COGNITIVE NEUROSCIENCE

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Differences in Neural Correlates of Face and Pareidolic Perception

Differences in Neural Processing of Face and Pareidolic Perception

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Abstract

Sample: n=1 (female), Age = 23

This pilot study used EEG methods to investigate face pareidolia - perceiving faces in non-face objects - through three types of visual stimuli. We analyzed event-related potentials (ERPs) to identify neural correlates of face processing and pareidolia. No reliable results were found, likely due to limitations such as a small sample size. Despite this, some significant results encourage further research, which could impact the diagnosis and treatment of neurodegenerative conditions such as Parkinson's. The relationship between face recognition, pareidolia, and neurodegeneration remains a promising neuroscience research area.

Keywords: EEG; Face Pareidolia; N170; N250; P1; Neurodegenerative Diseases

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1. Introduction

The human capacity for facial recognition is a marvel of evolution and a testament to our species' deeply ingrained social nature. Among these fascinating mechanisms is a phenomenon known as face pareidolia - the disposition to perceive faces in otherwise non-face objects or abstract patterns. In the tapestry of our surroundings, our mind weaves familiar visages out of the most unlikely threads, revealing an intriguing facet of our perceptual abilities. This paper delves into the exploration of the neural correlates of this phenomenon, seeking to illuminate the inner workings of our brain when it conjures faces where there are none.

While pareidolia provides an engaging talking point from a psychological perspective, understanding it at the lowest level requires shedding light on it from a neuroscientific perspective. A nuanced understanding of the underlying process could yield insights into conditions where perception and reality diverge, as seen in various neurodegenerative disorders. These diseases often exhibit alterations in the ability to recognize or interpret faces, a cornerstone of human interaction.

1.1 Brief Background

The cognitive and neurophysiological mechanisms underlying face processing have been a subject of scientific research for many years. However, the intensity and focus of this research have significantly escalated over the past couple of years, given their profound implications for various fields such as attention research, consumer behavior, and eye-tracking.

Interpreting our surroundings depends greatly on our ability to see, a process managed by our elaborate visual system. It's in the early stages of visual perception, known as early visual encoding, where the real magic happens - transforming raw sight data into meaningful insights.

A fascinating observation grounded in cognitive neuroscience is the speed at which we recognize faces. This quick recognition likely stems from the evolutionary advantage of

promptly identifying friend from foe, emotions, and intentions. Incredibly, this instinct extends to a phenomenon known as face pareidolia - where we see faces where there are none. One of the key theories that explain this occurrence is the "Face Superiority Effect." It proposes that faces are given precedence over other visual inputs in our brains. This heightened awareness probably starts from the earliest moments of visual perception, guiding our attention to face-like patterns. Areas in our brain, such as the fusiform face area (FFA), are dedicated to this task, underpinning this theory.
So even when there's no actual face, our brain's face-detection system may kick in, prioritizing and perceiving these illusory faces. This interesting behavior underscores how evolution has tuned us towards prioritizing face perception, an attribute that has significant social importance.

The phenomenon, face pareidolia, has gained our attention due to its possible implications for certain neurological psychiatric disorders where altered perception is a key symptom. The intriguing nature of pareidolia, coupled with its potential to further develop our understanding of face processing and its association with certain neurological conditions, has motivated us to delve deeper into this phenomenon. A critical question that arises in this context is whether the neural mechanisms underlying face recognition and pareidolia are identical or distinct, and how the intensities of these processes quantifiably vary.

Electroencephalography (EEG), with its superior temporal resolution, has emerged as an essential tool for investigating this phenomenon. It allows us to investigate the neural processes of both face recognition and pareidolia by recording and measuring the electrical activity generated by the brain.

Previous studies have leveraged EEG to unravel the mechanisms of face recognition (Eimer, 2000; Itier, 2004) revealing specific components associated with different stages of face processing. Similarly, research into pareidolia has begun to uncover its neural correlates (Liu et al., 2014; Pavlova et al., 2020). However, the exploration of how these two phenomena interrelate remains relatively uncharted territory. Preliminary studies suggest that the brain regions involved in face recognition and pareidolia, such as the Fusiform Face Area (FFA), may overlap or even be identical (Hadjikhani et al., 2009). Nevertheless, a significant gap

persists in our understanding of the relationship and differences between these two phenomena at the neurophysiological level.

The objective of this study is to probe the intriguing intersection of face recognition and pareidolia, with a particular emphasis on EEG studies investigating these phenomena. We aim to extend our understanding of the neuronal processes underlying perceiving, interpreting, and assigning meaning to faces, whether they are real or illusory, through the integration of neuroscientific methods (Wang & Yang, 2018).

1.2 Explanation of Pareidolia and Face Processing

Pareidolia is a psychological phenomenon that prompts individuals to perceive a vague and random stimulus as significant, often manifesting as the recognition of faces in inanimate objects. This phenomenon is believed to be a byproduct of human evolution, as recognizing faces and interpreting emotions are critical for social interaction. Simply said; In the grand scheme of human perception, it seems more advantageous for us to err on the side of seeing faces where there are none than to miss a face where one is present. However, face recognition is a complex cognitive process that allows us to identify and differentiate individuals based on their facial features. It involves several stages, from the detection of a face in the visual field to the retrieval of information about the individual's identity and emotional state.

Emerging research on the phenomenon of face pareidolia indicates that the early visual encoding stages involved in face perception may regard objects which resemble faces as real faces, and hereby further prioritizing the processing of these. Studies have found that this prioritization is highly present even when comparing objects that are similar in content, but where one of them may elicit face pareidolia. In these studies, it has been found that pareidolic object images are detected faster by the human visual system (Caruana & Seymour, 2022).

1.3 Importance of This Research and Its Implications

The investigation of face recognition and pareidolia has far-reaching implications for various fields, ranging from psychology and neuroscience to artificial intelligence and marketing. Understanding the neural mechanisms underlying these phenomena can provide insights into human cognition and perception, potentially informing the development of interventions for neurological conditions characterized by deficits in face processing. Furthermore, this research can contribute to the design of more effective marketing strategies and the development of more sophisticated facial recognition technologies. Explored in greater detail later in this paper, an enhanced understanding of the phenomenon holds promise in shedding light on certain neurological impairments or diseases, potentially offering further insights into their diagnosis.

2. Literature Review

2.1 Face Processing

Face recognition, a pivotal aspect of human cognition and social interaction, is a multifaceted cognitive process. It has been a subject of extensive scientific exploration due to its significance in our daily life interactions and is believed to involve several interconnected stages, underpinned by multiple cognitive models (Bruce & Young, 1986; Haxby et al., 2000; Liu et al., 2014).

The process initiates with a lower-level perceptual analysis, which pertains to the detection of a face within the visual field. This detection subsequently ascends to higher-level semantic processing, such as the retrieval of pertinent information about the individual's identity and emotional state.

In the extensive network of brain regions, several are particularly notable for their involvement in face processing, including the Fusiform Face Area (FFA), the Superior Temporal Sulcus (STS), and the Anterior Cingulate Cortex (ACC) (Haxby et al., 2000; Klein et al., 2009). These regions are tasked with handling different aspects of face recognition: the

STS processes the dynamic and changeable features of faces, while the FFA is responsible for analyzing the invariant aspects.
However, this intricate process of face recognition is susceptible to disruption under certain neurological conditions, such as prosopagnosia. Characterized by a distinct inability to recognize faces, individuals with prosopagnosia exhibit abnormal activity in the FFA and other face-processing regions, indicating the crucial role these areas play in the normal functioning of face recognition (Barton, 2008).

Overall, ongoing research continues to refine our understanding of the neural mechanisms underlying the stages of face processing, aiming to elucidate the complexities involved in this critical aspect of human cognition.

2.2 Pareidolia in Neuroscience

Pareidolia, the phenomenon of perceiving familiar patterns in random or ambiguous stimuli, represents a rare and unique area of research in neuroscience. This phenomenon, often manifested as the perception of faces in inanimate objects and provides a window into the mechanisms of face recognition. The investigation of pareidolia serves as an optimal research framework for examining how the brain processes bottom-up input and top-down modulation (Liu et al., 2014). Recent studies have begun to uncover the neural correlates of pareidolia, with findings suggesting the possible involvement of the same brain regions and EEG components implicated in face recognition (Hansen et al., 2010; Liu et al., 2014) This suggests that the same neural processes contributing to our ability to discern and interpret faces may also be engaged during episodes of pareidolia.

2.3 EEG

Electroencephalography (EEG) is a non-invasive technique for measuring the electrical activity of the brain. It serves as a valuable tool in studying these phenomena due to its exceptional temporal resolution, which enables us to capture the dynamic processes involved in face recognition and pareidolia.
Since its inception in the early 20th century, EEG has seen significant advancements, most notably with the introduction of the 10-20 system of electrode placement (Klem et al.,

1999). This systematic approach improved the consistency and reproducibility of EEG results. Additionally, the integration of the uprising computer technology in the latter part of the 20th century further impacted EEG data collection and analysis (Luck, 2014). Specifically, it enabled a more precise gathering and integration of EEG data (Niedermeyer et al., 2004). These technological innovations, in turn, facilitated the development of high-density EEG systems, offering even greater accuracy and detail in neurophysiological investigations. The development of high-density EEG systems has further refined our ability to capture the dynamic processes involved in cognitive phenomena such as face processing, attention, and even sleep research.

Several approaches have been developed to interpret EEG data effectively. These approaches include event-related potentials (ERP), which track the brain's responses to specific sensory, cognitive, or motor events, time-frequency analysis to understand the dynamics of brain oscillations (Morales & Bowers, 2022), and source localization to speculate about the potential neural sources of EEG signals (Pascual-Marqui et al., 1994).

2.4 EEG, Faces and Pareidolia

Event-related potentials (ERPs) such as N170 and N250 are particularly relevant in these studies. The N170 is an ERP component that peaks roughly 170 ms after the stimulus is presented, typically showing greater amplitude in response to faces than other objects, and particularly in the right hemisphere (Bentin et al., 1996; Rossion & Jacques, 2011). This suggests its role in the structural encoding of faces. Interestingly, face-like pareidolic images have been shown to influence the N170 (Liu et al., 2014), further implying its involvement in early face processing.

Some previous studies have reported that the amplitudes of N170 components increased and the latencies were delayed with presentation of inverted face images, as compared to upright face images, which suggested that this component is an early indicator of endogenous processing of visual stimuli and that the N170 component reflects an early stage of configural/holistic encoding, and is sensitive to changes in facial structure(Itier & Taylor, 2004). In addition, some studies have suggested that upright faces are dominated by

holistic processing, and inverted faces by featural processing(Caharel et al., 2013). For example, Rossion et al.(1999; 2000; 2003) reported that N170 inversion effects disrupted processing of configural/holistic information. This effect is considered as a marker for special processing of upright face stimuli in the brain(Davidenko et al., 2012; Yovel & Kanwisher, 2005).

There are several discrepancies in the conclusions drawn from various studies in this field. While some researchers argue that the N170 component is exclusively engaged in face-specific processing, other propose that it might also play a role in more general cognitive functions such as attention or categorization (Bentin et al., 1996).

The N250, also deserves our attention. The N250 typically peaks around 250 ms following the presentation of a stimulus and has been found to exhibit a midline and anterior scalp distribution (Schendan & Kutas, 2007). Interestingly, it's not only sensitive to any object, but it seems to play a vital role in object processing and repetition (Gruber, 2004; Zimmermann & Eimer, 2013).
Intriguingly, N250 is not solely dedicated to objects. Scott et al. (2006) suggest that the N250 component isn't just about familiarity with objects, but also extends its sensitivity to faces. This specificity gives N250 a unique characteristic among ERP components.
The role of the N250 becomes even more crucial when considering neurological conditions like Parkinson's disease. Parkinson's is often associated with an impaired ability to recognize emotional facial expressions, indicating potential involvement of visual processing and recognition disorders. Furthermore, Parkinson's patients are known to experience pareidolia (Uchiyama et al., 2012).

2.5 Pareidolia Research and Its Context

Tendencies to experience pareidolia has been observed in various neurological disorders, such as Parkinson's disease and dementia with Lewy bodies (DLB) (Uchiyama et al., 2012). These findings suggest that altered neural functioning in these disorders may contribute to the increased prevalence of pareidolia, although the specific mechanisms remain unclear. Recent studies have also indicated that pareidolia can be a useful clinical marker for Lewy

body disease, and in particular as a surrogate marker of visual hallucinations in these patients (Mamiya et al., 2016; Yokoi et al., 2014).
Additionally, some research suggests that investigating face pareidolia may offer new insights into understanding Parkinson's Disease (PD) (Göbel et al., 2021). It has been observed that individuals with PD often report seeing faces where none exist and struggle to detect real faces in images. This underscores the significant role of visuo-spatial and visual-perceptual deficits that are characteristic of PD (Ghazi-Saidi, 2020).

Significant associations have been noted between face pareidolia production in PD patients and factors like cognitive performance, age, and hallucinations incidences (Agüera-Ortiz et al., 2022). Further evidence from Uchiyama et al. (2012) indicates a higher prevalence of pareidolia in PD patients experiencing hallucinations. These findings point to a possible involvement of pareidolia-related neural mechanisms in the emergence of hallucinations within PD patients. Therefore, the study of pareidolia in the context of neurological disorders not only provides insights into the neural mechanisms underlying this phenomenon but also has potential clinical applications. Further research in this area is needed to fully understand the implications of pareidolia in various neurological conditions.

Previous studies have investigated the neural processing of face and face-pareidolia stimuli in PD patients using some of the earlier mentioned ERPs, including N170 and N250 components. Results showed increased amplitudes of N170, as well as decreased amplitude of N250 responses (Uchiyama et al., 2012, Akdeniz et al., 2020). Hence, examining pareidolia could provide a deeper understanding of the perceptual and cognitive aspects of PD, leading to more effective assessment approaches.

2.6 Channel Selection

It is of high importance to carefully consider the channels of interest when designing an EEG experiment. For the components relevant to this study, there is a variation in relevant channel selection. The N170 component is most prominent at the lateral occipito-temporal lobes, at which the electrodes P7 and P8 are positioned following the 10-20 system (Krombholz et al., 2007).. N250, in the context of face processing, is observed in the parieto-

occipital regions in both the left hemisphere at PO7 and P7 as well as in the right hemisphere at PO8 and P8 (Nihei et al., 2018) .

Nevertheless, it's crucial to note that the precise neural activity localization picked up by EEG electrodes is challenging due to the so-called "inverse problem" (Pascual-Marqui, 1999). Thus, even though we can identify general brain regions that correspond with EEG electrodes, it does not allow for perfect one-to-one mapping (Michel et al., 2004). Therefore, the selected channels are motivated by EEG studies with similar focuses on face processing, rather than solely choosing channels positioned over otherwise dominant brain areas involved in face processing!

2.7 Summary

In summary, the exploration of N170, P1 andN250 components through EEG represents a promising direction for deepening our understanding of face recognition and pareidolia. The existing inconsistencies in the literature underscore the necessity for more research in this area, a gap that the current study seeks to address (Nihei et al., 2018) Taken together, this study investigates face-likeness processing as reflected by selected ERP components in order to deepen the current kmnowledge of face proccesing.

3. Methods (PM & KMH)

3.1 Participants

The pilot study involved a single participant. The participant was a healthy individual of age 21 with no known cognitive impairments or neurological conditions. The participant was familiarised with the EEG equipment and the purpose of the study. The participant was recruited from the Cognitive Science program at Aarhus University. No monetary compensation was provided to the participant.

3.2 Stimuli and paradigm

Our experiment used three distinct types of images as stimuli: human faces, random objects, and pareidolic images that evoke a face-like perception. Participants were told that they will see a serie of images flashed on the screen for 0.8 second each. Their task was to

determine as quickly as possible whether the image displayed is a face or not. Participants are informed that there is no time limit, but they are encouraged to respond as quickly as they can. Our experimental design was constructed with the intent to explore the variations in neural activity triggered by different types of visual stimuli. In this context, the inclusion of object images played an important role with two primary functions.

Initially, object images were employed to establish a baseline that theoretically aligned with the processing of pareidolias. Given that pareidolias are essentially objects that mimic facial features, they served as a reference point, anchoring our understanding of how pareidolias are processed relative to everyday objects.

Secondly, these object images allowed us to quantify the degree of disparity in the neural responses between pareidolic images and ordinary objects. This differential measure is vital in our analysis, providing an effective yardstick to compare the distinctness of neural processing triggered by pareidolic images. Thus, the integration of object images not only contributed to the diversity of our stimuli but also offered a comparative framework for evaluating responses to faces and pareidolic images. The stimuli for faces and pareidolia were retrieved from GitHub repository which was dedicated to reliable pareidolia research https://github.com/nrshaidat/facial_detection. All of the stimuli were presented on a white background in unified size.

Figure 1: Example of stimuli. Face-like pareidolic image, object and face.

3.3 Procedure

The EEG recordings were conducted at Aarhus University Hospital, and the room utilized for the experiment provided substantial sound dampening, contributing to a consistent environment throughout the experiment. The room settings hereby facilitated an undisturbed experimental process.

The participant was first introduced to the EEG equipment. They were informed about the need for a conductive liquid to establish a good connection between the EEG electrodes and the scalp. The EEG cap was then fitted on the participant's head, and the conductive liquid was applied to each electrode site.

Once the EEG setup was complete, the participant was presented with the experimental paradigm programmed in PsychoPy. The paradigm involved the presentation of a series of images, and the participant was asked to determine whether each image was a face or not. The participant's electroencephalograms (EEG) were recorded using the EEG throughout the entire experiment.

The script presented the participant with a series of 150 trials, each consisting of an image and a prompt to identify whether the image was a face or not. The order of the images was randomized to control for order effects.

The experiment was conducted in a single session lasting for approximately 30 minutes. The participant's EEG was recorded continuously throughout the session, providing a comprehensive record of brain activity in response to the different types of stimuli.

3.4 Technical setup of the EEG

The EEG data were acquired by signals from a 32-electrode cap using an Acticap system (Brian Products GmbH, Gilching, Germany) based on the international 10-20 system (Klem et al., 1999). At the left eye, electro-ocular activity was monitored through a supraorbital electrode (VEOG) and an electrode located at the outer canthus (HEOG). The reference electrode for data collection was FCz, and the EEG signal was amplified using a BrainAmp DC amplifier system at a sampling rate of 1000 Hz. The experiment was programmed and presented in PsychoPy (Peirce et al., 2019). EEG analysis triggers were implemented to mark the presentation of each stimulus as well as responses.

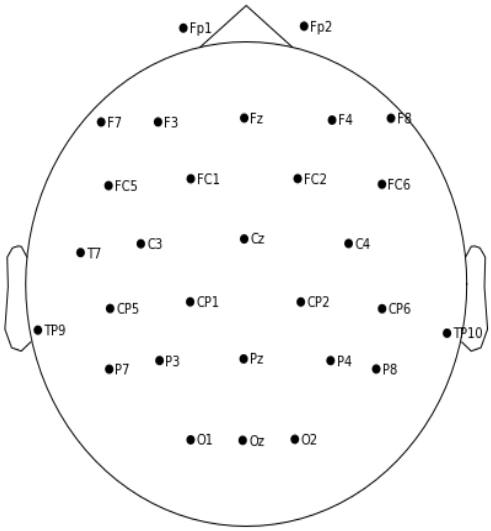

Figure 2: Placement and names of electrodes

3.5 Channel selection

The electrode channel selection for the data analysis is decided upon from the literature in the field. However, our selection was slightly limited due to the experimental setup of using a 32-electrode EEG cap. Therefore, the electrodes P7 and P8 were selected for the analysis of N170. For the analysis of P1, the channels O1, O2, and Oz were selected. For N250, channels P7 and P8 were selected. We can see that the early visual inspection of the topographies below:

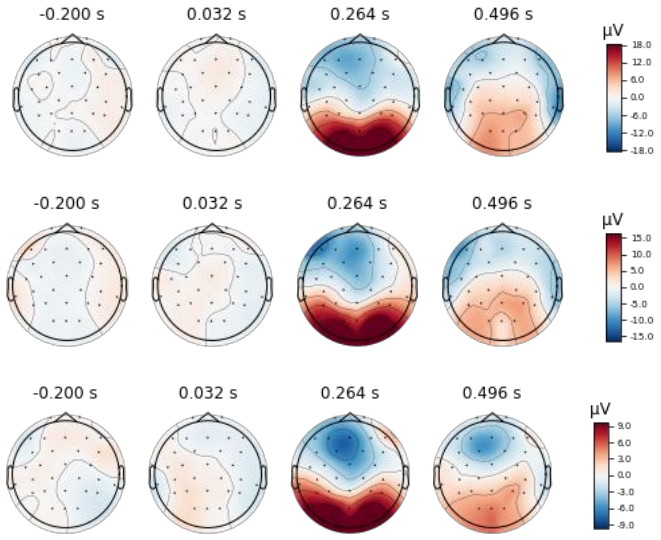

Figure 3: Topography of different time stamps

3.6 Hypothesis

The current study aims to contribute to this discourse by examining face processing in pareidolia using EEG. By grounding knowledge in the current literature in the field, the following hypothesis is motivated:

H0:There is no difference in ERP components when perceiving faces and pareidolic images

H1.1: There is a difference in the activity of the N170 component when perceiving faces compared to perceiving face-like pareidolic images.

H1.2: There is a difference in the activity in the N250 component when perceiving faces compared to perceiving face-like pareidolic images.

Through this comprehensive approach, we aim to simultaneously examine both ERP components within a single study. The EEG research often encounteres challenges in pareidolia research due to variability of approaches in data collection methods, analysis techniques, and selection of equipment. It is common for studies in this field to focus on just one component, which often results in findings that are difficult to compare directly due to above mentioned variability in different segments. By assessing both components (N170, N250) concurrently, and using objects as a control for processing pareidolias, our study strives to provide a more holistic and directly comparable view of face and pareidolia image processing. Due to our participant being neuro-typical, we expect to find no differences in processing faces and pareidolias, meaning that in neuro-typical population, there is a significant difference in processing face-pareidolias adn pareidolias.

3.7 Data Considerations

Prior to delving into the Analysis section, we must address some crucial observations about the data collection process. During this phase, we encountered numerous challenges, primarily due to difficulties in the communication between our script and the EEG equipment. This obstacle required swift and decisive action, leading to a last-minute coding solution implemented by Andreas Hojjlund. He verified that the issue was not within our

script, but rather arose from an unknown error in the communication between the equipment and the computer.

We also grappled with a situation involving a participant with particularly curly and voluminous hair. In this instance, an enormous amount of time and effort was required to only attain an acceptable level of connection with the electrodes. Under normal circumstances, or in the pursuit of proper scientific standards, we would likely have chosen to exclude the data for this participant or at least to compare it with data from other participants to determine the extent of deviation. However, given the constraints of the examination setting to collect data only for one participant, we proceeded with the analysis to showcase our gained skills during this course as if the data were reliable.

4. Analysis

4.1 EEG preprocessing

The EEG data were preprocessed using Python (Python Software Foundation, 2020) and the MNE toolbox (Gramfort et al., 2013). The data manipulation and analysis were performed using the following packages: Pandas (McKinney, 2010), NumPy (Harris et al., 2020), Matplotlib (Hunter, 2007), Scikit-learn (Pedregosa et al., 2011), and SciPy (Virtanen et al., 2020). The code is fully available at the Author's repository (https://github.com/katrinemunkholm/Neuro).

Avaliable EEG data were low-pass filtered at 40 Hz and high-pass filtered at 0.1 Hz. The chosen bandpass is relatively stringent, but necessary to remove unwanted noise interference.

Initially, an assessment of the raw data was performed, and bad channels were removed. Specifically, T8 was removed.

The choice of whether or not to use Independent Component Analysis (ICA) depends on the nature of the data as well as the research question. Since it is particularly useful when dealing with EEG data that contains artifacts, such as eye blinks and muscle contractions, we decided to decompose the EEG signals into independent components. This allows us to

improve the interpretability and quality of the data. The independent components were visualized in an ICA plot of the raw data to facilitate the identification of potential artifacts. The number of components selected was set to explain at least 95% of the variance in the data, ensuring a balance between noise reduction and data integrity. After careful inspection, two components (0 and 1) exhibited patterns consistent with eye blinks and were subsequently removed. These artifacts were confirmed by overlaying these components on the original data using the overlay plots:

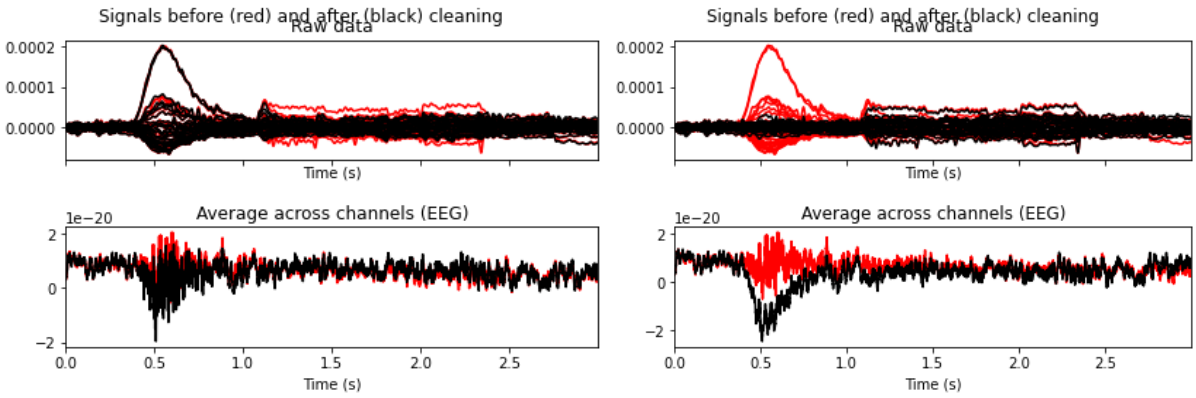

Figure 4: Overlay plots depicting artifacts and their removal

Following the ICA stage, the data was epoched to a time frame spanning from 200 ms before stimulus onset to 500 ms after the onset. To maintain data quality, epochs with voltage fluctuations exceeding 150 µV were rejected. For each category, event-related potentials (ERPs) were computed by averaging across all trials.

Our analysis specifically focused on the N170 and N250 components, as these components have been associated with face processing and object recognition in previous literature. When doing the analysis, the following time frames were chosen for the channels of interest: N170; 140-220 ms, N250; 230-330 ms (Williams et al., 2006).

4.2 ERP analysis

Following our established hypothesis framework, we conducted separate analyses on both ERP components. This allowed us the flexibility to tailor our analytical approach depending on the unique characteristics presented by the data distribution from each component.

4.2.1 N170

For the analysis of the N170 component, which is known to be associated with facial recognition, data were collected from electrodes 'P3', 'P4', 'P7', 'P8'. These electrodes are generally associated with the N170 ERP component as per the literature. The chosen time interval for data extraction is from 0.14 to 0.22 seconds post-stimulus onset based on the previous studies mentioend in the literature review.

The mean EEG data is calculated across time and electrodes for each stimulus type: objects, faces, and pareidolias. This process results in the average N170 responses per trial for each stimulus category.

The normality of the data from each stimulus category is tested using the Kolmogorov-Smirnov (KS) test. All three KS tests yield p-values that cross the alpha threshold of 0.05, suggesting that the data do not follow a normal distribution. As such, non-parametric tests are applied.

The Mann-Whitney U test is conducted. The test compares the N170 responses between faces and pareidolias, and then between objects and pareidolias. The comparison between faces and pareidolias results in a U-statistic of 805.0 and a p-value of 0.02, indicating a statistically significant difference between thes means of of the two groups. After applying Bonferoni correction, the p-value stayed at 0.05, still implying statistical significance. Conversely, the test comparing objects and pareidolias yields a non-significant result, demonstrating no notable difference between the means of these categories.
These amplitudes are visually represented on the plot below. This visual representation confirms the lack of significant differences in N170 responses between objects and pareidolias, and the significant difference between faces and pareidolias.

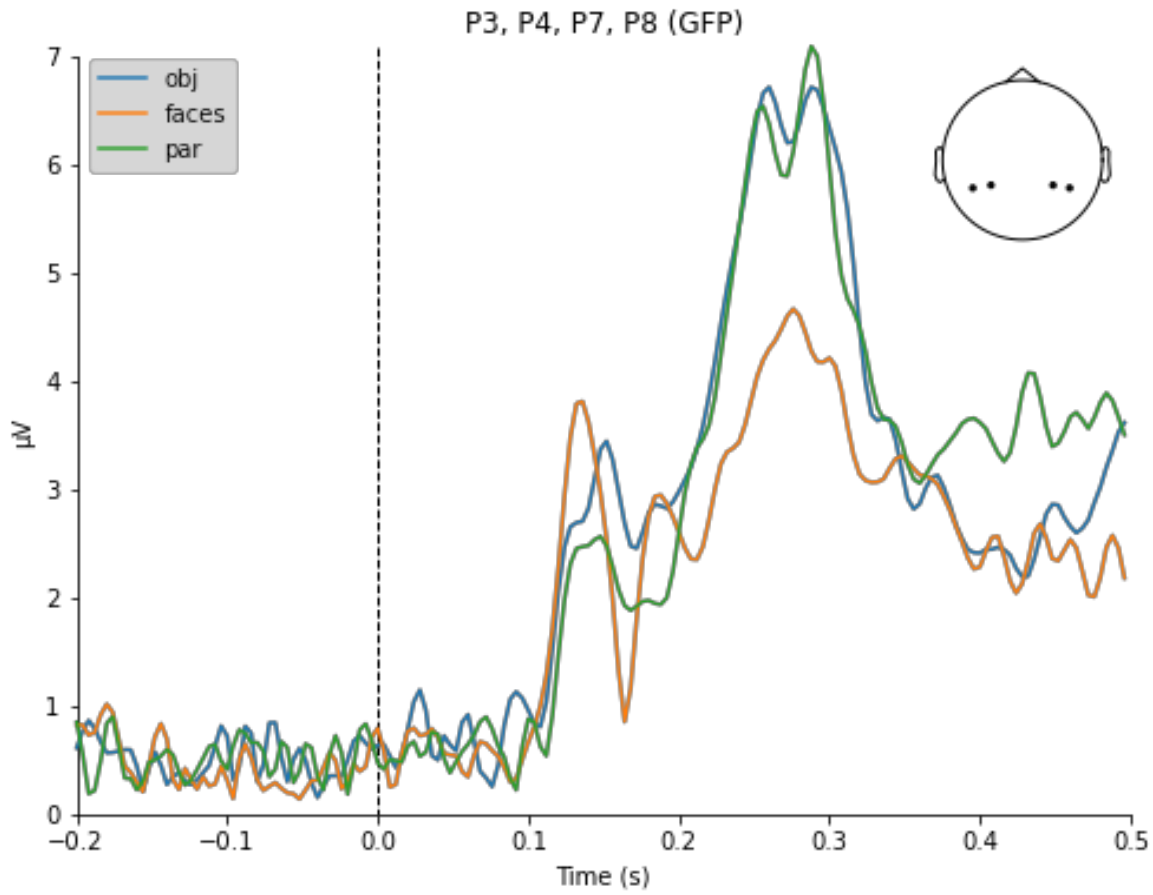

Figure 5: N170 component is more prominent in face perception compared to objects and pareidolic images, averaged over the specified channels.

4.3.2 N250

The analysis of the N250 component, recognized for being sensitive to face and object processing, is conducted with data procured from electrodes 'P7' and 'P8', located in the parieto-occipital region of the scalp. The time frame for this analysis extends from 0.23 to 0.35 seconds post-stimulus onset, a period typically associated with the N250 component in the literature.

As previously done, the mean is computed for each of the three stimulus types: objects, faces, and pareidolias. This process results in the average N250 responses per trial for each of the categories of stimuli.

The Kolmogorov-Smirnov (KS) test is applied to evaluate the normality of the distribution of the data from each stimulus category. In all three cases, the KS test yields a p-value that is well breaking the set alpha level of 0.05, indicating a non-normal distribution of data. Therefore, non-parametric tests are performed.

As with the N170 component, a Mann-Whitney U test is carried out to compare the N250 responses between faces and pareidolias, and then between objects and pareidolias. The comparison between faces and pareidolias yields a U-statistic of 690.0 and a p-value of 0.0019, suggesting a statistically significant difference of means between the two groups. After application of Bonferoni correction, p-value rose to 0.003, still conforming statistictical significance. However, the comparison between objects and pareidolias yields a U-statistic of 1174.0 and a p-value of 0.5776, suggesting no significant difference between the means of the two groups.

The visual inspection of the overlaid ERP waveforms, represented in the plot below, confirms these statistical findings, demonstrating a significant difference in N250 responses between faces and pareidolias, but no significant difference of means between objects and pareidolias.

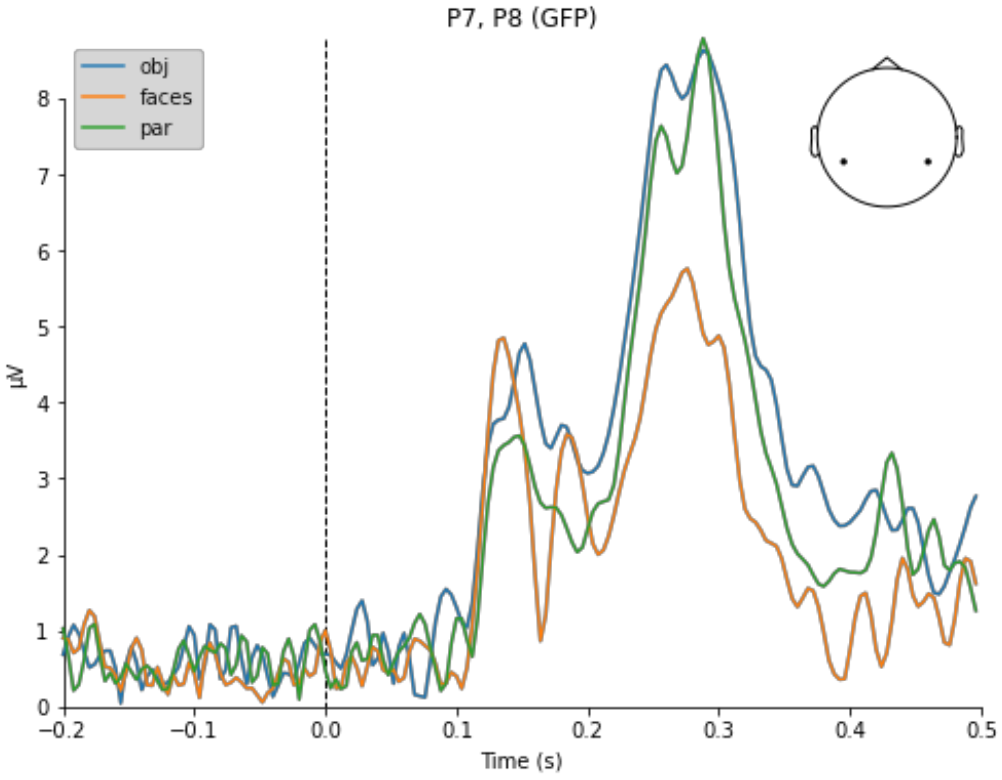

Figure 6: Depiction of the N250 component for the specified channels.

5. Results

In this study, we sought to examine the neural processing of faces and pareidolia images focusing on the N170 and N250 ERP components. For each component, we proposed null hypotheses suggesting no significant difference in the processing between face and pareidolia images. Correspondingly, the alternative hypotheses asserted a significant differences in processing between these two image types.

5.1 N170 Component

For the N170 component, the Kolmogorov-Smirnov (KS) test results showed a deviation from a normal distribution for all types of stimuli. The Mann-Whitney U test revealed a significant difference in the processing between faces and pareidolias, supporting the alternative hypothesis.

5.2 N250 Component

The K-S normality tests for the N250 component revealed a non-normal distribution of data for all types of stimuli. However, the Mann-Whitney U test displayed a significant difference in the responses between faces and pareidolias, thereby supporting the alternative hypothesis.

5.3 Summary

In this study, our exploration of the neural processing of face and pareidolia images focused on the N170 and N250 ERP components. We proposed null hypotheses that suggested no significant difference in the processing between face and pareidolia images, while the alternative hypotheses postulated significant differences between the two image types. Our results from the N170 and N250 components pointed to significant differences in processing between faces and pareidolia images, thereby supporting the alternative hypotheses. This difference was validated through the Mann-Whitney U test following the Kolmogorov-Smirnov test, which demonstrated a non-normal distribution for all types of stimuli.

These findings underscore the complexity of visual perception, illustrating how certain ERP components, such as the N170 and N250, differentiate between faces and pareidolias.

6. Discussion and Limitations

As a pilot study, the primary aim was to assess the feasibility and lay the groundwork for future investigations. First and foremost, an important point of consideration is the need for a larger sample size in future studies. A key limitation of this study as an exam project was limited to a single participant, which severely restricts the generalizability and reliability of the findings. By including a larger and more diverse sample, the statistical power will be greater and it will allow for more robust conclusions regarding the possible differences in the processing of pareidolia and faces in terms of their neural correlates. As a pilot study, the primary aim was to assess the feasibility and lay the groundwork for future investigations of 3 and more components.

Additionally, it is worth mentioning the technical limitations associated with EEG recordings again. As described earlier in the section, the complications with the equipment communication and curly hair arose (see the section Analysis). Potential enhancements to future studies might involve refining the EEG setup or experimenting with alternative electrode placements. It could also be beneficial to consider eligibility criteria that take into account hair conditions which could interfere with precise neural measurements. By adopting these methodological adjustments, we can anticipate more accurate observations and a more reliable interpretation of neural activity.

In this study, we primarily investigated three stimulus categories: face-like pareidolic images, objects, and faces. While our preliminary investigation provides valuable insights, future research could benefit from a more tailored approach to stimuli selection. It is important to remember that pareidolic illusions are subjective experiences that vary from person to person. Therefore, a more individualized selection of stimuli that consistently elicit pareidolia for each participant could reduce response variability and focus more specifically on neural activities associated with pareidolia.

In the light of this, future investigations could adopt an approach where stimuli are carefully pre-selected or dynamically chosen during the experiment, based on individual participant responses. This method would allow for a more controlled exploration of the neural

underpinnings of these individual pareidolic experiences and equal number of trials in the data set by presenting the pareidolia images until reaching the chosen number of pareidolia trials. By excluding stimuli that fail to provoke consistent pareidolic responses, we can decrease inter-participant variability, focusing solely on neural activity connected to pareidolic perception. Consequently, this tailored methodology may enhance the sensitivity of the experiment, increasing the likelihood of discerning significant differences in neural responses between pareidolia and non-pareidolia conditions.

6.1 Important Clinical Potential of Pareidolia Research

Pareidolia research has the potential to further our understanding of cognitive functions and their alterations in neurodegenerative diseases, for instance, Parkinson's.
While our study produce significant findings, they should be interpreted cautiously due to issues during the data collection. It is crucial to acknowledge the broader possible implications of this research.
Studying pareidolia in relevant patient groups offers potential for clinical application and might open avenues for devising targeted diagnostic tools. If a specific correlation between the processing of pareidolic illusions and neurodegenerative diseases is identified in specific brain regions and if this link is prominently occurring in patients with these neurodegenerative diseases, we could be approaching a straightforward and cost-effective method for diagnosing these conditions.

Moving forward, the researchers should continue exploring these clinical aspects and augmenting our understanding in this field to extend our understanding and ability of diagnosing neurodegenerative diseases.

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