Does volitional attention operate the same across domains? An investigation of willed attention to color

John Nadra, MA[1], Mingzhou Ding, PhD[2] & George R. Mangun, PhD[1]

[1]Center for Mind and Brain, University of California, Davis [2] J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida

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Introduction

Attention that is focused by an observer's free choices (willed attention) rather than by external cues has been studied during covert spatial attention[1-4]. Willed attention involves novel neural activity prior to and following decisions to attend in comparison to instructed attention. Whether the neural signatures of willed attention are specific to spatial attention remain unknown. Using EEG, we tested whether the willed attention findings from covert spatial attention are generalizable, which would indicate that regardless of domain, pre-cue electrophysiological signals can predict decisions to attend in a task-constrained free choice design, or whether predictive EEG activity in willed attention is specific to covert spatial attention, which indicates a distinction between domains. We also tested whether the orienting of attention to color is manifested in the alpha-band (8-12Hz) after a prompt to choose between two colors.

Methods

Participants were presented with one of three spoken words, either "Orange", "Purple", or "Choose". The 'color' words acted as instructions to selectively attend to the cued color in order to discriminate the orientation of a line segment in that color. The word "Choose" served as a prompt that the observer was to (willfully) choose between the two colors, and then complete the orientation task. The stimulus arrays consisted of 9 oriented line segments; on 80% of trials the line segments were all in different colors, on 10% of the trials only the colors orange and purple were presented, and on the final 10% of trials only one of these two colors was presented (which could be either cued/chosen or uncued/unchosen color); all trials were randomly interleaved. The support vector machine decoding analysis presented here focuses exclusively on the "choose" cues in the main (80%) condition, however, the 10% of trials having only one color permitted reaction time measures of attention (cued vs. uncued) to be obtained, thus validating the attention task. EEG was recorded from 64 scalp electrodes while subjects performed the task. Eye position was monitored using an infrared system.

Figure 1. The color willed attention paradigm.

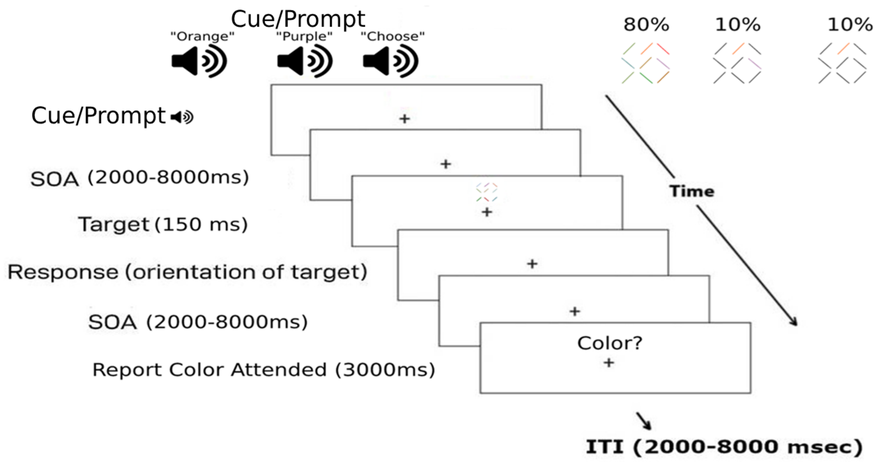


Figure 2a & 2b. Reaction times showing attention validity effect ('only one color' condition)

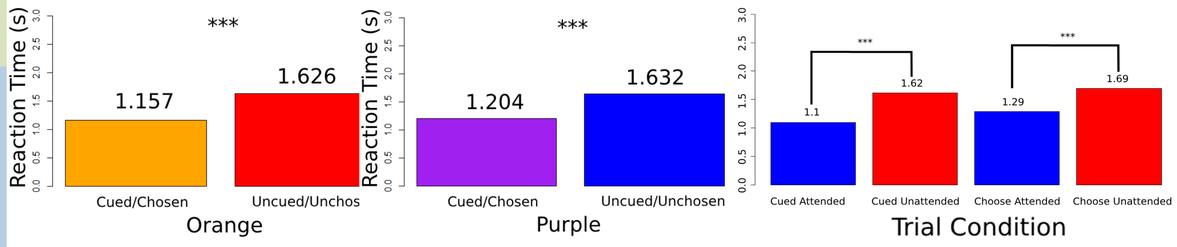


Figure 3. Support Vector Machine decoding before the auditory 'choose' prompt.

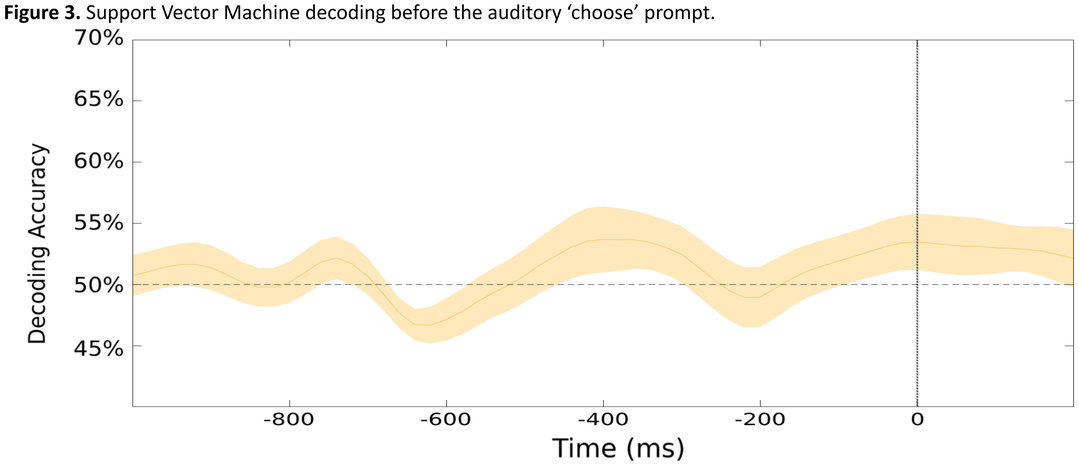
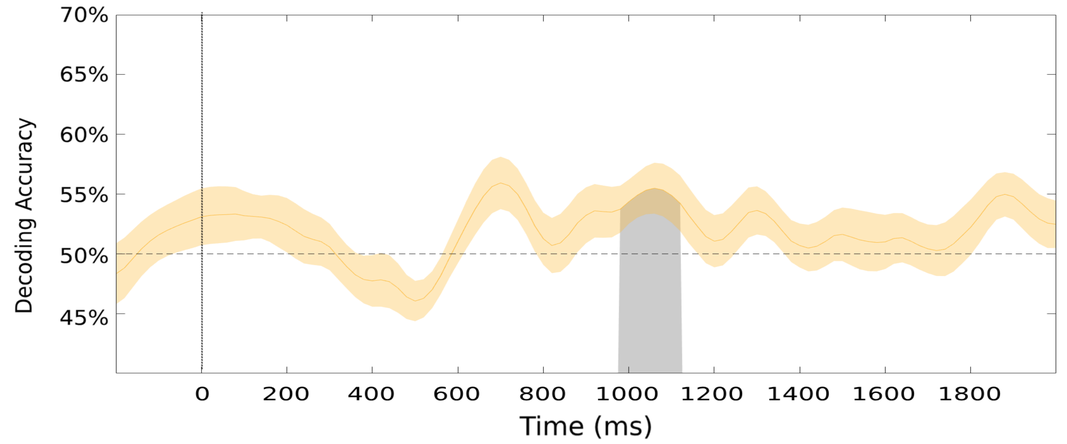


Figure 4. Support Vector Machine decoding after the auditory 'choose' prompt.



Results

Reaction times in the 10% one-color only condition are shown in Figure 2. Observers were faster to respond with the orientation of the cued color than the uncued color, thus demonstrating that subjects were allocating attention to the cued colors. Using a support vector machine decoding pipeline that compares two classes over each timepoint of the scalp-recorded EEG alpha band (8-12 Hz), we did not find a significant effect in the pre-prompt period (Figure 3). Using the same pipeline in the prompt-to-target period, we could decode a willed shift of attention to a color (orange or purple) after a prompt signaling a willed choice (Figure 4). This decoding of chosen color became statistically significant 1000 msec post choice.

Conclusion

In this project, we investigated whether free choices decisions to shift attention to individual colors (either orange or purple) are decodable in alpha-band EEG (8-12 Hz) across periods of time both preceding and succeeding a prompt to shift attention. This work follows up on willed attention research in covert spatial attention across various paradigms, with the goal of isolating the neural mechanisms of a decision to attend in the absence of external cues. Expanding the study of willed attention past the realm of covert spatial attention, this project found that predictive alpha-band EEG activity before the onset of a prompt to shift covert attention is not found in color attention, suggesting different underlying mechanisms across domains. However, this project has found that willed shifts of attention to one of two different colors are decodable in the prompt-to-target period, thus unveiling the electrophysiological mechanisms supporting willed attentional orienting to color. Isolating the neural mechanisms underlying a decision to attend across domains (i.e., space, feature, object, etc.) will provide insights into the nature of purely voluntary attention decisions, which could have a great impact on the development of online brain computer interfaces.

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