ATTENTIONAL SETS DO NOT IMPAIR THE EFFECT OF DILUTION IN SELECTIVE ATTENTION

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Abstract

Perceptual load theory (Lavie & Tsal, 1994; Lavie, 1995) proposes that distractors interference can be avoided only in situations of high perceptual load. The theory has been supported by blocked design manipulations separating low load (when the target appears alone) and high load (when the target is embedded among neutral letters). Tsal and Benoni (2010a; Benoni & Tsal, 2010) recently showed that these manipulations confound perceptual load with "dilution" (the mere presence of additional items in high load situations). Theeuwes, Kramer, and Belopolsky (2004), independently questioned load theory by showing similar distractor interference under high load and low load when the two conditions are intermixed. Their results also challenge the dilution account, which offers a stimulus driven mechanism. In the present study we separated the effects of dilution and load and tested the influence of attentional sets (fixed vs. mixed) on each factor. We found that whereas the load effect is influenced by expectancy of trial type, the effect of dilution is not influenced by attentional sets.

Over 15 years ago, Lavie and Tsal (1994; Lavie, 1995) proposed a Load Theory of visual selection. According to Perceptual Load Theory, attention is regarded as a limited resource allocated for processing items within the relevant visual field. In high load presentations, attention is completely consumed, and irrelevant items are not processed. In contrast, low load presentations do not deplete attention completely, and so irrelevant stimuli unintentionally capture spare capacity, which consequently leads to their processing.

In typical manipulations of perceptual load the target and distractor have appeared alone in the low load condition but in the presence of additional neutral elements in the high load condition. It has therefore been recently argued (Benoni & Tsal, 2010; Tsal & Benoni, 2010a; 2010b) that the reduction of distractor interference under the high load condition need not be attributed to increases in perceptual load resulting from the need to search for the target among the neutral letters. Instead, it could be due to the dilution of the distractor by the neutral letters as the representations of their features were highly activated in the process of searching for the target. To test this hypothesis, Tsal & Benoni (2010a, Benoni & Tsal, 2010) distinguished between the possible effects of perceptual load and dilution by introducing a third type of displays, the "Dilution" displays, which were characterized in low perceptual load, but high potential dilution. These new displays contained neutral letters (as in high load conditions) capable of diluting the distractor but ensured a low load processing mode as defined by the original theory (Lavie and Tsal, 1994). For example, in a multiple color display the target color was known in advance on the low load–high dilution condition but not in the high load condition (Tsal & Benoni, 2010a). Using a variety of converging operations, these experiments consistently showed that distractor processing was eliminated on Dilution displays, thereby supporting the conclusion that the elimination of distractor interference under the high load condition, repeatedly misattributed to perceptual load, is completely accounted for by dilution (for additional support for the dilution interpretation, see also Wilson, Muroi, & MacLeod, 2011).

Along with the Dilution account, there have been other studies which independently questioned load theory (e.g., Eltiti, Wallace & Fox, 2005; Johnson, McGrath & McNeil 2002; Paquet & Craig, 1997; Theeuwes, Kramer, & Belopolsky, 2004). Theeuwes, Kramer, and Belopolsky (2004), argued against the notion that attentional allocation is a completely stimulus-driven process, determined by the perceptual load of the target. Alternatively, they claimed that perceptual load might interact with the viewer's current attentional set, i.e. a strategy to spread attention to maximize performance in accordance with task demands (Theeuwes, 1994). To test their hypothesis, Theeuwes et al. tested the effect of perceptual load on distractor interference under mixed blocks, assuming that this design will encourage a broader attentional set. In their study the target was an X or an N among five neutral letters presented in a circular configuration. The five letters were either homogeneous - five Os (low-load trials) or heterogeneous (high-load trials). Theeuwes et al.'s results replicated the traditional perceptual load effect with a blocked design, but found distractor interference to emerge in both low and high load conditions when the trials were mixed. These findings suggest that advance knowledge of perceptual load level rather than perceptual load per se, modulates the effectiveness of selectivity.

The results of Theeuwes et al., also challenge the dilution account, which offers a stimulus-driven mechanism. Although not explicitly stated, the dilution mechanism is expected to dilute distractor interference whether the design is blocked or mixed. Why should wide attentional sets increase interference on high load trials but not dilution trials? Based on the findings of Tsal and Benoni (2010) of the Reversed Load Effect (i.e. an increase in distractor interference under high load conditions in comparison to dilution conditions), the dilution account proposes that the typical high load condition contains two components lacking in the low load condition: the higher load (required for searching the target) and the potential of dilution (resulting from the additional representations of the neutral items). These two components produce opposite effects: whereas dilution decreases distractor interference the high load increases it. Thus, it is possible that the results in Theeuwes et al's study stem from the interaction between the viewers' attentional set and the higher load, which does not necessarily interact or influence the dilution mechanism. Therefore, the purpose of this study was to separate the effects of viewers' attentional set, operationally manipulated by blocked vs. mixed designs, on the load component and dilution component. We hypothesized that although the load component might be influenced by attentional sets, the dilution mechanism will not show such influence.

In the experiment described here we replicate Theeuwes et. al (2004) study with the added dilution condition. Overall the experiment included 6 blocks: three fixed-trials blocks (Low-load, High-load, Dilution) and three mixed-trials blocks (Low-High, Low-Dilution, High-Dilution). On high and low load trials the target and the neutral letters (five Os in low load, five heterogeneous letters in high load) were in the same color. On dilution trials the target was distinguished from the neutral letter in its color, thus allowing for a low load mode with high potential of dilution. We expected to replicate Theeuwes et al.'s (2004) findings, namely, to obtain interference under high-load trials in mixed blocks but not in fixed blocks. In addition, if attentional sets influence the effect of load but not the effect of dilution as we predict, then interference under dilution trials should be eliminated regardless of the blocked design.

Method

Participants

The participants were 21 undergraduate students from Tel Aviv University, who participated to fulfill a course requirement. All had normal or corrected-to-normal vision. The data from 2 participants were discarded because of high error rates (over 30%).

Apparatus and Stimuli

The experiment was conducted in a dimly lit room. Displays were generated by an IBM PC computer attached to a 17” monitor. Responses were collected via the computer keyboard. A chinrest was used to stabilize viewing distance at 60 cm from the monitor. A black background was used. Each display consisted of a target letter, either X or N, subtended 0.9 deg in height and 0.7 deg in width, at a viewing distance of 55 cm. Each display also contained an irrelevant distractor subtending 1.05 deg in height and 0.85 deg in width. The distractor was either X or N. Thus, the distractor could either be congruent (identical to the target), or incongruent (identical to the nonpresented target). The two possible target letters were equally frequent and randomly intermixed. For each target letter the two possible distractors were equally frequent and randomly intermixed. The target letter was presented randomly in one of six possible locations arranged in a circle centered at 2 deg from fixation. In the Low-Load trials the other five locations occupied by five "O"s and in the High-Load and Dilution trials, the other five locations were occupied by five different neutral letters (G, E, H, T, and A), subtending 0.9 deg in height and 0.7 deg in width. These neutral letters were randomly assigned to the five locations in each display. The distractor was centered at random equally often at 3.2 or 4.2 deg from fixation to the left or to the right of the circle. The distractor was always colored in light gray (color 16X8 in the palette). The color of the target was chosen randomly from the two options: light gray (color 16X8 in the palette), or red (color 3X4).In high load and low load conditions, the additional letters were colored in the same color of the target. In the dilution condition, the additional letters were distinguished from the target, red when the target was light gray, and vice versa. The fixation display consisted a light gray cross sign (0.4X0.4 deg) displayed in the center of the screen.

Design and Procedure

Each participant was presented with the six different blocks: three fixed (Low-Load, High-Load, Dilution), and three mixed (Low-High, Low-Dilution, High-Dilution). The order of presentation was randomized within the mixed blocks and within the fixed blocks. Half of the participants started with the fixed blocks and half began with the mixed blocks. Each fixed block included 160 trials (divided into two parts) and each mixed block included 320 trials (divided into four parts). Each block was preceded by 16 practice trials. Participants were instructed to respond as fast and as accurately as possible to the target while ignoring the peripheral distractor. They were directed to press the “L” key with their right index finger when the target was X and the “A” key with their left index finger when the target was N. Each trial began with a 1 sec fixation display, followed by the stimulus display which appeared for 200 msec. Error trials were followed by a feedback beep in the practice blocks.

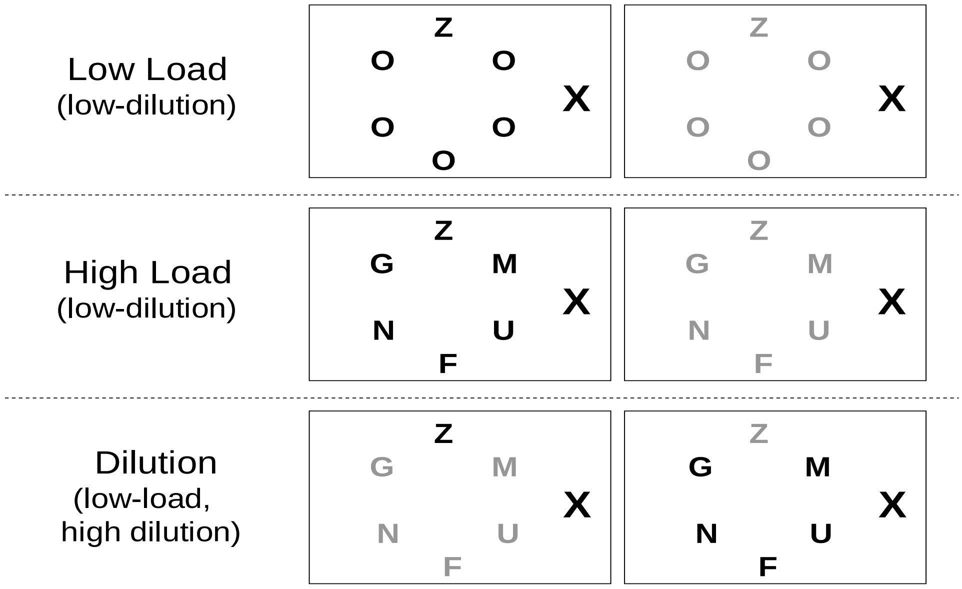

Figure 1: Examples of stimulus displays. * Gray color represents red.

Results and Discussion

Incorrect responses and responses deviating by more than 2 standard deviations from the means in every type of trials were removed from the RT analyses.

First, for every type of trials (High, Low, Dilution) we compared between the trials in the two relevant mixed blocks (i.e., between high trials in Mixed low-high, and high trials in Mixed high-dilution). The purpose of these comparisons was twofold: First, we wished to inquire if the viewer's attention on each type of trials is manifested differently under different mixed blocks, which was not predicted in advance (as will be discussed in the next paragraph). Second, if the type of trials does not interact with the mixed blocks, we could safely combine the results of each type of trails for further analyses.

To compare between high-load trials under the relevant blocks of mixed design (Mixed low-high; Mixed high-dilution), we conducted a 2X2 repeated measures ANOVA with Block and Congruency as factors on mean RT. The mixed high-low block is characterized by transitions between different loads but also in transitions in dilution. In contrast, the mixed high-dilution block is characterized by transitions only in load but not in dilution, since both types of trials in this block contain heterogeneous displays of neutral letters. Thus, if the same interference is obtained in the high load trials under these two blocks, then we can conclude that transitions in load level and not dilution levels are the reason of the increase in interference under high load in the mixed design. The analysis revealed that the main affect of block was not significant ($F(1,20) = 0.427$, $p = .521$) and the interaction between block and congruency was also not significant ($F(1,20) = 0.391$, $p = .539$). That is, the analyses reveled that the transitions in the load component are the cause of the interference that emerge in high load trails under mixed design, and not the dilution component.

To compare between low-load trails under the relevant blocks of mixed design (Mixed low-high; Mixed low-dilution), we conducted a 2X2 repeated measures ANOVA with Block and Congruency as factors on mean RT. The analysis revealed that neither the main effect of block ($F(1,20) = 0.019$, $p = .892$) nor the interaction between block and congruency reached significance ($F(1,20) = 0.604$, $p = .446$). Finally, to compare between the dilution trials under the relevant mixed blocks (Mixed high-dilution; Mixed low-dilution), we conducted a 2X2 repeated measures ANOVA with Block and Congruency as factors on mean RT. The analysis revealed that neither the main affect of block (F(1,20)= 0.677, p = .420) nor the interaction between block and congruency (F(1,20) = 0.008, p=.930) approached significance.

Since none of the interactions above approached significance, we combined each type of trials (High, Low, Dilution), from the relevant mixed blocks. This procedure resulted in three new blocks: High-Mixed, Low-mixed, and Dilution-Mixed. The following analyses will relate to these blocks.

	Congruency Effect	
	Fixed Blocks	Mixed Blocks
Condition		
Low Load	26 *	32 *
High Load	9	25 *
Dilution	1	5

Table 1: Congruency effect (Incongruent-Congruent) in ms, in every condition under fixed and mixed blocks.

Interference under fixed blocks

To evaluate the different levels of interference under the fixed block design we conducted a Congruency X Condition (Low, High, Dilution) within subjects ANOVA on mean RT for fixed block trials (excluding mixed block trials). The analysis revealed that the two main effects and their interaction were highly significant (F(2,40) = 42.424, p = .000 for Condition; F(1,20) = 8.699, p = .008 for Congruency; and F(2,40) = 4.061, p = .025 for the interaction). To reveal the nature of this interaction, we compared congruent and incongruent trials under each condition. The analyses revealed that the congruent effect was significant under the Low-Load condition (F(1,20) = 32.024, p = .000) but not under the High-Load condition (F(1,20) = 1.090, p=.308) or the Dilution condition (F(1,20) = 0.121, p = .731).

Interference under mixed blocks

To evaluate different levels of interference under the mixed block design we conducted a Congruency X Condition (Low, High, Dilution) within subjects ANOVA on mean RT for mixed block trials (excluding fixed block trials). The analysis revealed that the two main effects and their interaction were highly significant: (F(2,40) = 62.457, p = .000 for Condition; F(1,20) = 18.951, p = .000 for Congruency; and F(2,40) = 4.888, p = .013 for the interaction). To clarify the interaction, we compared between congruent and incongruent trials under each condition. The analyses revealed that as under the fixed conditions, the congruent effect was significant under the Low-Load condition (F(1,20) =28.090, p = .000) but not under the Dilution condition (F(1,20) = 1.756, p = .200). But conversely to the results under the fixed condition, here the congruency effect in the High-Load condition was also significant (F(1,20) = 6.492, p = .019).

Conclusions

In this study we separated the components of perceptual load and dilution and showed that increases in distractor interference in high load conditions in mixed designs in comparison to fixed design is fully attributed to the component of load, while the effect of dilution in selective attention remains unaffected by expectancy.

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