Undergraduate technical report for IWORX on the use of the IX-EEG system

Are You Imagining? Neural Differences In A Case Of Congenital Aphantasia

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Introduction

The electroencephalography (EEG) experiment described in this undergraduate technical report contributes to our long term goal of determining how the brain generates mental representations that are not present as distal stimuli. EEG is a non-invasive method that can assess abnormalities in brain waves and more broadly, neurophysiological functions. EEG devices record the electrical signal of postsynaptic potentials of clusters of neurons in the brain. This allows researchers to measure direct neural activity through the sum of synchronous synaptic activity captured by different electrodes on the scalp or face (Nunez & Srinivasan, 2006). This relatively low-cost approach is also non-invasive, unlike microelectrodes and PET scans while providing high temporal resolution. Time- locked EEG activity or event- related potential (ERP) captures electrophysiological responses to a defined stimulus or event (Blackwood and Muir, 1990). ERPs can be evoked by a plurality of motor, sensory or cognitive events. It is believed that ERPs reveal the amassed activity of postsynaptic potentials generated by hundreds of thousands or even millions of closely positioned synchronal firing cortical pyramidal neurons (Sur & Sinha, 2009). Most often, ERPs are used to elucidate stages of information processing. Because ERP amplitudes are typically smaller than background EEG amplifications, ERPs are determined by the mean of ongoing EEG fragments gathered through numerous trials. ERPs through the use of EEGs have provided a new window of information about a range of cognitive processes including neurodegenerative diseases like dementia (Horvath, 2018) and brain disorders like schizophrenia (Mazer et al., 2021). In the current case study, IWORX EEG and IWORX EM-220 Event Marker were used to investigate if there is any neural evidence for visual imagery in the neurological disorder called congenital aphantasia.

Visual imagery involves voluntarily re-creating experiences in the mind, without distal stimuli. A person living with aphantasia is unable to consciously create visual images in their mind's eye (Zeman et al., 2015). Francis Galton first described this phenomenon in the quantitative study of mental imagery in 1880 (Galton, 1880). The biological foundation of the mind's eye is not yet fully understood. However, fMRI studies have begun to elucidate that early processing areas of the visual cortex including the lateral geniculate and V1 areas are activated during mental visual imagery tasks (Ishai et al., 2002). The present case study was based on past findings that imagining a stimulus before it is presented influences ensuing stimulus-locked event-related potentials (ERPs; Farah et al. 1988).

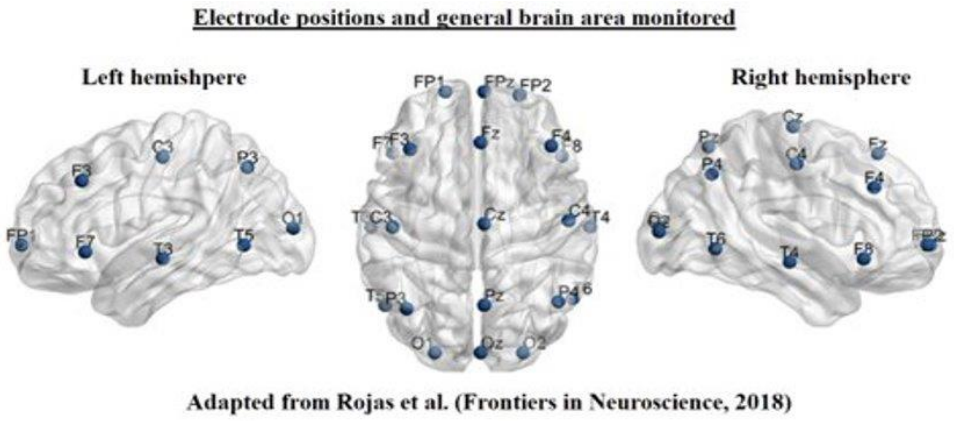
Farah et al. (1988) utilized a shared-representation paradigm in an ERP experiment with visual imagery. Their logic was as follows: If visual imagery and the representation of distal visual stimuli are similarly represented in visual areas of the brain, then the formation of a visual image of a specific stimulus just before the same stimulus is presented as a distal stimulus should affect ERPs more strongly (from summation) than if a visual image of the stimulus had not been previously formed. ERP results showed an effect of imagery within 200 ms of distal stimulus presentation, directly over the visual cortex (i.e. over occipital and posterior temporal scalp electrodes). Farah et al's (1988) results support the theory that visual images (which are generated in the absence of distal stimuli) and distal stimuii share the same representation in the visual cortex. A similar shared-representation paradigm was utilized in the present case study on aphantasia. The goal was to look for any indication of cortical representation of visual imagery when an individual with congenital aphantasia was instructed to attempt the formation of visual images.

Method

The study subject (AS) was a 25-year-old male with congenital aphantasia. The participant had normal visual acuity and contrast sensitivity (Hamilton-Veale). The participant scored 4.9/5 on the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973). The VVIQ rates the vividness of an image along a 5- point scale, a rating of 1 would indicate the image is perfectly clear and as vivid as real life, a rating of 5 indicates no vividness or image at all.

The adult male aphantasia subject (AS) was tasked with attempting imagery of the letter 'H' when given an audio cue (Attempted Imagery condition), or waiting passively (Control condition), until a low contrast letter 'H' or 'Y' was presented on a screen. A forced-choice manual response was made to indicate what letter (H or Y) was presented on the screen. Electroencephalographic data were collected for 300 trials per Imagery/Control session over 6 days, using an IWORX EEG 19-electrode system. Electrode positions and general brain areas monitored are shown in Figure 1.

Figure 1



Adapted from Rojas et al. (Frontiers in Neuroscience, 2018)

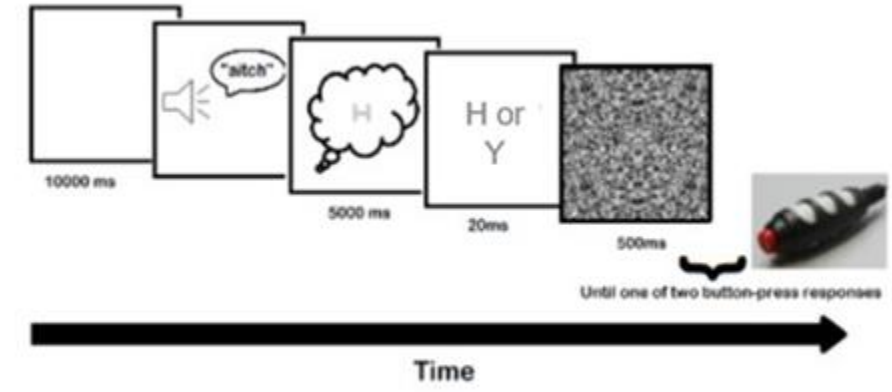
To prepare the subject (AS) for IWORX EEG recording, several steps were taken to ensure efficacy and standardization. First, AS was placed in an elastic body harness around the chest and under the armpits secured by Velcro. Disposable sponge disks were then placed around the Fp1 and Fp2 forehead electrode mounts in the cap. After taking anatomical measurements, the IWORX EEG 19-electrode cap was placed on the subject's head and attached to the body harness. Once secured, the cap was connected to the EEG recorder. Lastly, each electrode cavity was filled with EEG gel to retain low impedance.

The participant was tasked with sitting directly in front of a Dell 16" monitor that presented the visual and audio stimuli. The stimuli in the study consisted of a supra-threshold audio of the letter 'H' and a 1 deg x 1 deg low contrast grey 'H' or 'Y'. There were two experimental conditions (see schematic description of the procedure in Figure 2A). The first was

attempted visual imagery. In this condition the participant was tasked with attempting imagery of the letter ‘H’ if they heard the audio cue of the letter ‘H’. At the start of each trial, a blank screen was displayed on the monitor for 10000 ms before the audio was played. After the cue ‘H’ was played, there was a 5000 millisecond pause. After the pause, a low contrast ‘H’ or ‘Y’ appeared on the screen for 20 ms. The letter was immediately followed by a random dot mask for 500 ms, which cleared any remnant of the H or Y stimulus beyond 20 ms in sensory memory. After this masking stage, the participant was tasked with using an Event Marker to respond to the stimuli just shown. AS was instructed to click the Event Marker once if he saw an ‘H’ stimuli and twice if he saw a ‘Y’. The second condition was identical to the first condition, but no audio ‘H’ was played thus visual imagery was not cued or attempted (see Figure 2B).

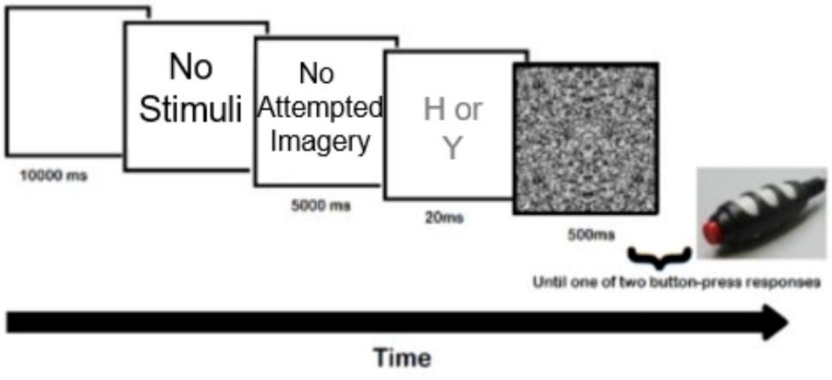
Figure 2

A. *Condition 1: Attempted Visual Imagery*



Schematic description of the procedure

B *Condition 2: No Visual Imagery Attempted*



Schematic description of the procedure

Results and Discussion

The primary concern in the present case study was evidence of image generation in aphantasia in/near the visual cortex (O1, O2, T5, T6). After preprocessing for blink artifacts, event-related potentials (ERPs) within 1s of screen stimulus onset were averaged. Preprocessing and the computation of average ERPs were done using MATLAB and open source software, eeglab and erplab. For comparison, ERP profiles for the *difference* between Attempted Visual Imagery and No Visual Imagery Attempted conditions are reported (see Figure 3). In this context,a zero deflection indicates that the participant showed no difference in cortical response in the Attempted Visual Imagery and No Visual Imagery Attempted conditions. Outlier deflections beyond 0$\pm$1.96 standard deviations of a condition's mean mV were interpreted as a difference between Attempted Visual Imagery and No Visual Imagery Attempted.

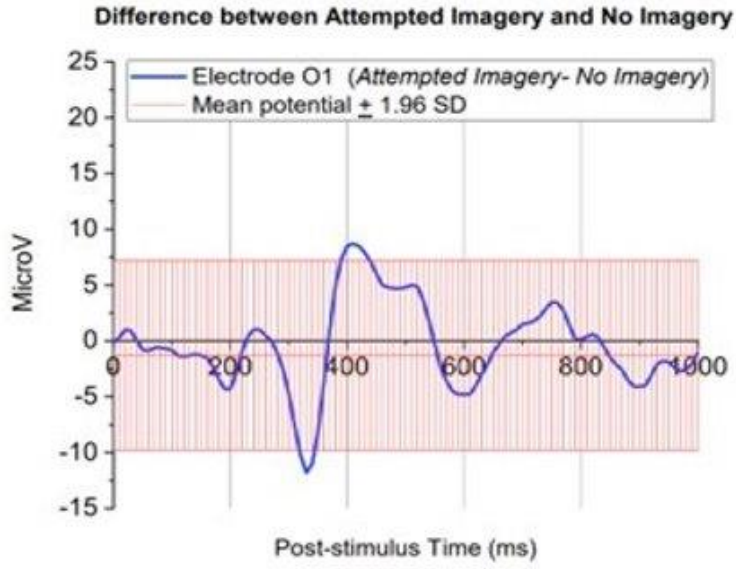
There were periods of persistent outlying difference seen at the 300-400ms point (i.e. P300) in the Occipital lobes, and 600-700ms point (i.e. N700) in the Temporal lobes. P300 and N700 represent working memory and conscious stimulus recognition processing (Bender et al., 2008). A large positive difference deflections in occipital lobes around 300-400ms indicated that the Attempted Visual Imagery condition had a more positive P300 than the No Visual Imagery Attempted condition at this point (Figure 3A and also Figure 3B). In addition, a large negative difference deflections at 600-700 ms in the temporal lobes (near the visual cortex) indicated that the Attempted Visual Imagery condition had a more negative N700 than the No Visual Imagery Attempted condition at this point (Figure 3C and also Figure 3D).

Comparison with Farah et al. (1988)

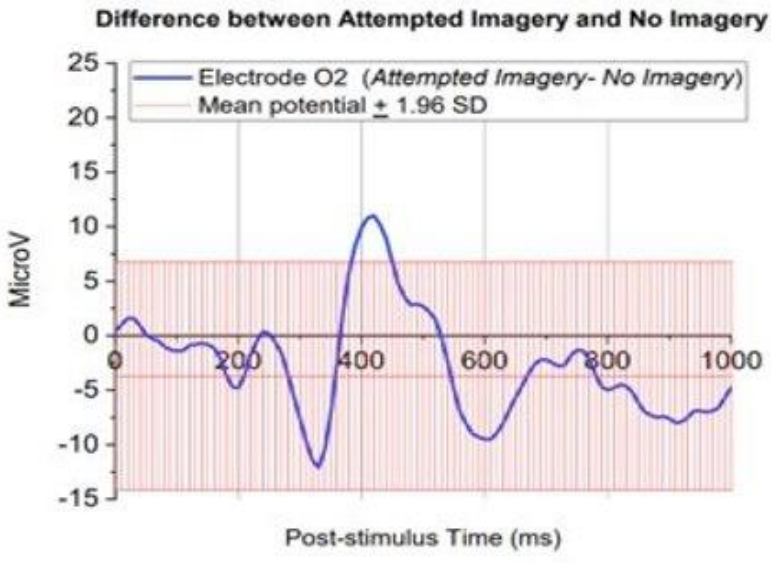
Farah et al. (1988) showed an effect of visual imagery for non-aphantasic participants within 200 ms of distal stimulus presentation, over occipital and posterior temporal scalp electrodes. A more negative N200 was observed if the stimulus was imagined before it was presented on the screen. N200 is hypothesized to be indicative of early stages of object categorization (see Woodman, 2010). In the present case study, there was a small negative difference deflections at 200 ms indicating that Attempted Visual Imagery condition had a more negative N200 than No Visual Imagery Attempted condition at that point. The present trend for the aphantasic participant matches the results of Farah et al. (1988) for non-aphantasic participants.

Figure 3 *Difference* between Attempted Visual Imagery and No Visual Imagery Attempted. The results are suggestive of cortical representation of visual imagery when this individual with congenital aphantasia was instructed to attempt the formation of visual images.

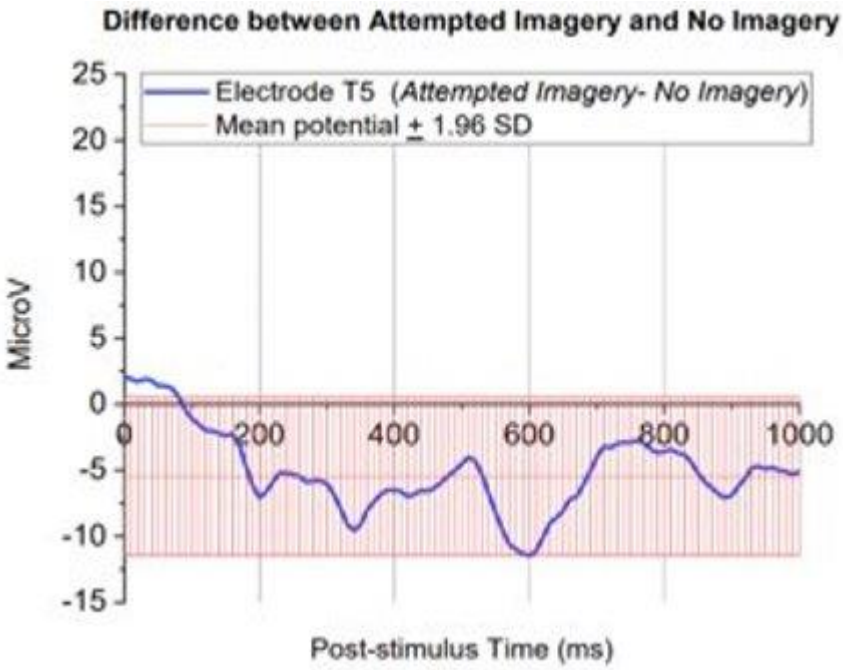
A.



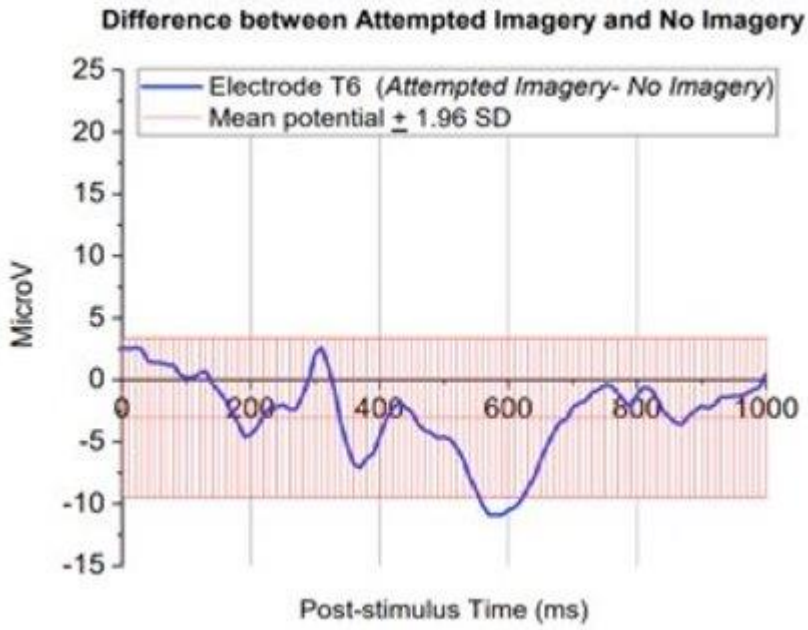
B.



C.



D.



Conclusion

The results of the present case study may be interpreted as evidence for unconscious visual imagery priming in the case of participant AS who has congenital aphantasia. Of course, a

comprehensive account of visual image generation in aphantasia requires more experiments, with more aphantasic participants. Nevertheless, the discernable difference in brain activity when visual imagery is attempted provides us with further insight into future directions of study. Determining how the brain functions regarding visual imagery can better prepare us to deal with common neurological disorders like schizophrenia (Mazer et al., 2021) and neurodegenerative diseases like dementia (Horvath, 2018) , all of which are characterized by faulty mental image generation. The IWORX IX-EEG system is allowing us to pursue our goal of determining how the brain generates mental representations that are not present as distal stimuli.

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