

The effect of directing early attention on the central attentional limitation of dual tasks with various difficulty levels: An event-related potential study

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Abstract

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Introduction: It was shown that directing early attention toward the target location enhances sensory-perceptual processing of the target. However, it is not clear whether visual-spatial attention is controlled by the limited capacity of central attention. This study aimed to investigate behavioral and electrophysiological changes, directing early attention on central attention limitations of dual tasks with various difficulty levels.

Methods: Twenty-four participants were selected voluntarily, and they were randomly assigned into two groups with simple and selective. A dual-task paradigm with and without cue was incorporated in which the second task was either detection or discrimination, and the cue was presented before the first stimulus. The stimulus onset asynchrony between the first and second stimulus was 200, 400, and 800ms. The response time to the first and second stimulus and event-related potential was recorded and analyzed.

Results: The simple pattern had a faster response time than the combined pattern. Also, the response time of the target in the valid position was faster than the invalid position. The lowest response time was for the simple group and the highest for the selected group. The main effect of pattern, group, and time interval on primary sensory components P1 and N1 was significant.

Conclusion: Facilitating the early sensory-perceptual by directing attention toward the cued location would reduce the dual-task interference.

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Extended Abstract

Introduction

Several empirical results demonstrate that the human information processing system is sharply limited in several different ways. Visual-spatial attention is critical for selectively processing the most relevant visual stimuli in

the early stage of processing (4). It seems that more than one stimulus can proceed in the early stage of processing. Another limitation arises in multitasking situations, in which relevant information after early selection would be

processed more in the later capacity-limited stage(s). The psychological refractory period (PRP) paradigm has been used extensively to study attentional limitations in the central or late processing stages (15). There are two types of hypotheses concerning the interaction of visual-spatial attention and response selection capacity-limited stages (16). Some studies have provided evidence that they operate independently, while others have provided evidence in conflict with these results. The current study presents new evidence to add valuable empirical evidence about the relation between orienting and central attentional limitation by manipulating visual-spatial attention and central attention in a modified PRP paradigm.

Methods

Twenty-four students were recruited with flyers posted on the Shahid Beheshti University campus. Participants' age ranged from 18 to 30 years, and three participants were left-handed. Within each trial, three main stimulus events were presented in succession (cue, target 1, and target 2). Only T1 and T2 required a response to be made; however, the cue did not require any response. Four trial conditions emerging from the combination of two cue conditions and two types of T2. T1 could be either cued or uncued; the cue and target locations were the same in cued trials. In the uncued condition, the cue was in the opposite location to that of T1. T2 was either a detection or discrimination task. In detection trials, T2 was the detection task, and T2 was the colored discrimination task in discrimination trials. The response time to the first and second stimulus and event-related potential was recorded and analyzed.

Results

A 2x2 x3 within-subjects ANOVA was used to analyze RT1 data for trials, with groups (detection, discrimination), cueing (cued, uncued), and SOA (200, 400, 900ms)

as factors. The main effect of the group on RT1 was significant, $F(1, 23)=16.706$, $P<0.001$; with RT1s being slower overall to the detection group ($M=557.0$) than the discrimination group ($M=738.0$). Cueing had a significant effect on RT1, $F(1, 23)=8.56$, $P<0.008$, with RT1s being slower overall to the cued location ($M=630.0$ ms) than the uncued location ($M=684.3$ ms). The main effect of SOA on RT1 was significant, $F(2, 46)=20.33$, $P<0.001$; as SOA decreased, RT1 increased. None of the two-way interactions and three-way interactions on RT1 was significant.

A 2x2x3 within-subjects ANOVA was used to analyze RT2 data for trials, with groups (detection, discrimination), cueing (cued, uncued), and SOA (200, 400, 900ms) as factors. The main effect of group on RT2 was significant, $F(1, 23)=50.095$, $P<0.001$; with RT2s being slower overall to the detection group ($M=546.0$) than the discrimination group ($M=701.0$). Cueing had a significant effect on RT2, $F(1, 23)=8.56$, $P<0.008$, with RT2s being slower overall to the cued location ($M=582.0$ ms) than the uncued location ($M=665.3$ ms). The main effect of SOA on RT2 was significant, $F(2, 46)=8.24$, $P<0.001$; as SOA decreased, RT1 increased. None of the two-way interactions and three-way interactions on RT2 was significant.

Mean response times to the first and second stimulus were significantly faster in the valid than in the invalid condition ($F=8.56$, $P=0.009$). In Short SOA, analyses on T2-locked ERPs revealed that the amplitude of the occipital P1 ($MD=2.44$, $t=3.12$, $P=0.007$) and N1 ($MD=2.49$, $t=4.05$, $P=0.001$) was more significant in the valid cue condition than in the invalid cue condition. In long SOA, the occipital P1 ($MD=2.28$, $t=3.67$, $P=0.002$) and N1 ($MD=2.18$, $t=2.49$, $P=0.02$) was more significant in the valid than invalid condition. The latency of the occipital P2 was more significant in the valid than invalid condition ($MD=1.73$, $t=6.79$, $P=0.04$).

The simple pattern had a faster response time than the combined pattern. The main effect of pattern, group, and time interval on primary sensory components P1 and N1 was significant.

Conclusion

The present study used a spatial cue as a tool to orient visual-spatial attention in the context of the psychological refractory period paradigm. This combination of different paradigms allowed to study the underlying mechanisms that mediate visual spatial attention and central attentional operation.

Interestingly, the obtained results showed a significant reduction in PRP interference in the cued conditions (RT2 was smaller at the cued conditions than uncued conditions across all task 2 difficulty and SOAs). It suggests that the facilitation effect of orienting on task1 processing had consequence effects on the second task processing. There are some explanations for these findings based on bottleneck models and capacity sharing models. Each of these theories that consider facilitation in the first task processing stages leads to whether a decrement in the waiting time of the second task to begin its processing (based on the bottleneck models) or to allocate more attentional capacity to the second task (based on the capacity-sharing model). Therefore, facilitation of the first task processing in the PRP paradigm affected the second task processing, resulting in more negligible PRP interference. These findings provided evidence for an interaction between the visuospatial attention and central attentional limitation, which is consistent with electrophysiological evidence presented by Brisson and Jolicœur (2007) (16) and Lien et al. 2011 (13). However, this finding did not prove the findings from Pashler 1998 (7), Pashler 1991 (14), Johnston et al. 1995 (15). Therefore, facilitating the early sensory-perceptual by directing attention toward the cued

location would reduce the dual-task interference.

Ethical Considerations

Compliance with ethical guidelines

All methods were carried out in accordance with the relevant guidelines and regulations of the Biological Research Ethics Committee of Shahid Beheshti University. All the experimental protocols were approved by the Biological Research Ethics Committee of Shahid Beheshti University (IR.SBU.REC.1395.002). Informed consent was obtained from the participants before participating in the study. Besides, all participants were free to cancel their cooperation at any stage of the test.

Authors' contributions

Maryam Kavyani and Alireza Farsi: Designed and conceived the presented idea, performed experiments, analyzed data and co-wrote the paper. Maryam Kavyani: Performed testing section during the experiment. Maryam Kavyani, Alireza Farsi, and Behrouz Abdoli Supervised the research. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

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Conflict of interest

The authors acknowledged no potential conflicts of interest regarding this article's research, authorship, and/or publication.