fixation point (see Figure 1). After 100 ms, a set of colourful, high-contrast and contour-rich masks (9.2°) were presented to the dominant eye, updating at 10 Hz. A target stimulus was simultaneously presented to the non-dominant eye, ramping up linearly in stimulus contrast from 0 to 100% over 100 ms. The target appeared in one of four quadrant locations within the fused frame. Target location was counterbalanced across conditions. The mask contrast was ramped down after 8 s from 100% to 0% over a 2000-ms period.

Participants were required to make a keyboard response with the arrow keys to indicate whether the target appeared to the left or right of fixation as soon as any part of it became visible. Participants were not asked to make any judgements about the stimulus and were naive to the task manipulations. Suppression times were recorded as the time taken for participants to localize the target stimulus from its onset. Participants were given a 2- to 5-minute break half-way through the experiment which lasted approximately 15 min in total.

RESULTS

Suppression times were recorded as the time it took for participants to press a button to indicate the correct location of the presented stimulus. Analyses only included data from trials in which participants accurately detected the target during CFS (i.e., whilst the mask and target stimulus were being simultaneously presented to participants). As such, trials were removed if participants: (1) indicated the incorrect target location; (2) responded prematurely, within 200 ms of the target's presentation; or (3) responded after the mask stimulus was ramped down. Mean suppression times were log-transformed ($\log_{10}$) to account for positively skewed reaction time distributions (Heyman & Moors, 2014). Untransformed data were used for the reporting of descriptive statistics and data visualization in order to facilitate an intuitive interpretation (see Table 1 and Figure 2).

Mean accuracy for localizing the masked target stimuli was on average 97.7% (*SD* = 2.3%) across the full sample of healthy participants (*n* = 24). For the secondary analysis involving patients with schizophrenia (*n* = 17) and a subset of this sample of healthy controls (*n* = 17), the proportion of valid trials did not significantly differ across groups (HC: *n* = 17; *M* = 98.3%, SD = 1.46%; SZ: *n* = 17; *M* = 97.5%, SD = 2.70%; $t(32) = 1.06$, $p = .298$, $BF_{10} = .506$). Moreover, accuracy was consistent across conditions across the full sample (upright face pareidolia: *M* = 97.7%, *SD* = 2.99%; inverted face pareidolia: *M* = 97.9%, *SD* = 2.41%; upright non-face: *M* = 97.5%, *SD* = 2.76%; inverted non-face: *M* = 97.7%, *SD* = 2.33%).

Do face pareidolia stimuli gain privileged access to visual awareness?

To analyse log-transformed suppression times in our full sample of healthy adults (*n* = 24), a two-way repeated measures ANOVA was used with factors: stimulus type (face pareidolia, non-face) and stimulus orientation (upright, inverted). This analysis revealed a significant main effect of stimulus type with participants being faster to localize objects that induce illusory face perception compared to objects that

TABLE 1 Descriptive statistics for untransformed suppression times by sample and condition

	Face pareidolia		Non-face	
	Upright	Inverted	Upright	Inverted
Healthy adults (*n* = 24)	2816 (1144)	2939 (1207)	3190 (1347)	3218 (1315)
Schizophrenia (*n* = 17)	2705 (832)	2737 (896)	3057 (794)	3184 (995)
Healthy controls (*n* = 17)	2828 (1038)	2927 (1090)	3200 (1252)	3211 (1212)

Note: Descriptive statistics are reported in the form of *M* (*SD*). Suppression times are reported in milliseconds.

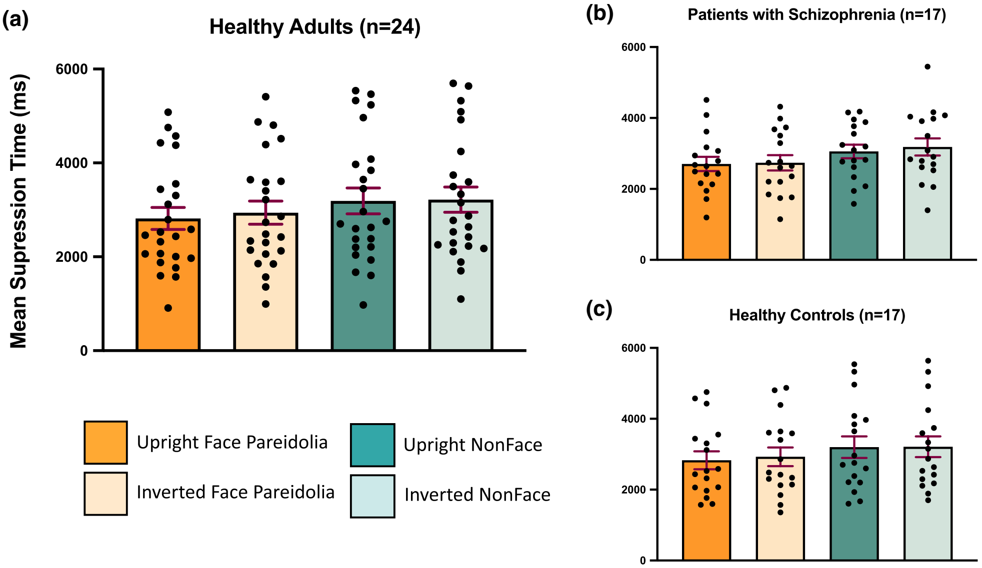

FIGURE 2 Mean suppression times in milliseconds (ms) by condition for (a) the full sample of healthy adults (*n* = 24); (b) individuals with schizophrenia (*n* = 17); and (c) the age and IQ matched sample of healthy controls (*n* = 17). Error bars represent the standard error of the mean

do not ($F(23) = 92.42$, $p < .001$, $\eta^2 = .015$). We also found evidence for a main effect of orientation in which participants were faster to detect stimuli when the object was presented in an upright rather than an inverted orientation ($F(23) = 6.95$, $p = .015$, $\eta^2 = .001$). No evidence for a stimulus type by orientation interaction was found ($F(23) = 1.08$, $p = .309$, $\eta^2 < .001$).

Are suppression times associated with face pareidolia stimuli altered in schizophrenia?

To compare our patient sample with an age- and IQ-matched subset of our healthy adult sample ($n = 17$), we conducted a three-way mixed effects ANOVA with factors: group (patients, controls), stimulus type (face pareidolia, non-face) and stimulus orientation (upright, inverted). Our analysis revealed a significant main effect of stimulus type, characterized by shorter suppression times for objects inducing illusory face perception ($F(32) = 118.93$, $p < .001$, $\eta^2 = .033$). With this analysis, no evidence for a main effect of stimulus orientation was found ($F(32) = 3.26$, $p = .081$, $\eta^2 = .001$) and no interaction effects were apparent (all ps > .341). Importantly, our results also provided no evidence for a main effect of group ($F(32) = 0.035$, $p = .852$, $\eta^2 = .001$). This suggests that, at least in our sample, the rapid preconscious processes of face perception that underlie face pareidolia are intact in patients with schizophrenia.

In order to confirm that patients exhibited the same pattern of suppression times as healthy adults, we analysed the schizophrenia group data separately using the same repeated measures ANOVA structure used for the analysis of healthy adults. This revealed that patients also exhibited the same main effect of stimulus type, with significantly shorter suppression times for objects comprising illusory faces compared to non-face objects ($F(16) =65.05$, $p <.001$, $\eta^2 =.051$).

DISCUSSION

The primary aim of this study was to test whether the human visual system prioritizes the early detection of objects that induce face pareidolia. Using b-CFS as a means to probe early preconscious stages of visual processing, we examined whether objects inducing face pareidolia gain privileged access to conscious awareness over other objects that do not induce illusory face percepts. Our results showed that face pareidolia stimuli are released from CFS suppression earlier than other stimuli matched for object content, suggesting the visual system does prioritize the rapid detection of illusory faces.

Our finding that face pareidolia stimuli receive privileged access to conscious awareness is consistent with evidence suggesting that early stages of face processing are broadly tuned and prone to error (Keys et al., 2021; Taubert et al., 2019; Wardle et al., 2020). In particular, it has been proposed that an ancient subcortical face detection mechanism (Johnson, 2005; Senju & Johnson, 2009; Stein et al., 2011; Tsuchiya & Koch, 2005) which operates, reflexively and outside of conscious awareness, has evolved to favour the fast response to faces at the potential cost of detecting 'false positives' (Taubert et al., 2018, 2019; Wardle et al., 2020). Converging evidence supports a rapid subcortical face detection mechanism (Johnson, 2005; McFadyen et al., 2017, 2020; Morris et al., 1999; Senju & Johnson, 2009). This includes earlier b-CFS research that has shown images of real faces to gain privileged access to visual awareness over images of inanimate objects (Caruana et al., 2019; Jiang et al., 2007; Stein et al., 2016). However, it is important to note that the effects sizes for stimulus type observed in the current study for object-matched face pareidolia and non-face stimuli are markedly more modest than those observed in studies comparing true face stimuli with a single category of objects (e.g., chairs; Caruana et al., 2019). This is unsurprising given the high degree of variability within each stimulus condition (i.e., many different object types) and the high degree of visual similarity across stimulus conditions (i.e., objects matched for object type and low-level visual features) in the current study.

Nevertheless, in the current study, we show that pareidolia faces may be treated in a similar way to real faces by our 'hard-wired' face detection mechanism to facilitate their rapid detection. Future work including direct comparisons between real and illusory face stimuli under b-CFS would be useful in characterizing the extent to which these stimuli are prioritized in the same way. However, the practical challenges of matching for low-level visual properties between stimulus conditions would be far from trivial. In the current study, we ensured that our conditions were visually matched as best as possible and that visual variance was much higher within, rather than across, stimulus conditions, allowing us to rule out an explanation of suppression time differences based on differences in image statistics (e.g., colour, orientation and luminance distributions) between pareidolia and non-face stimuli. Nonetheless, some differences in visual information such as the high-contrast shapes corresponding to the approximate location of the 'eyes' and 'mouth' (Stein & Sterzer, 2012; Yang et al., 2007) were likely to be driving the effect. In a recent study by Wardle et al. (2020), it was shown that a GIST visual feature model was capable of distinguishing features of illusory faces. Research in non-human primates using the same stimuli also showed that the fixation patterns that immediately follow an automatic orienting response are concentrated on the high-contrast 'mouth and eye' regions (Taubert et al., 2017). This suggests that a rapid face detection mechanism may be sensitive to coarse low-level visual features but may also be tolerant to substantial visual variance in the definition of facial features (McFadyen et al., 2020; Stein & Sterzer, 2012; Taubert et al., 2018, 2019; Wardle et al., 2020).

In addition to the above findings, our study explored whether differences in face pareidolia processing are evident in individuals diagnosed with schizophrenia. Our motivation was based on suggestions of a link between hallucination proneness and a tendency to report face pareidolia, which has primarily been documented with another condition associated with hallucination proneness—Lewy Body Dementia (Uchiyama et al., 2012; Yokoi et al., 2014). In a group of participants diagnosed with schizophrenia—a condition associated with an 80% prevalence of hallucinations (Lim et al., 2016)—we ran the same b-CFS experiment and found that pareidolia faces were detected faster than object-matched control stimuli. Importantly, we found no evidence for any difference between groups. Critically, the b-CFS paradigm eliminates the influence of cognitive biases on reporting pareidolia percepts. Namely, participants are asked to simply localize the stimulus, but are not required to interrogate their percept. As such, our results provide no evidence for the proposed link between a proneness for hallucinations and face pareidolia in schizophrenia, at least at the earliest stages of visual processing. Instead, our findings suggest that individual differences in face pareidolia may be due to cognitive biases rather than low-level perceptual differences. This is also consistent with other evidence suggesting that early stages in the visual processing of facial information (e.g., gaze and emotion expression) are largely intact in schizophrenia and that a number of perceptual biases reported in the literature are most likely to be cognitive in nature (Caruana & Seymour, 2021; Caruana et al., 2019; Kaliuzhna et al., 2019, 2020; Kring et al., 2014; Palmer et al., 2018a, 2018b; Seymour et al., 2016, 2017).

The overall absence in our data of face inversion interaction effects—that is, larger effects of orientation for pareidolia than non-face objects (Jiang et al., 2007)—across all analyses and participant groups, might suggest that the face inversion effect for pareidolia stimuli is not as strong as those observed for real faces. This is not altogether surprising given the high degree of similarity between matched object images across our stimulus conditions and the fact that inversion effects observed under CFS are not unique to faces, but are also observed in varying degrees for human bodies without faces (Stein et al., 2012) and in particular inanimate objects (Stein et al., 2016). While our exploratory analysis found no main effect of orientation in either group, despite it being observed in our analysis in healthy participants, this could be attributed, in part, to the fact that the mean age of participants used in this secondary analysis was significantly older than the first. Given that face processing ability as well as more general hierarchical visual processing is known to decline across the lifespan (Mondloch et al., 2003; Staudinger et al., 2011), future work to examine the influence of age on face pareidolia perception, inversion effects and other forms of holistic processing under CFS would be fruitful.

In summary, our findings lend support for the idea that faces are special and that a broadly tuned mechanism operating at the earliest stages of face processing may facilitate the detection of illusory faces in inanimate objects. Whilst it should be noted that our study reports differences in suppression times as evidence for differences in the preconscious processing that our stimuli receive while being suppressed, it is possible such differences reflect disparities at very early *post*-conscious stages of processing (Hedger et al., 2016; Moors et al., 2019; Stein & Peelen, 2021). Importantly, this interpretation does not detract from our conclusion that objects inducing face pareidolia gain an advantage over other objects in terms of eliciting a behavioural response. Such findings are similar to results previously observed with real faces, suggesting the advantage may be served by a shared mechanism. Indeed, our findings are consistent with the idea that face pareidolia engages a rapid and highly sensitive face detection system and rules out the possibility that later cognitive reinterpretations of the visual stimulus underlie face pareidolia perception. Individual cognitive biases may, however, explain a tendency for some people to report seeing faces more often in standard face pareidolia tasks where participants are asked to indicate whether or not they see a face.

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CONFLICT OF INTEREST

None of the authors of this manuscript had any competing interests.

AUTHOR CONTRIBUTION

Nathan Caruana: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Funding acquisition (equal); Investigation (equal); Methodology (equal); Project administration (equal); Visualization (equal); Writing – original draft (equal); Writing – review & editing (equal). **Kiley Seymour:** Conceptualization (equal); Data curation (equal); Formal analysis (equal); Funding acquisition (equal); Investigation (equal); Methodology (equal); Supervision (equal); Writing – review & editing (equal).

DATA AVAILABILITY STATEMENT

Associated research data are available.

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REFERENCES

Akdeniz, G., Vural, G., Gumusyayla, S., Bektas, H., & Deniz, O. (2020, March 31). Event-related potentials elicited by face and face pareidolia in Parkinson's disease. *Parkinson's Disease*, *2020*, 1–10. https://doi.org/10.1155/2020/3107185

Alais, D., Xu, Y., Wardle, S. G., & Taubert, J. (2021). A shared mechanism for facial expression in human faces and face pareidolia. *Proceedings of the Royal Society B: Biological Sciences*, *288*(1954), 20210966. https://doi.org/10.1098/rspb.2021.0966

Baethge, C., Baldessarini, R. J., Freudenthal, K., Streeruwitz, A., Bauer, M., & Bschor, T. (2005). Hallucinations in bipolar disorder: Characteristics and comparison to unipolar depression and schizophrenia. *Bipolar Disorders*, *7*(2), 136–145. https://doi.org/10.1111/j.1399-5618.2004.00175.x

Bracha, H. S., Wolkowitz, O. M., Lohr, J. B., Karson, C. N., & Bigelow, L. B. (1989). High prevalence of visual hallucinations in research subjects with chronic schizophrenia. *American Journal of Psychiatry*, *146*(4), 526–528. Scopus. https://doi.org/10.1176/ajp.146.4.526

Caruana, N., Inkley, C., Zein, M. E., & Seymour, K. (2019). No influence of eye gaze on emotional face processing in the absence of conscious awareness. *Scientific Reports*, *9*(1), 16198. https://doi.org/10.1038/s41598-019-52728-y

Caruana, N., & Seymour, K. (2021). Bottom-up processing of fearful and angry facial expressions is intact in schizophrenia. *Cognitive Neuropsychiatry*, *26*(3), 183–198. https://doi.org/10.1080/13546805.2021.1902794

Caruana, N., Stein, T., Watson, T., Williams, N., & Seymour, K. (2019). Intact prioritisation of unconscious face processing in schizophrenia. *Cognitive Neuropsychiatry*, *24*(2), 135–151. https://doi.org/10.1080/13546805.2019.1590189

David, C. N., Greenstein, D., Clasen, L., Gochman, P., Miller, R., Tossell, J. W., Mattai, A. A., Gogtay, N., & Rapoport, J. L. (2011). Childhood onset schizophrenia: High rate of visual hallucinations. *Journal of the American Academy of Child and Adolescent Psychiatry*, *50*(7), 681–686.e3. https://doi.org/10.1016/j.jaac.2011.03.020

Delespaul, P., deVries, M., & van Os, J. (2002). Determinants of occurrence and recovery from hallucinations in daily life. *Social Psychiatry and Psychiatric Epidemiology*, *37*(3), 97–104. https://doi.org/10.1007/s001270200000

Dudley, R., Aynsworth, C., Cheetham, R., McCarthy-Jones, S., & Collerton, D. (2018). Prevalence and characteristics of multimodal hallucinations in people with psychosis who experience visual hallucinations. *Psychiatry Research*, *269*, 25–30. https://doi.org/10.1016/j.psychres.2018.08.032

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (2002). *Structured clinical interview for DSM-IV-TR Axis I disorders, research version, patient edition with psychotic screen (SCID-I/P W/ PSY SCREEN)*. Biometrics Research, New York State Psychiatric Institute.

Gauntlett-Gilbert, J., & Kuipers, E. (2003). Phenomenology of visual hallucinations in psychiatric conditions. *The Journal of Nervous and Mental Disease*, *191*(3), 203–205. https://doi.org/10.1097/01.NMD.0000055084.01402.02

Hadjikhani, N., Kveraga, K., Naik, P., & Ahlfors, S. P. (2009). Early (M170) activation of face-specific cortex by face-like objects. *NeuroReport*, *20*(4), 403–407. https://doi.org/10.1097/WNR.0b013e328325a8e1

Harries, M. H., & Perrett, D. I. (1991). Visual processing of faces in temporal cortex: Physiological evidence for a modular organization and possible anatomical correlates. *Journal of Cognitive Neuroscience*, *3*(1), 9–24. https://doi.org/10.1162/jocn.1991.3.1.9

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, *51*(1), 59–67. https://doi.org/10.1016/S0006-3223(01)01330-0

Haxby, J. V., Ungerleider, L. G., Clark, V. P., Schouten, J. L., Hoffman, E. A., & Martin, A. (1999). The effect of face inversion on activity in human neural systems for face and object perception. *Neuron*, *22*(1), 189–199. https://doi.org/10.1016/S0896-6273(00)80690-X

Hedger, N., Gray, K. L. H., Garner, M., & Adams, W. J. (2016). Are visual threats prioritized without awareness? A critical review and meta-analysis involving 3 behavioral paradigms and 2696 observers. *Psychological Bulletin*, *142*(9), 934–968. https://doi.org/10.1037/bul0000054

Heyman, T., & Moors, P. (2014). Frequent words do not break continuous flash suppression differently from infrequent or nonexistent words: Implications for semantic processing of words in the absence of awareness. *PLoS One*, *9*(8), e104719. https://doi.org/10.1371/journal.pone.0104719

Jiang, Y., Costello, P., & He, S. (2007). Processing of invisible stimuli: Advantage of upright faces and recognizable words in overcoming interocular suppression. *Psychological Science*, *18*(4), 349–355. https://doi.org/10.1111/j.1467-9280.2007.01902.x

Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews Neuroscience*, *6*(10), 766–774. https://doi.org/10.1038/nrn1766

Kaliuzhna, M., Stein, T., Rusch, T., Sekutowicz, M., Sterzer, P., & Seymour, K. J. (2019). No evidence for abnormal priors in early vision in schizophrenia. *Schizophrenia Research*, *210*, 245–254. https://doi.org/10.1016/j.schres.2018.12.027

Kaliuzhna, M., Stein, T., Sterzer, P., & Seymour, K. J. (2020). Examining motion speed processing in schizophrenia using the flash lag illusion. *Schizophrenia Research: Cognition*, *19*, 100165. https://doi.org/10.1016/j.scog.2019.100165

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, *17*(11), 4302–4311. https://doi.org/10.1523/JNEUROSCI.17-11-04302.1997

Keys, R. T., Taubert, J., & Wardle, S. G. (2021). A visual search advantage for illusory faces in objects. *Attention, Perception, and Psychophysics*, *83*(5), 1942–1953. https://doi.org/10.3758/s13414-021-02267-4

Kring, A. M., Siegel, E. H., & Barrett, L. F. (2014). Unseen affective faces influence person perception judgments in schizophrenia. *Clinical Psychological Science: A Journal of the Association for Psychological Science*, *2*(4), 443–454. https://doi.org/10.1177/2167702614536161

Lim, A., Hoek, H. W., Deen, M. L., Blom, J. D., Bruggeman, R., Cahn, W., de Haan, L., Kahn, R. S., Meijer, C. J., Myin-Germeys, I., van Os, J., & Wiersma, D. (2016). Prevalence and classification of hallucinations in multiple sensory modalities in schizophrenia spectrum disorders. *Schizophrenia Research*, *176*(2–3), 493–499. https://doi.org/10.1016/j.schres.2016.06.010

McFadyen, J., Dolan, R. J., & Garrido, M. I. (2020). The influence of subcortical shortcuts on disordered sensory and cognitive processing. *Nature Reviews Neuroscience*, *21*(5), 264–276. https://doi.org/10.1038/s41583-020-0287-1

McFadyen, J., Mermillod, M., Mattingley, J. B., Halász, V., & Garrido, M. I. (2017). A rapid subcortical amygdala route for faces irrespective of spatial frequency and emotion. *Journal of Neuroscience*, *37*(14), 3864–3874. https://doi.org/10.1523/JNEUROSCI.3525-16.2017

Mondloch, C. J., Geldart, S., Maurer, D., & Grand, R. L. (2003). Developmental changes in face processing skills. *Journal of Experimental Child Psychology*, *86*(1), 67–84. https://doi.org/10.1016/S0022-0965(03)00102-4

Moors, P., Gayet, S., Hedger, N., Stein, T., Sterzer, P., van Ee, R., Wagemans, J., & Hesselmann, G. (2019). Three criteria for evaluating high-level processing in continuous flash suppression. *Trends in Cognitive Sciences*, *23*(4), 267–269. https://doi.org/10.1016/j.tics.2019.01.008

Morris, J. S., Öhman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating "unseen" fear. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(4), 1680–1685. https://doi.org/10.1073/pnas.96.4.1680

Mueser, K. T., Bellack, A. S., & Brady, E. U. (1990). Hallucinations in schizophrenia. *Acta Psychiatrica Scandinavica*, *82*(1), 26–29. https://doi.org/10.1111/j.1600-0447.1990.tb01350.x

Nelson, H., & Willison, J. (1991). *The revised national adult reading test (NART) – Test manual* (2nd ed.). NFER-Nelson.

Öhman, A. (2009). Of snakes and faces: An evolutionary perspective on the psychology of fear. *Scandinavian Journal of Psychology*, *50*(6), 543–552. https://doi.org/10.1111/j.1467-9450.2009.00784.x

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology*, *80*(3), 381–396. https://doi.org/10.1037/0022-3514.80.3.381

Palmer, C. J., Caruana, N., Clifford, C. W. G., & Seymour, K. J. (2018a). Adaptive sensory coding of gaze direction in schizophrenia. *Royal Society Open Science*, *5*(12), 180886. https://doi.org/10.1098/rsos.180886

Palmer, C. J., Caruana, N., Clifford, C. W. G., & Seymour, K. J. (2018b). Perceptual integration of head and eye cues to gaze direction in schizophrenia. *Royal Society Open Science*, *5*(12), 180885. https://doi.org/10.1098/rsos.180885

Palmer, C. J., & Clifford, C. W. G. (2020). Face pareidolia recruits mechanisms for detecting human social attention. *Psychological Science*, *31*(8), 1001–1012. https://doi.org/10.1177/0956797620924814

Partos, T. R., Cropper, S. J., & Rawlings, D. (2016). You Don't See What I See: Individual differences in the perception of meaning from visual stimuli. *PLoS One*, *11*(3), e0150615. https://doi.org/10.1371/journal.pone.0150615

Pascalis, O., & Kelly, D. J. (2009). The origins of face processing in humans: phylogeny and ontogeny. *Perspectives on Psychological Science*, *4*(2), 200–209. https://doi.org/10.1111/j.1745-6924.2009.01119.x

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., Jeeves, M. A., & Weiskrantz, L. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London. Series B. Biological Sciences*, *223*(1232), 293–317. https://doi.org/10.1098/rspb.1985.0003

Rice, M. L., Leske, D. A., Smestad, C. E., & Holmes, J. M. (2008). Results of ocular dominance testing depend on assessment method. *Journal of AAPOS: The Official Publication of the American Association for Pediatric Ophthalmology and Strabismus*, *12*(4), 365–369. https://doi.org/10.1016/j.jaapos.2008.01.017

Sander, D., Grandjean, D., Kaiser, S., Wehrle, T., & Scherer, K. R. (2007). Interaction effects of perceived gaze direction and dynamic facial expression: Evidence for appraisal theories of emotion. *European Journal of Cognitive Psychology*, *19*(3), 470–480. https://doi.org/10.1080/09541440600757426

Senju, A., & Johnson, M. H. (2009). The eye contact effect: Mechanisms and development. *Trends in Cognitive Sciences*, *13*(3), 127–134. https://doi.org/10.1016/j.tics.2008.11.009

Seymour, K., Rhodes, G., McGuire, J., Williams, N., Jeffery, L., & Langdon, R. (2017). Assessing early processing of eye gaze in schizophrenia: Measuring the cone of direct gaze and reflexive orienting of attention. *Cognitive Neuropsychiatry*, *22*(2), 122–136. https://doi.org/10.1080/13546805.2017.1285755

Seymour, K., Rhodes, G., Stein, T., & Langdon, R. (2016). Intact unconscious processing of eye contact in schizophrenia. *Schizophrenia Research: Cognition*, *3*, 15–19. https://doi.org/10.1016/j.scog.2015.11.001

Smailes, D., Burdis, E., Gregoriou, C., Fenton, B., & Dudley, R. (2020). Pareidolia-proneness, reality discrimination errors, and visual hallucination-like experiences in a non-clinical sample. *Cognitive Neuropsychiatry*, *25*(2), 113–125. https://doi.org/10.1080/13546805.2019.1700789

Staudinger, M. R., Fink, G. R., Mackay, C. E., & Lux, S. (2011). Gestalt perception and the decline of global precedence in older subjects. *Cortex*, *47*(7), 854–862. https://doi.org/10.1016/j.cortex.2010.08.001

Stein, T., & Peelen, M. V. (2021). Dissociating conscious and unconscious influences on visual detection effects. *Nature Human Behaviour*, *5*(5), 612–624. https://doi.org/10.1038/s41562-020-01004-5

Stein, T., Peelen, M. V., & Sterzer, P. (2011). Adults' awareness of faces follows newborns' looking preferences. *PLoS One*, *6*(12), e29361. https://doi.org/10.1371/journal.pone.0029361

Stein, T., Reeder, R. R., & Peelen, M. V. (2016). Privileged access to awareness for faces and objects of expertise. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(6), 788–798. https://doi.org/10.1037/xhp0000188

Stein, T., & Sterzer, P. (2012). Not just another face in the crowd: Detecting emotional schematic faces during continuous flash suppression. *Emotion*, *12*(5), 988–996. https://doi.org/10.1037/a0026944

Stein, T., Sterzer, P., & Peelen, M. V. (2012). Privileged detection of conspecifics: Evidence from inversion effects during continuous flash suppression. *Cognition*, *125*(1), 64–79. https://doi.org/10.1016/j.cognition.2012.06.005

Takahashi, K., & Watanabe, K. (2013). Gaze cueing by pareidolia faces. *I-perception*, *4*(8), 490–492. https://doi.org/10.1068/i0617sas

Taubert, J., Flessert, M., Wardle, S. G., Basile, B. M., Murphy, A. P., Murray, E. A., & Ungerleider, L. G. (2018). Amygdala lesions eliminate viewing preferences for faces in rhesus monkeys. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(31), 8043–8048. https://doi.org/10.1073/pnas.1807245115

Taubert, J., Wardle, S. G., Flessert, M., Leopold, D. A., & Ungerleider, L. G. (2017). Face pareidolia in the rhesus monkey. *Current Biology*, *27*(16), 2505–2509.e2. https://doi.org/10.1016/j.cub.2017.06.075

Taubert, J., Wardle, S. G., Kumar, S., James, C., Koele, E., Messinger, A., & Ungerledier, L. G. (2019). How does the macaque brain characterize face pareidolia? *Journal of Vision*, *19*(10), 260. https://doi.org/10.1167/19.10.260

Tsuchiya, N., & Koch, C. (2005). Continuous flash suppression reduces negative afterimages. *Nature Neuroscience*, *8*(8), 1096–1101. https://doi.org/10.1038/nn1500

Uchiyama, M., Nishio, Y., Yokoi, K., Hirayama, K., Imamura, T., Shimomura, T., & Mori, E. (2012). Pareidolias: Complex visual illusions in dementia with Lewy bodies. *Brain: A. Journal of Neurology*, *135*(Pt 8), 2458–2469. https://doi.org/10.1093/brain/aws126

Wardle, S. G., Seymour, K., & Taubert, J. (2017). Characterizing the response to face pareidolia in human category-selective visual cortex. BioRxiv, 233387, https://doi.org/10.1101/233387

Wardle, S., Seymour, K., & Taubert, J. (2017). Decoding face pareidolia in the human brain with fMRI. *Journal of Vision*, *17*(10), 294. https://doi.org/10.1167/17.10.294

Wardle, S. G., Taubert, J., Teichmann, L., & Baker, C. I. (2020). Rapid and dynamic processing of face pareidolia in the human brain. *Nature Communications*, *11*(1), 4518. https://doi.org/10.1038/s41467-020-18325-8

Yang, E., Zald, D. H., & Blake, R. (2007). Fearful expressions gain preferential access to awareness during continuous flash suppression. *Emotion*, *7*(4), 882–886. https://doi.org/10.1037/1528-3542.7.4.882

Yokoi, K., Nishio, Y., Uchiyama, M., Shimomura, T., Iizuka, O., & Mori, E. (2014). Hallucinators find meaning in noises: Pareidolic illusions in dementia with Lewy bodies. *Neuropsychologia*, *56*, 245–254. https://doi.org/10.1016/j.neuropsychologia.2014.01.017

Zhou, L.-F., & Meng, M. (2020). Do you see the "face"? Individual differences in face pareidolia. *Journal of Pacific Rim Psychology*, *14*, https://doi.org/10.1017/prp.2019.27

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