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Research report

Seeing Jesus in toast: Neural and behavioral correlates of face pareidolia

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ABSTRACT

Face pareidolia is the illusory perception of non-existent faces. The present study, for the first time, contrasted behavioral and neural responses of face pareidolia with those of letter pareidolia to explore face-specific behavioral and neural responses during illusory face processing. Participants were shown pure-noise images but were led to believe that 50% of them contained either faces or letters; they reported seeing faces or letters illusorily 34% and 38% of the time, respectively. The right fusiform face area (rFFA) showed a specific response when participants "saw" faces as opposed to letters in the pure-noise images. Behavioral responses during face pareidolia produced a classification image (CI) that resembled a face, whereas those during letter pareidolia produced a CI that was letter-like. Further, the extent to which such behavioral CIs resembled faces was directly related to the level of face-specific activations in the rFFA. This finding suggests that the rFFA plays a specific role not only in processing of real faces but also in illusory face perception, perhaps serving to facilitate the interaction between bottom-up information from the primary visual cortex and top-down signals from the prefrontal cortex (PFC). Whole brain analyses revealed a network specialized in face pareidolia, including both the frontal and occipitotemporal regions. Our findings suggest that human face processing has a strong top-down component whereby sensory input with even the slightest suggestion of a face can result in the interpretation of a face.

1. Introduction

Illusory sensory perception, or 'pareidolia', is common. It occurs when external stimuli trigger perceptions of non-existent entities, reflecting erroneous matches between internal representations and the sensory inputs. Pareidolia is thus ideal for understanding how the brain integrates bottom-up input and top-down modulation. Among all forms of pareidolia, face pareidolia is the best recognized: individuals often report seeing a face in the clouds, Jesus in toast, or the

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Virgin Mary in a tortilla. Face pareidolia suggests that our visual system is highly tuned to perceive faces, likely due to the social importance of faces and our exquisite ability to process them.

Despite the fact that face pareidolia has been a well-documented phenomenon for centuries, little is known about the underlying neural mechanisms. Recent behavioral and functional imaging studies using a reverse correlation method have provided some intriguing insights about how face pareidolia might emerge. These studies have demonstrated that the internal representation of faces underlying face pareidolia can be reconstructed experimentally based on behavioral responses (Gosselin & Schyns, 2003; Rieth, Lee, Lui, Tian & Huber, 2011; Smith, Gosselin, & Schyns, 2012) or on brain activities measured by electroencephalography (EEG) (Hansen, Thompson, Hess, & Ellemberg, 2010) and functional magnetic resonance imaging (fMRI) (Nestor, Vettel, & Tarr, 2013). For example, in Gosselin and Schyns' (2003) study, participants were instructed to detect a face from pure-noise images where, in fact, no-face images existed. A face-like structure emerged in the classification image (CI) which was obtained by subtracting the pure-noise images to which participants failed to detect faces (no-face response) from those that participants claimed to have seen faces (face response). Using a similar experimental paradigm, Hansen et al. (2010) rendered a face-like structure not only based on behavioral responses but also from event-related potential (ERP) responses. These findings suggest that face pareidolia is not purely imaginary; rather, it has a basis in physical reality. However, because the images do not actually contain faces, face pareidolia clearly requires substantial involvement of the brain's interpretive power to detect and bind the faint face-like features to create a match with an internal face representation.

Recently, a few functional imaging studies have begun to explore brain regions involved in face pareidolia in abnormal individual (e.g., Iaria, Fox, Scheel, Stowe, & Barton, 2010) and normal individuals (e.g., Li et al., 2009; Zhang et al., 2008). For example, Iaria et al. (2010) found that a patient with a schizoaffective history and a past of abusing lysergic acid diethylamide (LSD) and marijuana regularly showed decreased activity in his FFA when he claimed to see faces on trees. However, as the only healthy participant in Iaria et al.'s study could not generate the face pareidolia as the patient did, it is unclear whether the patient's decrease in FFA activity during the experience of face pareidolia was due to his history of schizoaffective disorder or drug abuse and therefore it may not reflect the neural activity patterns among healthy individuals when they experience face pareidolia. Additionally, a recent fMRI study (Hadjikhani et al., 2001) found that when migraine patients experienced visual hallucination, known as a migraine aura, a change in time course of BOLD response was observed in the occipital cortex. This aura-related change was initiated in extrastriate cortex (V3A) and then spread to other regions of the visual cortex. Although such aura typically takes on "scintillating, shining, crenelated shapes" (Hadjikhani et al., 2001) rather than a face, these findings suggest that the neural responses of the visual cortex may be modulated by pareidolia.

In contrast to those findings from Iaria et al. (2010) and Hadjikhani et al. (2001), some studies of normal participants revealed an enhanced brain response to illusory face detection. For example, Smith et al. (2012) revealed an enhanced EEG record elicited by face response relative to no-face response over the frontal and occipitotemporal cortexes, with the former occurring prior to the latter. In agreement with Smith et al. (2012), Zhang et al. (2008) used a similar experimental paradigm but with fMRI methodology, and identified a network of brain regions showing greater activations when face pareidolia occurred, most notably in the fusiform face area or FFA (Kanwisher & Yovel, 2006) and in the inferior frontal gyrus (IFG). It was suggested that these cortical regions might play a crucial role in face pareidolia, perhaps by serving to integrate bottom-up signals and top-down modulations.

However, because neither Smith et al. (2012) nor Zhang et al. (2008) included a crucial condition assessing pareidolia of non-face objects, it is entirely unclear whether their neuroimaging findings elicited by illusory face perception are indeed specific to face pareidolia or the pareidolia of any visual object. For example, although converging evidence has demonstrated that the FFA shows increased response to faces than to other objects (Kanwisher & Yovel, 2006), its selectivity in face processing is of great controversy (Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Grill-Spector, Knouf, & Kanwisher, 2004; Grill-Spector, Sayres, & Ress, 2006; Tarr & Gauthier, 2000). A recent study using high-resolution fMRI revealed that the FFA identified using traditional methods also includes clusters showing response to non-face objects (Grill-Spector et al., 2006). Further, the FFA is also known to be activated by non-face objects with which we have expertise (Gauthier, Skudlarski, et al., 2000; Gauthier et al., 1999). Moreover, recent studies have reported that the IFG was also involved in the pareidolia of non-face objects with which we have expertise (letters, Liu et al., 2010), the location of which was highly consistent with that for face pareidolia identified by Zhang et al. (2008). Thus, due to the lack of direct comparison of face versus non-face pareidolia, it is unclear whether the FFA and its associated cortical network (e.g., IFG) identified in the existing studies are specifically involved in face pareidolia (the face specificity hypothesis) or in the pareidolia of any objects with which we have processing expertise (the object expertise hypothesis).

The present study aims to bridge this important gap in the literature and to test these hypotheses. We, for the first time, directly compare the neural responses of face pareidolia to that of non-face object (letter) pareidolia. Specifically, we explore the specific role that the FFA plays in face pareidolia. In the present study, participants were instructed to detect faces from pure-noise images in the face condition, and letters from the same pure-noise images in the letter condition. To ensure that face or letter pareidolia really occurred, we used a reverse correlation method similar to that used by Hansen et al. (2010) to obtain CIs based on behavioral responses (face or no-face response in the face condition and letter or no-letter response in the letter condition). Hansen et al. (2010) have demonstrated that the frequency spectrum of the CI containing a face-structure was significantly correlated with that of a noise image in which an average face was embedded. However, because Hansen et al. (2010) did not instruct participants to detect non-face objects from pure-noise images,