Relative effectiveness of attention capture between color singleton and working memory

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INTRODUCTION

The perceptual load (PL) hypothesis claims that PL is a determining factor of attentional selection. The PL task utilizes an Eriksen type flanker task, in which the main task is target discrimination (e.g., discriminate between N and X). When PL is low, attentional resources spill over to process a response-related distractor, resulting in a compatibility effect (late selection). However, when PL is high, attentional resources are exhausted to process stimuli containing a target; and therefore no resources are left to process a response-related distractor, resulting in no compatibility effect (early selection). However, recent studies showed that distractor processing might be affected by other factors such as stimulus saliency (e.g., Biggs & Gibson, 2010; Elititi et al., 2005; Gaspelin et al., 2012; Theeuwes & Burger, 1998) and dilution (Tsal & Benoni, 2010). Content of working memory has also been shown to capture attention (e.g., Awh et al., 1998; Downing, 2001; Pashler & Shiu, 1999). In the present study, we manipulated color singleton and working memory content in high and low perceptual load (PL) displays, to investigate relative effectiveness of attention capture among the three factors.

Experiment 1

METHODS

Participants. 19 undergraduate students (Males and females) from California State University, San Bernardino (CSUSB) participated for course credit. They gave the informed consent that was approved by the Institutional Review Board.

Stimuli. The task was a visual search task with a PL manipulation, in which participants were asked to search for a target (N or X) with distractors. Set size was fixed at six items, and the stimulus items were arranged in a circular fashion around the central fixation point. Five letters were in green, including one target letter. There was one letter in red (color singleton). This letter was a response-related distractor, either the same as the target (response compatible) or as the alternative target (response incompatible). For the PL manipulation, a high PL display contained heterogeneous distractors (e.g., K, T, V, Y, Z), whereas a low PL display included homogeneous distractors (all Os). The design was a 2 (High vs. Low PL) X 2 (compatible vs. incompatible distracter).

Procedure. At the beginning of each trial, a central fixation point appeared followed by the visual search display for 200 msec. Participants were told to find the target (N or X) among green letters and to ignore the red item. They were told to press "n" key with their right index finger for the target "N" and the "m" key with right middle finger for "X". An example of the trial sequence is shown in Figure 1.

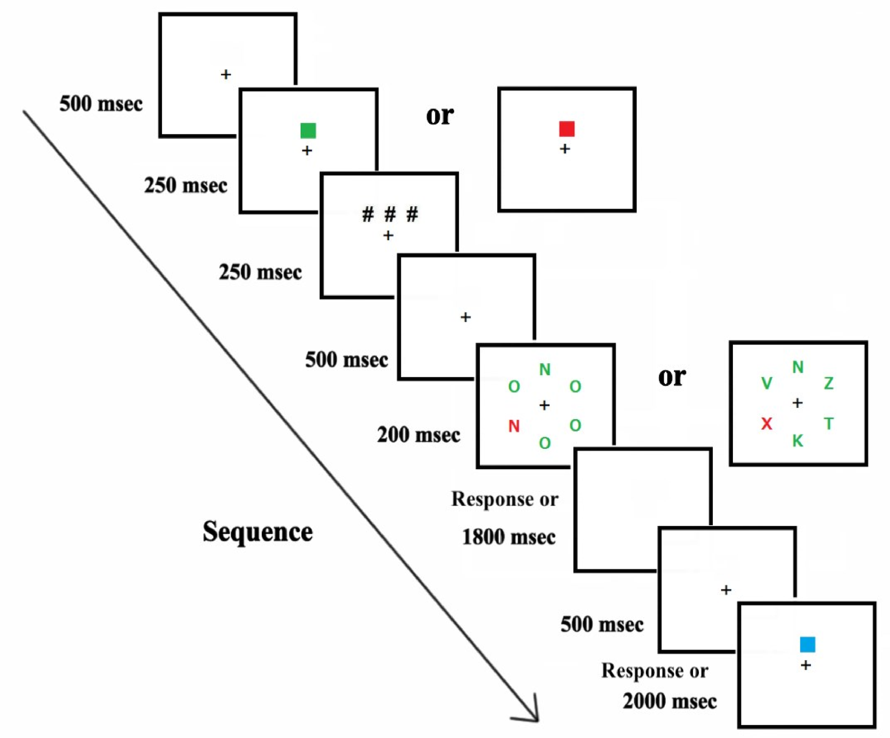

Figure. 1. Trial Sequence for Experiment 2. The trial sequence for Experiment 1 was identical, except there was no memory task.

RESULTS & DISCUSSION

Mean Reaction Times (RTs) were submitted to a 2 (PL) × 2 (Compatibility) within participant ANOVA. RTs were longer for high PL than for low PL, $F(1,18) = 32.88$, $p < 0.001$, $\eta_p^2 = 0.65$. There was a compatibility main effect, $F(1,18) = 85.82$, $p < 0.001$, $\eta_p^2 = 0.83$. However, there was no two-way interaction, $F(1,18) = 2.04$, $p = 0.17$, $\eta_p^2 = 0.10$.

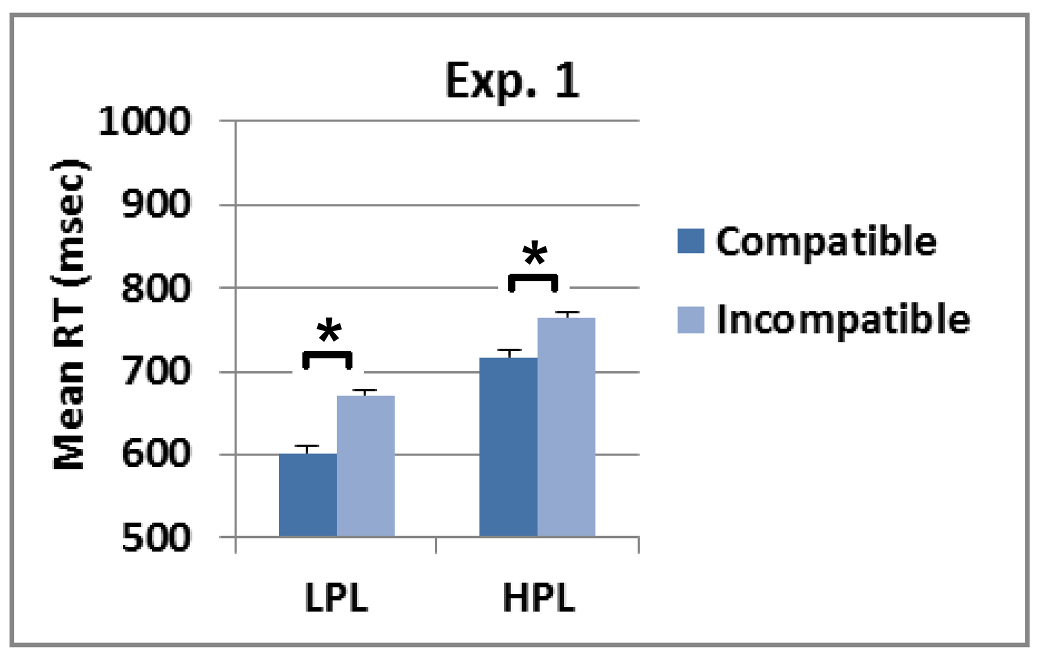

Figure 2. Measures of compatibility effect between the low and high PL conditions in Experiment 1. The compatibility effect is the difference in reaction time between compatible and incompatible conditions. Error bars represent standard errors. * shows a significant compatibility effect.

The main finding was that there were compatibility effects for both low PL and high PL conditions, though there was no difference between them. The color singleton distractor captured attention regardless of PL. The results are consistent with previous findings that suggested that PL is not the only determinant of attentional selection, and stimulus saliency such as color singleton could capture attention.

Experiment 2

METHODS

Participants. 12 undergraduate students (males and females) from California State University, San Bernardino participated in a 1 hour session.

Stimuli. Experiment 2 consisted of a dual task procedure, memory and visual search task. Stimuli for the visual search task were identical to Experiment 1. For the memory task, a color square was presented as a memory item before visual search. The memory square was placed above the fixation point. The memory item was either the same color as the target (Green, Memory Match Target) or as the singleton distractor (Red, Memory Match Distractor). A color square memory probe was presented after the visual search task. The design was 2 (WM) × 2 (PL) × 2 (Compatibility).

Procedure. At the beginning of each trial, a central fixation point was presented followed by a memory item. Then the visual search display was presented. Participants were given the same instructions for the visual search task as Experiment 1. After participants made a response to the visual search display. Then, a memory probe was presented and the participants were asked to decide whether or not the probe was the same as the memory item. If they were the same, participants were asked to press "x" key with the left index finger, and if they were different "z" key with the left middle finger.

RESULTS & DISCUSSION

Mean RTs were submitted to a 2 (PL) × 2 (Memory) × 2 (Compatibility) within participant ANOVA. RTs were longer for high PL than for low PL, $F(1,11) = 36.99$, $p < 0.001$, $\eta_p^2 = 0.77$. A memory main effect was not significant, $F(1,11) = 1.4$, $p = 0.27$, $\eta_p^2 = 0.11$. There was a compatibility main effect, $F(1,11) = 72.25$, $p < 0.001$, $\eta_p^2 = 0.87$. There was a two-way interaction between PL and compatibility, $F(1,11) = 7.01$, $p = 0.023$, $\eta_p^2 = 0.39$. No other effect reached statistical significance.

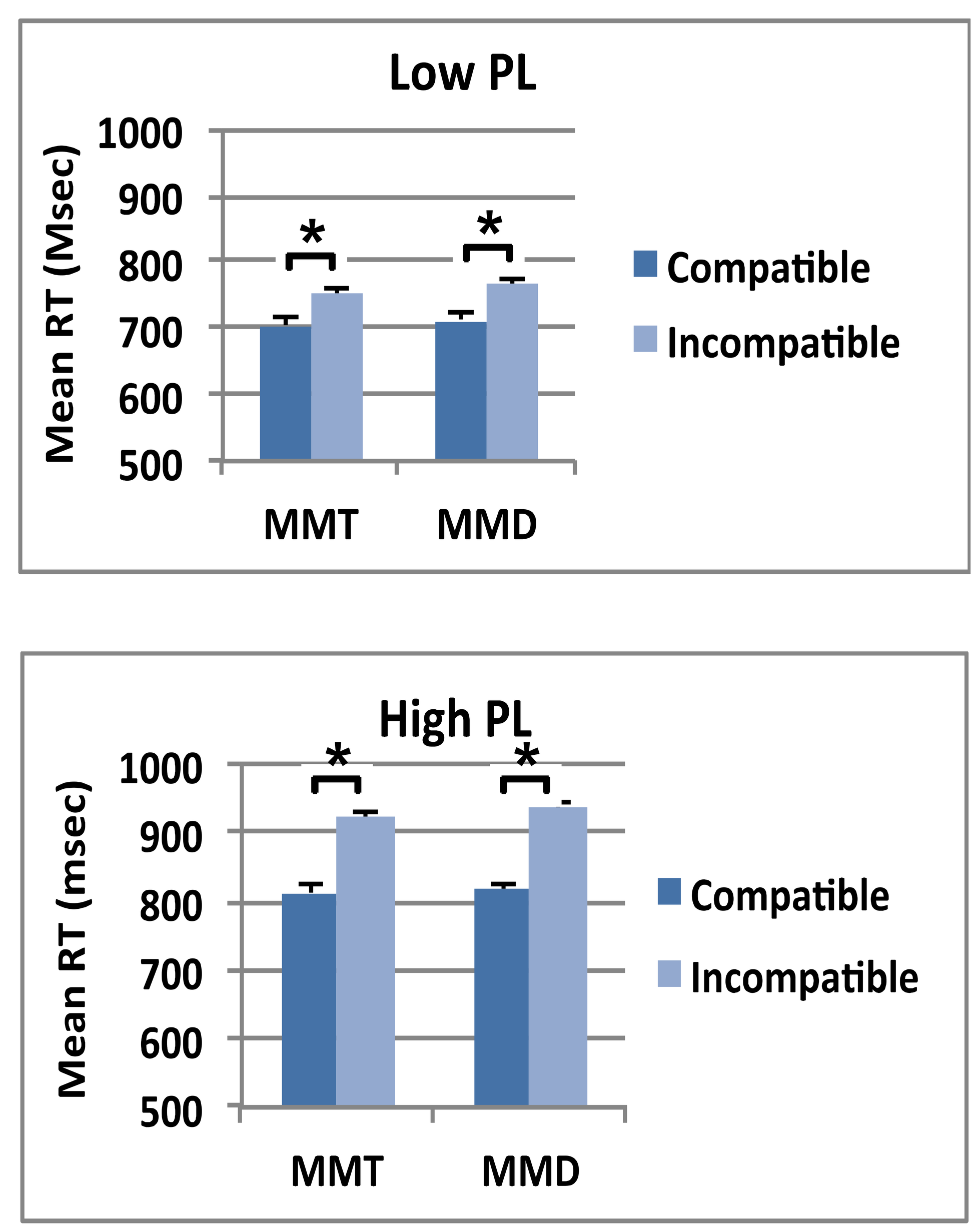

Figure 3. Measures of compatibility effect between the two memory conditions, and low and high PL conditions in Experiment 2. Error bars represent standard errors.

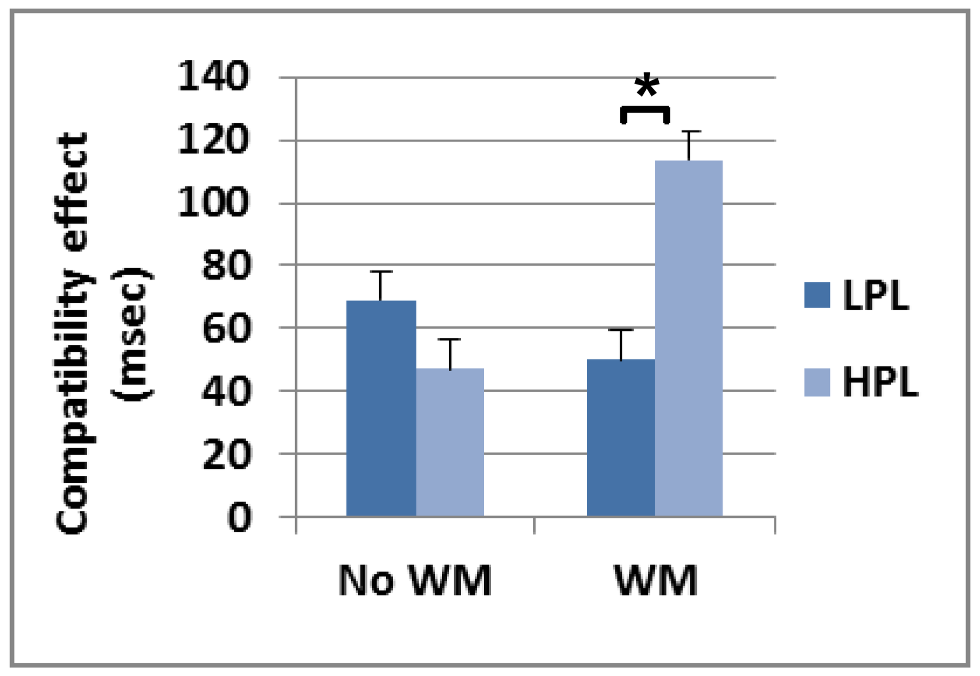

Figure 4. Measures of compatibility effect between the two Experiments, and high and low PL conditions. For Experiment 2, the data were collapsed across the two Memory conditions.

For the visual search task, Experiment 1 was a single task and Experiment 2 was a dual task; therefore, RT data for the visual search task from the two experiments were compared with 2 (Task) × 2 (PL) × 2 (Compatibility) mixed design ANOVA. Here, the data from Experiment 2 were collapsed across the two levels of the Memory condition because there was no memory effect. RTs were longer for high PL than for low PL condition, $F(1,29) = 68.85$, $p < 0.001$, $\eta_p^2 = 0.70$. RTs were shorter for compatible than for incompatible trials, $F(1,29) = 163.21$, $p < 0.001$, $\eta_p^2 = 0.85$. There was a Compatibility × Task interaction, $F(1,29) = 4.81$, $p = 0.036$, $\eta_p^2 = 0.14$. There was a three way interaction among PL × Compatibility × Task, $F(1,29) = 10.01$, $p = 0.004$, $\eta_p^2 = 0.26$. There was no difference in the compatibility effect between low PL and high PL for the single task, whereas the compatibility effect was higher for the high PL than for low PL for the dual task as shown in Figure 4.

CONCLUSIONS

The main findings in Experiment 2 are as follows. (1) The compatibility effect was greater for high PL than for low PL. (2) There was no difference between Memory Match Target and Memory Match Distractor; therefore, working memory did not have any effect on the magnitude of the compatibility effect. However, maintaining WM item increased the compatibility effect for high PL. This is related to the load theory of attention by Lavie et al., (2004), in which they claimed that PL decreases distractor interference, whereas WM load increases it. In our study, however, we manipulated the content of WM, not WM load. Therefore, it is possible that not only WM load but also WM content could increase distractor processing. In our study, one possibility is that participants were able to compartmentalize the WM content; and therefore, the WM content did not interfere with the target. However, the compartmentalization consumed some attentional resources, resulting in increase in the interference effect for high PL.

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