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Do you see the "face"? Individual differences in face pareidolia

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Abstract

People tend to see faces from non-face objects or meaningless patterns. Such illusory face perception is called face pareidolia. Previous studies have revealed an interesting fact that there are huge individual differences in face pareidolia experience among the population. Here, we review previous findings on individual differences in face pareidolia experience from four categories: sex differences, developmental factors, personality traits and neurodevelopmental factors. We further discuss underlying cognitive or neural mechanisms to explain why some perceive the objects as faces while others do not. The individual differences in face pareidolia could not only offer scientific insights on how the brain works to process face information, but also suggest potential clinical applications.

Have you ever seen a face in mountains, clouds or everyday objects? If you have, you experienced face pareidolia, a psychological phenomenon of seeing faces in non-face objects or patterns. As a common form of apohenia, the human tendency to perceive meaningful patterns from random data, face pareidolia reveals a particular preference for faces when observing ambiguous stimuli in the real world. Some noted examples of face pareidolia include a face on Mars, the Virgin Mary in a piece of toast, Mother Teresa in a cinnamon bun, and the face of testicular pain (Roberts & Touma, 2011).

Recently, studies have shown that face pareidolia is not restricted to human cognition. Non-human primates are found to have a strong viewing preference toward objects containing pareidolia face, suggesting that they also perceive face pareidolia from inanimate objects. Monkeys would fixate on illusory facial features (i.e., eyes and mouth) in a consistent pattern with real-face photographs, but in a distinct fixation pattern with matching non-face objects. These results suggest the existence of a broadly tuned face-detection system shared across species (Taubert, Wardle, Flessert, Leopold, & Ungerleider, 2017).

Then, what exactly happens in the brain when experiencing face pareidolia? Using magnetoencephalography (MEG), researchers found that when non-face objects are perceived as faces, they would evoke early (~170 ms) activation of face fusiform area (FFA), in a similar way to face processing (Hadjikhani, Kveraga, Naik, & Ahlfors, 2009). In another functional magnetic resonance imaging (fMRI) study, researchers discovered that activity in the FFA is strongly modulated by the perception of a pareidolia face, with high tolerance to visual feature variations at the image level (Wardle, Seymour, & Taubert, 2017). Furthermore, bottom-up and top-down factors have been proposed to contribute to pareidolia face processing (Liu et al., 2014; Meng, Cherian, Singal, & Sinha, 2012; Nihei, Minami, & Nakauchi, 2018; Paras & Webster, 2013).

However, while human brains seem to be hard-wired for face detection, the subjective face pareidolia experience varies from individual to individual. Some claim to see faces everywhere, while others find it difficult to detect faces in unusual locations. Here we will first review and categorize previous findings on individual differences in face pareidolia experience. Then we will discuss how the individual differences can be understood within a theoretical framework and what neural mechanisms may underlie the individual differences. Finally, regarding its variation among populations, how we can benefit from the research of face pareidolia will also be discussed.

Previous findings of individual differences in face pareidolia

We will first give a mini-review about previous findings of individual differences in face pareidolia experience. Based on the subject population used for comparison in the studies, we sorted the findings into four major categories, including sex (male vs. female), developmental factors (development during infancy period), personality traits (high vs. low trait population), and neurodevelopmental factors (clinical population vs. typical-development population). Note that the division here is not exclusive. We attempted to clearly present the pareidolia

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findings in a way that could speak to other established findings in broader fields and shed light on understanding relevant perceptual processes.

Sex differences in face pareidolia experience

Mounting evidence has shown a female advantage in face perception and cognition (Lewin & Herlitz, 2002; Lewin, Wolgers, & Herlitz, 2001; Sommer, Hildebrandt, Kunina-Habenicht, Schacht, & Wilhelm, 2013). For instance, women outperform men in typical face recognition tasks (old/new face judgment; Herlitz, Nilsson, & Bäckman, 1997), in face emotion recognition tasks (i.e., more accurate and sensitive in labeling facial expressions; Hampson, van Anders, & Mullin, 2006; Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005), as well as in face gender recognition tasks (Cellerino, Borghetti, & Sartucci, 2004; Sun, Gao, & Han, 2010). Especially, the female advantage in recognizing female faces (own-sex bias) was found for both women and girls irrespective of face ethnicity and age (Herlitz & Rehnman, 2008; Lewin & Herlitz, 2002; Rehnman & Herlitz, 2006).

To investigate whether there is a gender difference in face pareidolia experience, Pavlova, Scheffler, and Sokolov (2015) created a set of food-plate images that were composed of food ingredients (e.g., fruits, vegetables) and may resemble faces. They discovered a gender difference in the tendency to recognize a face in such Arcimboldo-style images (Pavlova et al., 2015). The results showed that adult women not only more readily report seeing a face (while men still see it as food composition), but also give more overall face responses, indicating the superiority of female brains in terms of face tuning. A later study reported that such gender specificity is subject to cultural modulation (Pavlova, Heiz, Sokolov, Fallgatter, & Barisnikov, 2018).

Proverbio and Galli (2016) explored the neural underpinnings of the sex difference using event-related potential (ERP) technique. The face-selective occipito/temporal N170 for face pareidolia is similar to that of faces, but does not show any sex differences. However, the vertex positive potential (VPP) recorded at frontal sites exhibited a sex difference when seeing face pareidolia. Specifically, for women, the VPP responses to pareidolia faces were of equal amplitude to those for faces; but for men, the VPP responses to pareidolia faces were of intermediate amplitude between those elicited by faces and objects. It has been speculated that VPP arose from the limbic system rather than face-selective regions (i.e., FFA), and might reflect the sexual differences in face relevance/salience encoding (Proverbio & Galli, 2016). Furthermore, source reconstruction analysis provided stronger evidence for sexual dimorphism in pareidolia face processing. In the female brain, activation of a wider range of brain areas involved in the affective processing of faces were observed, including right STS (BA22), posterior cingulate cortex (BA30), and orbitofrontal cortex (BA10). In comparison, in the male brain, pareidolia face perception was associated with the activation of occipital/parietal regions, together with a much smaller activation of the orbitofrontal cortex. These results suggested differential pareidolia face encoding between males and females, with the female brain engaging more in affective and social processing.

How can the sex difference in face pareidolia perception be related to previous findings in other face-related tasks? Why do females have an advantage in face-related cognition? Some researchers have found that from infancy period, girls start to show a stronger interest in faces than boys, by spending more time looking at faces (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). Adult women also have higher interest in social aspects of daily life than men (Su, Rounds, & Armstrong, 2009). It is possible that the female superiority in face-related cognition can be partially explained by a social involvement difference between females and males (Sommer et al., 2013). In addition, some neuroimaging findings revealed mirrored neural correlates of the female advantage in face processing. Using fMRI, researchers found that girls and women have larger FFAs compared to boys and men (Tahmasebi et al., 2012), and larger volumes of FFA activations have been associated with better performance in face recognition (Furl, Garrido, Dolan, Driver, & Duchaine, 2011; Golarai, Liberman, Yoon, & Grill-Spector, 2010). In general, face processing is believed to be right-hemisphere dominant while the processing of common objects is not. Interestingly, women are found to have a much lesser degree of lateralization than men for face coding and facial emotion processing (Bourne, 2005; Proverbio, Riva, Martin, & Zani, 2010; Rahman & Anchassi, 2012). The more bilateral distributed responses in females indicate greater access to mechanisms located in each hemisphere and thus interhemispheric facilitation for face recognition (Bourne, 2005). Further discussion about how to understand the sex difference in face pareidolia experience can be found in the next section.

Development of face pareidolia experience in infancy

It has been well established that newborns (<1 hour old) already show an innate viewing preference for protofacial stimuli, but then this preference declines after a few months (Johnson, Dziurawiec, Ellis, & Morton, 1991; Morton & Johnson, 1991). The face viewing preference will re-establish later in life, as a result from maturation of corresponding cortical areas. An interesting question is, however, when do infants start to perceive face pareidolia?

Kato and Mugitani (2015) used sound-mouth association to explore whether infants perceive face pareidolia from non-face objects. Some studies have reported that sound-mouth association is established in 8- to 12-month-olds, who show a viewing preference for the mouth area than the eye area during sound presentation (Lewkowicz & Hansen-Tift, 2012; Tenenbaum, Shah, Sobel, Malle, & Morgan, 2013). Kato and Mugitani (2015) found that after a pure tone display, infants 10 and 12 months of age prefer to look at the bottom blob of a four-blob contoured image, but not infants who are 8 months old. These results suggest that infants 8–10 months of age come to experience face pareidolia "knowing" in advance about the "mouth" in a diamond-shape object (Kato & Mugitani, 2015).

In another study, when using Arcimboldo images, researchers found that 7- and 8-month-old infants prefer to look at upright images than the inverted ones, but 5- and 6-month-old infants do not (Kobayashi et al., 2012). Their results indicate that from 7 to 8 months, infants can already perceive the upright Arcimboldo images as faces. The age difference for infants to experience face pareidolia from these two studies might be due to the stimuli used, with Arcimboldo images having much richer visual information than a four-blob image (Kato & Mugitani, 2015).

Taken together, these results showed that the perception of pareidolia faces develops at a very early stage of life (~8 months), and thus offer evidence to support the hypothsis that face pareidolia is associated with early development. Mounting evidence has validated the fast development of face processing in the very first months of life. For instance, between 3 and 7 months, infants begin to be able to robustly recognize upright faces better than inverted faces (Fagan, 1972), and categorize faces by gender (Cohen & Strauss, 1979) and

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by facial expressions (Ludemann & Nelson, 1988). Besides, it has been found that the brain activity in 6-month-old infants can already discriminate faces versus non-face objects during visual information processing. The P400 component at occipital electrodes shows shorter latency for faces than for familiar or unfamiliar objects (De Haan & Nelson, 1999). It seems that the development trajectory of pareidolia face perception closely follows the development of face recognition and other object categorization abilities. It is plausible that the functional specialization of the brain for face and object processing is the essential neural basis for illusory face perception to occur.

Personality traits influence face pareidolia experience

Would any special population be more likely to see pareidolia faces where no face actually exists? An intuitive speculation would be those with paranormal and religious beliefs. Believers around the world have posted online extensive lists where they see Jesus, from a cut-open orange to a crumpled sock, taken as a blessing for their ritual practices (Burns, 2011; Moore, 2012). A group of researchers tested the hypothesis in 2013 and found that strong believers in paranormal phenomena and religions are not only better at detecting pareidolia faces than skeptics and non-believers, but are also more prone to report false alarms in non-face pictures (Riekki, Lindeman, Aleneff, Halme, & Nuortimo, 2013). The results are consistent with earlier findings that paranormal believers incline to report meaningful patterns (i.e., face or word) out of meaningless inputs (Krummenacher, Mohr, Haker, & Brugger, 2010).

In addition, other researchers found that individuals with higher positive-psychotic personality traits are more likely to see complex meaning in noise patterns (Partos, Cropper, & Rawlings, 2016). The positive-psychotic subtype of schizotypy concerned with unusual experiences (e.g., hallucinations) has been found to be associated with personal well-being and creativity (Mohr & Claridge, 2015). Partos et al. (2016) further found that the bias to see things in pure noise is associated with reduced sensitivity to the real presence of a vague stimulus, indicating a faulty system in those with high positive schizotypy.

Epley, Akalis, Waytz, and Cacioppo (2008) investigated whether mood state (e.g., chronically lonely or induced to feel disconnected from the others) alters how people interpret inanimate objects. The results showed that social disconnection increases the tendency to anthropomorphize non-human gadgets and to detect human-like agents (e.g., a face) in ambiguous drawings (Epley et al., 2008). However, a follow-up study failed to replicate this finding (Sandstrom & Dunn, 2013).

What can the connection between face pareidolia and personality traits tell us? Is face pareidolia related to top-down influences from higher-level beliefs or knowledge? It has been proposed that face pareidolia requires a match between external visual input and internal face templates. Using fMRI, researchers found that when an illusory face was detected from pure noise images, it was associated with blood-oxygen-level-dependent (BOLD) imaging activity in the face-selective areas, including bilateral OFA and FFA (Liu et al., 2014; Zhang et al., 2008; but see Zimmermann, Stratil, Thome, Sommer, & Jansen, 2019). Further whole brain analysis revealed a distributed network extending from the ventral occipitotemporal cortex to the prefrontal cortex and sublobar regions, indicating the activation of the internal face templates and top-down modulation on the external input. From the individual differences' perspective, the balance between bottom-up and top-down processes may shift towards the top-down processes more in some individuals than others. One possible cause is that their bottom-up facial signals are weaker than others, as in the individuals with higher positive-psychotic personality traits. An alternative is that their top-down modulation (e.g., expectation to see faces) is stronger than others, as in those with paranormal and religious beliefs. It still needs further investigations about how exactly higher-level personality traits influence lower-level visual perception.

Pareidolia experience in patients with neurodevelopmental conditions

In this section, we will review articles about population differences in experiencing face pareidolia among typical developing populations and individuals with neurodevelopmental disorders. Over the last few years, researchers have tested patients with various disorders using pareidolia materials, and the results turn out to be in two divergent directions.

In 2012, a group of Japanese researchers developed the pareidolia test to try to establish a quantitative measure of pareidolia to discriminate between dementia with Lewy bodies (DLB) and Alzheimer's disease (Uchiyama et al., 2012). The occurrence of visual hallucination has been a diagnostic basis to differentiate the two. In particular, DLB patients may experience complex visual hallucinations (e.g., faces or bodies) more frequently than simple visual hallucination (e.g., flashes or dots; Mosimann et al., 2006). Uchiyama et al. (2012) found that patients with DLB reported much more pareidolia experience than those with Alzheimer's disease or controls, and the number of pareidolia responses was correlated with hallucination scores on the Neuropsychiatric Inventory. They argued that pareidolia shares phenomenological similarities and may reflect susceptibility to visual hallucinations. Later, Uchiyama et al. (2015) discovered that patients with Parkinson's disease (PD) without dementia also produced more pareidolia responses than the controls, and both pareidolia and visual hallucinations are associated with posterior cortical dysfunction. Furthermore, researchers found pareidolia experiences are more easily elicited in patients with idiopathic rapid eye movement (REM) sleep behavior disorder (iRBD). Interestingly, iRBD patients with pareidolia showed symptoms suggesting that they belong to a subgroup close to DLB (Sasai-Sakuma, Nishio, Yokoi, Mori, & Inoue, 2017). Högl commented their findings were "not only another fast and convenient test for neurodegeneration in iRBD, but also has the potential to indicate a more specific pathologic profile and clinical endpoint" (Högl, 2017).

By contrast, there are also cases in which face pareidolia experience was less frequently reported than the typically developing population. Autism spectrum disorder (ASD) children and teenagers have been found to have profound deficits in recognition of faces from face-like ambiguous stimuli; not only do they have higher thresholds for face recognition than typically developing controls (reporting negative responses on images that TD already report seeing a face), but they also make overall fewer face responses (Pavlova et al., 2017; Ryan, Stafford, & King, 2016). Similar results were also found for William syndrome (Pavlova, Heiz, Sokolov, & Barisnikov, 2016) and Down syndrome populations (Pavlova, Galli et al., 2018). However, the reasons behind reduced face pareidolia in ASD, William syndrome and Down syndrome might not be the same. Deficits in social interaction and communication have been characterized as a key symptom of ASD, which may be associated with their atypical face encoding processes. However, William syndrome individuals tend to have a

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Table 1. A summary of reviewed papers on individual differences in face pareidolia experience

Study	Participants' information				Materials	Main task
	Sample size	Population	Age	Sex (female/male)		
Pavlova et al. (2015)	$N = 64$	Healthy participants	Range 18–36 years	34/30	Face-n-Food images	Verbal self-report (describe what you saw)
Pavlova, Heiz et al. (2018)	$N = 62$	College students	24.5 ± 1.5 years	32/30	Face-n-Food images	Same as above
Proverbio and Galli (2016)	$N = 26$	College students	Range 19–29 years	13/13	Face-like object images	Animal detection task
Kato and Mugitani (2015)	$N = 46$	Infants	8- to 12-months-old		Images with four blobs and an outline	Free viewing
Kobayashi et al. (2012)	$N = 48$	Infants	5- to 8-months-old	26/22	Face-n-Food images	Preferential looking
Riekki et al. (2013)	$N = 47$	Healthy participants	Range 20–50 years	26/21	Photographs of artifact faces	Face detection (if yes, point to the "nose")
Krummenacher et al. (2010)	$N = 40$	Healthy participants	Range 20–39 years	0/40	Scrambled eye-nose-mouth configuration	Facial decision task
Partos et al. (2016)	$N = 197$	College students	Range 16–44 years	138/59	Noise images	Verbal self-report (describe loud what you saw)
Epley et al. (2008, Study 3)	$N = 57$	Undergraduates		44/13	Ambiguous drawing	Written self-report
Sandstrom and Dunn (2013)	$N = 81$	Undergraduates		58/23	Inkblot drawing	Verbal self-report (describe what you saw)
Uchiyama et al. (2012)	$N = 34$	Patients with probable DLB	81.0 ± 3.9 years	19/15	Senenary pictures containing animals, plants and objects	Point to and describe in as much detail as possible the objects shown in each picture
Uchiyama et al. (2015)	$N = 53$	PD patients without dementia	66.1 ± 0.9 years	31/22	Same as above	Same as above
Sasai-Sakuma et al. (2017)	$N = 202$	Patients with iRBD	66.8 ± 8.0 years	58/144	Same as above	Same as above
Pavlova et al. (2017)	$N = 16$	Children with ASD	14.1 ± 1.9 years	1/15	Face-n-Food images	Verbal self-report (describe what you saw)
Ryan et al. (2016)	$N = 60$	Children with ASD	Range 8–18 years	14/46	Face-like object images	Multiple choice task (among name of the present object, face and name of another object)
Pavlova et al. (2016)	$N = 20$	Patients with WS	23.3 ± 10.6 years	10/10	Face-n-Food images	Verbal self-report (describe what you saw)
Pavlova, Galli et al. (2018)	$N = 25$	Children with DS	13.2 ± 2.1 years	6/19	Face-n-Food images	Same as above

hyper-social personality profile that drives for increased social interactions. Down syndrome individuals have delayed cognitive development but relatively strong social skills. The reasons responsible for individual differences in face pareidolia among clinical populations would need further investigations.

Understanding individual differences in face pareidolia experience

From the mini-review above, one can easily find a huge diversity in the face pareidolia experience among the population. We list more details about the subject population recruited in those studies together with the materials and specific task demands in Table 1. Altogether, those studies were pooled over a relatively large population, ranging from infants only months old to elderly people, from typical-developing populations to neurodevelopmental patients. However, how to understand the individual/group differences remains a challenging question to be explored. As was advised by one of the reviewers, some factors may interplay with each other. For instance, sex might be an obvious confounding factor for people with ASD to have less face pareidolia experience. As is revealed by previous reviews, ASD happens more often in boys and men than in girls and women (Mandy et al., 2012; Werling & Geschwind, 2013). In the two studies that examined pareidolia experience in an ASD population, there is also an obvious sex bias in the pooled subjects (male/female: 1/15 in Pavlova et al., 2017; 14/46 in Ryan et al., 2016). Although it is still not clear about how exactly sex impacts ASD and how these two factors influence pareidolia experience, it indicates the underlying linkage between sex and ASD and pareidolia processing, and therefore generates new possibilities for understanding the underlying mechanisms. In the following section, we propose three possible ways to dig

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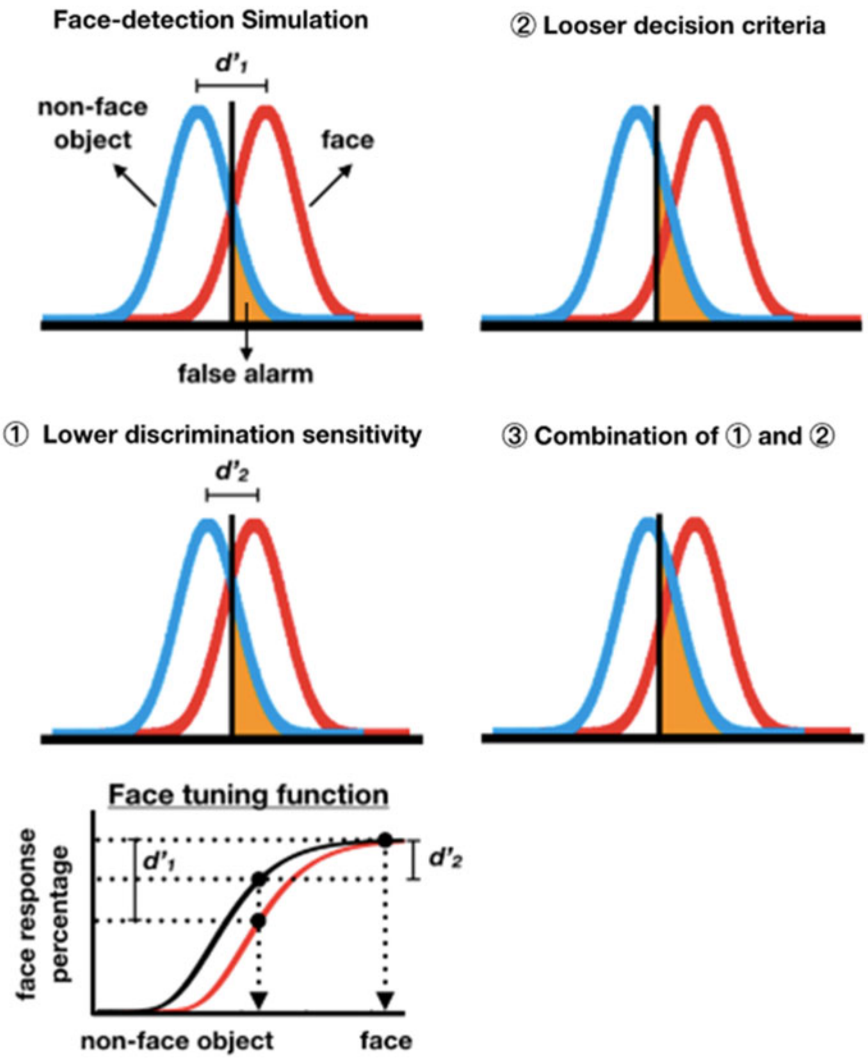

Figure 1. Simulation of a face-detection experiment. In each trial, an ideal observer sees an image sampled from either the Gaussian distribution of faces (red curve) or the Gaussian distribution of non-face objects (blue curve). The observer reports whether they see a face nor not. The vertical line stands for response criterion. A false alarm is made if the observer reports seeing a face while actually a non-face object is presented (orange-shaded area), which is when face pareidolia happens. The observers who report more face pareidolia experience (larger orange area) are those with lower discrimination sensitivity (Scenario 1), or with looser decision criterion for a face response (Scenario 2), or with both (Scenario 3). The bottom panel illustrates how discrimination sensitivity (d') differs with different face tuning functions.

into the experimental data that may bridge the findings in pareidolia with other researches in the broader fields.

Theoretical thinking: sensitivity or criteria?

In signal detection theory (SDT), false alarm refers to making a positive response when the signal is actually absent. Face pareidolia can be seen a form of "visual false alarm" in face detection, by mistaking non-face objects or meaningless patterns as faces. As shown in Figure 1, we simulated a SDT model for face detection. In each trial, an observer sees an image sampled from either the Gaussian distribution for faces or the Gaussian distribution for non-face objects. They would be asked to report whether they see a face or not. The vertical bar stands for response criterion. A false alarm, that is, face pareidolia, is to report seeing a face when presented with a non-face object (orange-shaded area). The distance between face and non-face object Gaussian distribution represents the discrimination sensitivity (d'). For observers with higher sensitivity (d'1 > d'2), the face tuning curve would be shifted to the right (the red curve in the bottom panel) suggesting more distinguishable response patterns for faces and non-face objects. In the face-tuning function, the middle area lying between the object/subjective continuity between face and non-face object is where face-like objects (pareidolia) posit.

In this framework, in Scenario 1, those who experience more face pareidolia may have lower discrimination sensitivity (d') between faces and non-face objects. This might be due to a leftward shift in face-tuning function in face detection, as shown in many studies (Pavlova, Galli et al., 2018; Pavlova et al., 2017; Pavlova et al., 2015). In Scenario 2, those who experience more face pareidolia may have a looser decision criterion for reporting face detection. It suggests that these individuals are freer to make a face response. Finally, in Scenario 3, those who experience more face pareidolia may have both lower sensitivity and looser decision criterion for face detection.

Rethinking the factors that influence face pareidolia reviewed in the previous sections, it does not seem easy to frame those factors into SDT, where individual differences in face pareidolia might be caused by differences in perceptual sensitivity (face-tuning function), or decision criterion, or the combination of both. Nonetheless, a handful of studies have suggested individual differences in face pareidolia in the context of SDT. For instance, when presented with scenery images that may contain a face-like area or not, paranormal and religious believers are better at identifying target areas and are also more prone to making false alarms. Further signal detection analysis revealed that believers are more liberal in making face responses than skeptics, but they do not differ in the detection sensitivity (Riekki et al., 2013), fitting into

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Scenario 2. In another study, participants were presented with noise images that were embedded with meaningful images (i.e., faces and scenes). Individuals with high positive schizotypy tended to be less sensitive and have a looser criterion for meaningful images detection than those with low positive schizotyoy (Partos et al., 2016). In this case, the reduction in sensitivity together with stronger bias towards reporting illusory face perception falls into Scenario 3.

Further work should investigate how perceptual sensitivity and response bias are responsible for individual differences in face pareidolia and may offer insights for understanding the underlying mechanisms. For example, one promising question to ask would be, do sex differences in face pareidolia experience come from sensitivity differences in face detection or from a gender-related face bias? If the sex differences are due to sensitivity difference, then women should have less distinct perceptual response distributions to faces and non-face objects than men (i.e., shallower face tuning function). This might seem counterintuitive, as women are found to be more responsive to facial information and have greater activation levels of face-selective brain areas in face-related processing (Furl et al., 2011; Golarai et al., 2010; Tahmasebi et al., 2012), which might differentiate faces from other objects. However, higher sensitivity for facial information might also greatly facilitate the illusory face perception from non-face object, leading to enhanced responses to face-like objects. The similar response patterns for faces and objects that resemble faces would shift the overall object-response distribution closer to the face-response distribution. As shown in Figure 1, with a given criterion, the closer the two distributions are, the higher rate a false alarm for face detection (i.e., face pareidolia) will happen. In the other case, if the sex differences are due to cognitive face-favoring bias, then women would have more liberal criteria and be more prone to make a face decision than men do. This account is in accordance with the classical sex stereotype (men and things, women and people) that females are more oriented to social information (Sommer et al., 2013; Su et al., 2009). Females are also thought to have a more empathizing style, being more driven to identify other people's mental states for social interaction (Baron-Cohen, 2010). The brain areas responsible for empathizing mentalization are found also being engaged in anthropomorphic thinking, the attribution of human characteristics to non-living things (Cullen, 2014). The anthropomorphic bias would lead to a more liberal criterion to decide what a face is (i.e., a leftward shift of the criterion bar in Figure 1); there will then be an increase in overall hit rate (face judgment) as well as in false alarm rate (pareidolia). Whether sensitivity difference or cognitive bias or both of the two would account for sex difference in face pareidolia experience needs empirical study in the future.

Origin of face pareidolia: Innate or acquired?

Here we would like to discuss how individual differences in face pareidolia experience is generated from innate characteristics or influenced by acquired tendencies. By saying that characteristics are innate, we mean they are carved in the genes. It has been proposed that pareidolia has its roots in biological and evolutionary selection and may bring advantages for detecting potential danger (e.g., imagining when there is a tiger in the woods). Do some people see more faces in non-face objects or ambiguous patterns because their brain is hard-wired differently to more readily detect faces? Alternatively, do they have more face pareidolia experiences because they have learned to perceive in that way? Perhaps due to excessive exposures to animated cartoon characters? Or due to believing in god or pantheism?

Similar to the debate on whether face recognition ability is inherited or learned through experience (Kelly et al., 2007; Pascalis, de Haan, & Nelson, 2002; Shakeshaft & Plomin, 2015; Wilmer et al., 2010), the answer regarding the origin of face pareidolia experience will not be a simple yes or no. Note that sex differences in the mini-review above should not be taken as a purely innate factor, as they are also subject to being shaped by culture and social environment effects later in life. Researchers have found that female brains have a stronger anthropomorphizing bias than male brains (Proverbio & Galli, 2016). One possible reason for this might be that female brains are naturally developed to be more sensitive to social and emotional information. Alternatively, it might be because women are better than men in understanding emotions and having empathy (Eisenberg & Lennon, 1983; Hoffman, 1977). Even though the ultimate answer might be difficult to seek, the question of innate or acquired individual differences would shed light for directing future research. For instance, it would be of great interest to find out whether perceptual training may lead to an increase or decrease of pareidolia face detection.

Interplay between two systems: perceptual processing and affective processing

The actual objects that generate pareidolia faces may vary distinctively, from a cut-open pepper to a car's font. This certainly poses a difficult situation for our visual system to solve what exactly is out there. Somehow, it works out that it is based on some kind of facial resemblance. The fact of individual differences in face pareidolia shows that some people's visual system may work it out "better" than others do. Does it mean that their visual processing system is superior at recognizing faces? Not necessarily. The face is one of the most salient object categories in our social life. To fully process a face is not only about how to recognize the stimulus as a face, but more importantly to receive social information (e.g., emotion or intention). We proposed that those who see more pareidolia faces would have a more sensitive affective processing system, which actively contributes to the recognition of a face from ambiguous stimulations. That could lead to the prediction that a more extensive network involving both "cold" and "hot" parts of the brain would be activated during pareidolia experience in those who see more pareidolia faces.

Proverbio and Galli (2016) recorded the ERPs when men and women viewed objects that resemble faces (pareidolia) and provided preliminary evidence for the role of interconnection between perceptual and affective processing in pareidolia experience. Using source reconstruction technique, they observed greater activations in affective processing areas in female brains than male brains, including the right superior temporal sulcus, posterior cingulate cortex and orbitofrontal cortex (Proverbio & Galli, 2016). In contrast, in male brains, there are prevalent activations of occipito/parietal regions along with a considerably smaller activation of orbitofrontal cortex. Previous studies have reported that women exhibit higher levels of emotional responses than men (Kret & De Gelder, 2012; Kring & Gordon, 1998) and may lead to attentional biases toward emotional stimuli due to higher level of alertness (Andric et al., 2016; Doty, Japee, Ingvar, & Ungerleider, 2013). This is also in accordance with the female advantage in face emotion recognition. In general, females recognize emotional faces faster than males do (Hampson et al., 2006; Kret & De Gelder,

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2012; McClure, 2000). For instance, when performing an emotion recognition task with real facial expression images, Hampson et al. (2006) found that women reacted faster in recognizing both positive and negative emotional faces than men. Whether and how individual's face pareidolia perception is modulated by his/her sensitivity to emotional information in the environment needs future investigation.

Recently, Taubert et al. (2018) found that when the bilateral amygdala was damaged in monkeys, they stop selecting real faces or pareidolia faces as a viewing preference in a face-versus-object free-viewing task. The authors suggested that the amygdala lesion might disrupt the visual processing in the temporal lobe and lead to the elimination of face viewing preference. All these studies indicate that the perceptual and affective systems interact with each other during pareidolia processing, and that the involvement of affective processing system may be a key reason for inducing face pareidolia.

Summary and perspectives

Over the last 30 years, abundant researches have established and enriched our understanding about how the human brain processes a face. While face recognition abilities in humans may reach ceiling performance levels, false positive responses for face detection occur from time to time. In this review, we introduced the illusory face perception from a non-face object or pattern, *face pareidolia*. One fascinating fact about face pareidolia is that some people see it more frequently than others do. We summarized previous findings on individual differences in experiencing face pareidolia into four categories, including sex differences, developmental factors, personality traits and neurodevelopmental conditions. Then we discussed what cognitive or neural mechanisms might generally account for in the individual differences.

What can we benefit from with the current knowledge of face pareidolia? We think the benefits are threefold. First, face pareidolia can be used as a window to study the face-processing system. When the actual patterns are never real faces, the illusory face perception holds with high tolerance to specific visual features of faces. The naturally occurring "error" of face detection may therefore inform us what really defines "a face" independently of the visual features. What does the face-tuning function look like for different individuals? What are the determinants to the shape of the tuning function? Second, face pareidolia can help to understand the interaction between perception and affective processing. As mentioned above, the two systems are interdependent and both contribute to pareidolia face processing. How do the two systems interact? In detail, how does the affective processing influence how and what we see? Finally, face pareidolia can be applied to clinical research. The Pareidolia Test has been shown to be a fast and easy to use application, and reveals potential biomarkers for neurodegeneratios in patients. Further development of face pareidolia application may facilitate diagnosis and intervention for social-related disorders, such as ASD and William syndrome.

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