To study Selective Attention and Cognitive Control through a Visual Letter Oddball Experiment with a Go/no-go Paradigm

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GitHub link:
https://github.com/devanship-stack/PSY310/tree/SOLO-project

Abstract

In neuroscience, the P300 is described as a positive deflection in an event-related potential (ERP) that occurs approximately 300 milliseconds after a participant recognizes a stimulus that is relevant to their task. It is a key indicator of cognitive functions like working memory, attention, and stimulus assessment. An "oddball paradigm" is used to measure the P300 by presenting a rare target stimulus among frequent, non-target stimuli. The present study examined selective attention, cognitive and inhibitory control, and stimulus evaluation using a simple visual letter oddball task, and incorporating the Go/no-go paradigm. This experiment does not complexify the study by integrating electrophysiological measures such as P300 in ERP (experimentally done through an electroencephalograph), whereas it uses the reaction time (RT) and accuracy as behavioral indicators of attentional efficiency and response control. In the experiment, the participants were supposed to detect a rare oddball target stimuli among repetitive frequent non-target stimuli. The results showed that all the participants exhibited high cognitive and inhibitory control and were able to adequately detect and attend to the target stimuli.

Introduction

A key element of selective attention and cognitive control is the effective identification of infrequent and task-relevant events. A simple yet efficient technique for assessing these cognitive processes is the visual oddball paradigm, in which participants must identify infrequent "oddball" events among a stream of regular standard stimuli.

The P300 is an important and extensively explored late component of ERPs that is widely applied to assess cognitive function in humans. The P300 wave is an event-related brain potential measured using electroencephalography (EEG). P300 refers to a spike in activity approximately 300 ms following the presentation of the target stimulus, which is alternated with standard stimuli to create an ‘oddball’ paradigm. Instead of responding to the frequent standard stimulus, the individual must only react to the occasional target stimulus (Sandy, 2013). The amplitude of the P300 response is proportional to the amount of attentional resource committed to the job and the degree of information processing required, while the latency is regarded as a measure of stimulus classification speed and is unrelated to behavioral response time. According to Twomey et al. (2015), we discover that the P300 reaches a stereotyped amplitude just before response execution, and that its rate of rise scales with target detection difficulty and explains trial-to-trial variation in RT.

Although the oddball task is widely used in electrophysiological research to elicit the P3b event-related potential (Polich, 2007), its behavioral measures alone- reaction time (RT) and accuracy- also provide rich insight into attentional allocation, decision-making efficiency, and response inhibition.

Another aspect of the experiment conducted below is the inclusion of the “Go/No-go” paradigm. Response inhibition, also known as inhibitory control, is an executive function that entails managing one's thoughts, emotions, behavior, and/or attention in order to overcome a strong internal tendency or a compelling external stimulus (Meule, 2017). Go/No-go tasks are used to measure this kind of inhibitory control. When specific stimuli (i.e., targets) are shown on a computer screen, participants in these tasks are typically required to perform a quick motor response (e.g., pressing a button on a keyboard as fast as possible) and to withhold this reaction for other stimuli (i.e., non-targets; also called distractors or lures). The accuracy (based on hit rates) and commission rates (based on false alarm rates) of the participants are then calculated to assess their inhibitory control and signal detection.

In the present task, I have used frequent standard letters that served as distractors requiring no response, while a rare target letter required a speeded keypress. The letters were chosen such that both the stimuli had more feature similarities than dissimilarities, for the standard stimuli to serve as a distractor. It was hypothesised that the participants would have a significantly greater hit rate for targets, showing reliable stimulus discrimination and detection, and would exhibit fewer commission rates, showing a biased and intact inhibition control.

Method

Participants

A total of 6 students from Ahmedabad University- all of them being 20 years old, participated in this experiment. The participants of this study were briefed about the experiment and its purpose, which was to understand cognitive control and signal detection. The participants’ were briefed about the procedure of the experiment and their consent was taken. They volunteered to participate and were promised anonymity. No reward was given to the participants as compensation for their participation.

Apparatus and Stimuli

The experiment was designed on PsychoPy Builder v2021.2.3, on a desktop of 1440 x 900 pixels. The stimuli I chose were two letter stimuli- the letter ‘Q’ being the frequent standard stimuli and the letter ‘O’ being the infrequent target stimuli.

Procedure and Design

The experiment was a within-subjects design. The independent variable was the differentiating stimuli (standard vs target oddball), and the dependent variables were reaction time (RT) and accuracy, and commission error rates.

The participants were first presented with clear instructions on the screen- “press the spacebar when you see the letter ‘O’. Do not press any key for any other letter” (Figure 1), which required them to make a key response. Following a fixation (a small circle for 300 milliseconds), the participants were presented with the frequent standard stimuli (70% probability of appearing on the screen) of the letter ‘Q’ (Figure 2) and the infrequent target stimuli (30% probability of appearing on the screen) of the letter ‘O’ (Figure 3).

The stimuli were presented for 1000 milliseconds, and in a random order. The participants were required to press the spacebar when the letter ‘O’ (target stimuli) appeared, and had to make no such response when they were presented with the letter ‘Q’ (standard stimuli). The response frame given to the participants was 1000 milliseconds. A total of 120 such trials were conducted and the correct-v/s-incorrect responses and the mean reaction time (RT) was measured.

Figure 1: Instructions

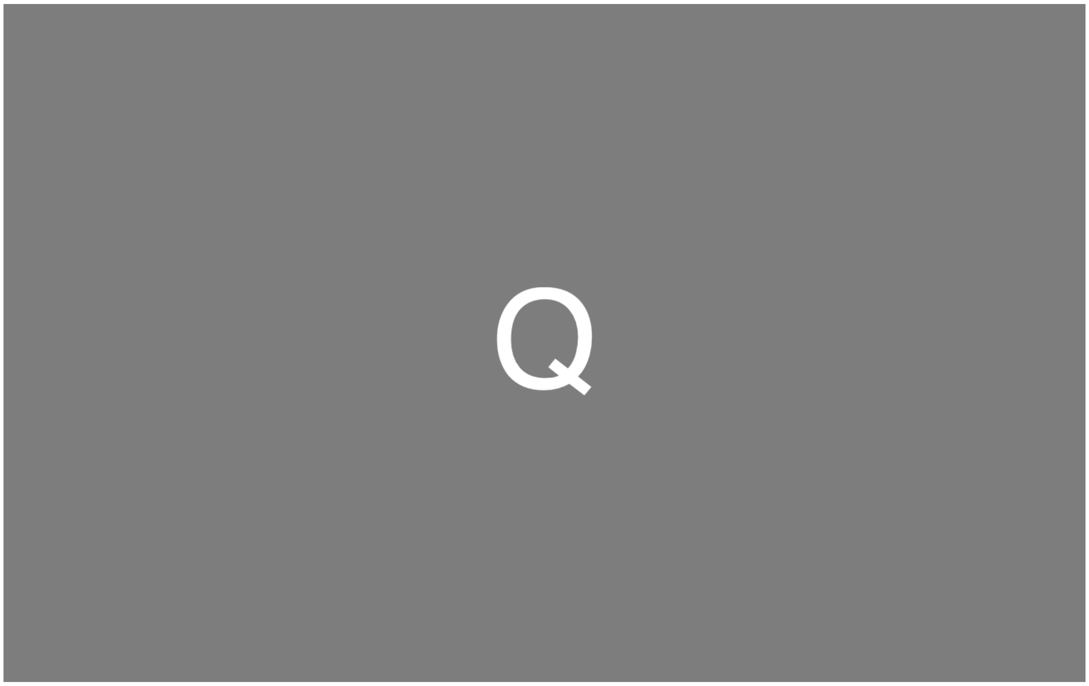

Figure 2: Standard stimulus- letter ‘Q’

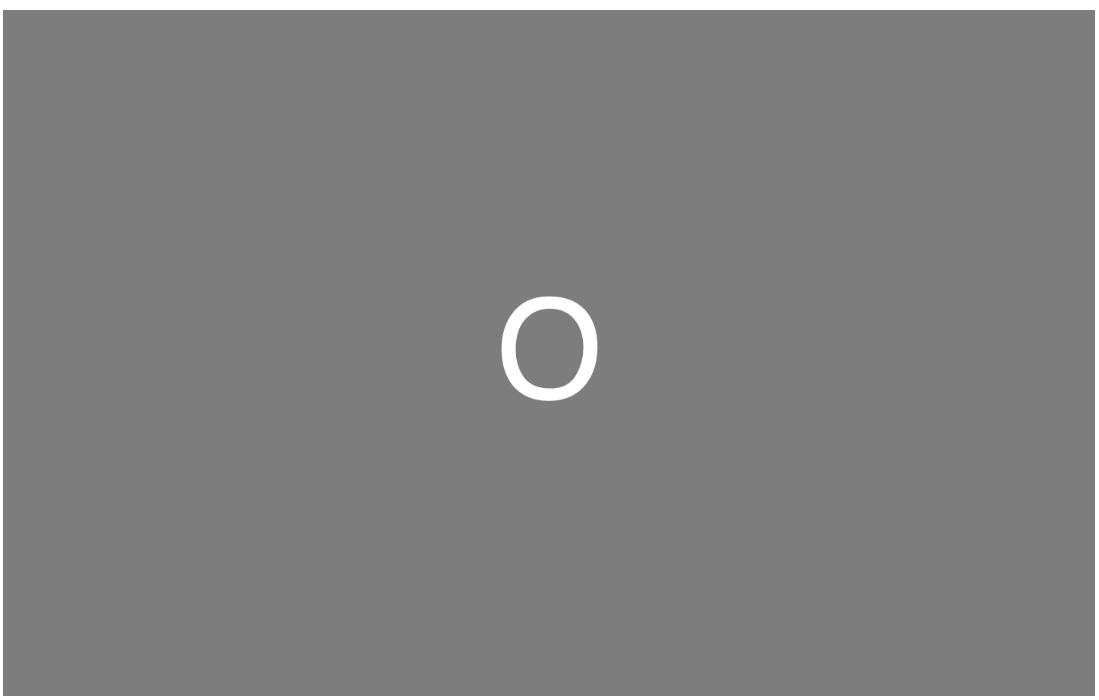

Figure 3: Target oddball stimulus- letter ‘O’

Results and Analysis

The mean RTs of each participant was calculated. Each participant's accuracy and commission rates (as per the correct vs incorrect responses for both the conditions) were calculated. Accuracy rates were calculated by finding the ratio of correct responses of 'O' to the total number of oddball target stimuli trials. Commission errors rates were calculated by finding the ratio of incorrect responses of 'Q' to the total number of standard stimuli trials.

Mean RTs (in ms)

Participant 1 (VO_SP 1): **0.550214725**
Participant 2 (VO_SP 2): **0.394762746**
Participant 3 (VO_SP 3): **0.462153545**
Participant 4 (VO_SP 4): **0.383896606**
Participant 5 (VO_SP 5): **0.450014966**
Participant 6 (VO_SP 6): **0.431247736**

Accuracy and commission rates

Participant 1 (VO_SP 1): **Accuracy rate = 0.944444444, Commission rate = 0**
Participant 2 (VO_SP 2): **Accuracy rate = 1, Commission rate = 0.071428571**
Participant 3 (VO_SP 3): **Accuracy rate = 1, Commission rate = 0.011904762**
Participant 4 (VO_SP 4): **Accuracy rate = 1, Commission rate = 0.035714286**
Participant 5 (VO_SP 5): **Accuracy rate = 1, Commission rate = 0**
Participant 6 (VO_SP 6): **Accuracy rate = 1, Commission rate = 0.023809524**

I did not calculate a paired t-test for the accuracy rates and commission rates, because the two in question are psychologically different constructs, and unmatched and asymmetric conditions. A go/no-go task does not use such comparison for ERP measures, as one condition requires responding, while the other requires response inhibition.

Discussion

As per the data collected, I found that for five out of six participants, the accuracy was 100%, and on an average, the accuracy was about 99.07%. The commission rates ranged from about 0 to 7%. Such numbers gave an insight to the attention, cognitive and inhibitory control of an individual. As mentioned earlier, visual oddball tasks are good measures of P300 components which attribute to selective attention, and cognitive control. Behavioral indicators such as reaction time (RT) and accuracy are strongly linked to the neurological processes that generate the P3a and P3b event-related potential (ERP) components.

P3a stems from stimulus-driven frontal attention mechanisms during task processing, while P3b comes from attention-related temporal-parietal activity and seems to be connected to later memory processing (Polich, 2007). The orienting response and the involuntary capture of attention are frequently linked to the P3a component (Jiang et al., 2025). Many people believe that the P3b is a neural signature of context updating and the assessment of a stimulus in the context of the present task.

Faster (RTs) or more accurate behavioral responses indicate a stronger P3a response which causes a more effective allocation of attention to the new stimulus. There is a strong correlation between the quickness of a behavioral response and the latency (timing) of the P3b component. Shorter P3b latencies are correlated with faster RTs, indicating that the brain takes less time to assess the stimulus and generate the consequent behavioral response. Task performance and the certainty of the stimulus evaluation are frequently correlated with the amplitude (size) of the P3b component. Larger P3b amplitudes are generally linked to higher accuracy (hit rates and lesser commission errors). A larger amplitude is thought to reflect a more robust neural commitment to processing the stimulus and updating working memory with the correct information, as was seen in the accuracy rates and commission rates of all the participants.

References

Jiang, C., Wang, J., & Sun, Y. (2025, March). Unveiling distinct representations of P3a in schizophrenia through two-stimulus and three-stimulus auditory oddball paradigms. *Schizophrenia Research*, *277*, 159-168. https://www.sciencedirect.com/science/article/abs/pii/S0920996425000684

Meule, A. (2017, May 9). Reporting and Interpreting Task Performance in Go/No-Go Affective Shifting Tasks. *Frontiers in Psychology*, *8*. https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2017.00701/full#B6

Polich, J. (2007, October). Updating P300: An Integrative Theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128–2148. https://www.sciencedirect.com/science/article/abs/pii/S1388245707001897

Sandy. (2013, May 15). *P300*. NeuRA Library. https://library.neura.edu.au/schizophrenia/physical-features/functional-changes/electrophysiology/p300/index.html#:~:text=The%20P300%20wave%20is%20an%20event%2Drelated%20brain,which%20alternates%20target%20stimuli%20with%20standard%20stimuli.

Twomey, D. M., Murphy, P. R., Kelly, S. P., & O'Connell, R. G. (2015, April 29). The classic P300 encodes a build-to-threshold decision variable. *European Journal of Neuroscience*, *42*(1), 1636-1643. https://onlinelibrary.wiley.com/doi/abs/10.1111/ejn.12936