

HOW DOES PERCEPTUAL LOAD DIFFER FROM SENSORY CONSTRAINTS? TOWARD A UNIFIED THEORY OF GENERAL TASK DIFFICULTY

Hanna Benoni and Yehoshua Tsal
Department of Psychology, Tel-Aviv University
hannaben@post.tau.ac.il

Abstract

Load theory of attention stipulates that distinct attentional mechanisms underlie the effects of perceptual load and sensory degradation on search performance. Such distinction mainly relies on the finding that increasing perceptual load reduces distractor interference whereas increasing sensory degradation magnifies distractor interference (Lavie & DeFockert, 2003). We propose instead that the two types of load highlight different aspects of general task difficulty. We claim that the different patterns of results are due to the fact that increasing perceptual load has typically entailed the addition of neutral items capable of diluting distractor interference (Benoni & Tsal, 2010; Tsal & Benoni, 2010), whereas increasing sensory load has not. In the present experiment we jointly manipulated dilution with each type of load. Similar results were obtained for the two types of load: when dilution was controlled, increasing task difficulty increased distractor interference, but the addition of potential diluters reduced all types of distractor interference.

The theory of perceptual load (Lavie, 1995; Lavie & Tsal, 1994) proposes that the level of perceptual load of relevant processing determines the level of interference of irrelevant distractors. Thus, irrelevant information will be excluded from processing only if the prioritized relevant processing exhausts all of the available resources. When the relevant stimuli do not demand all of the available attentional capacity, irrelevant stimuli will unintentionally capture spare capacity, consequently enabling their processing.

In typical manipulations of perceptual load the target and distractor 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 representation of their features was 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 low-load high-dilution displays. These displays contained neutral letters (as in high load conditions) capable of diluting the distractor, but unlike the high load condition, the additional letters were distinguished from the target (e.g., by color), therefore allowing for a low load processing mode. In all experiments using a variety of converging operations distractor processing was completely eliminated for these new 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).

The purpose of the present study was to investigate the possibility that dilution can also explain an important extension of perceptual load theory, namely, the opposite effects obtained for manipulations of perceptual load and sensory degradation. Lavie and de Fockert (2003) attempted to further substantiate load theory by distinguishing perceptual load

from general task difficulty. Specifically, they contrasted the effects of perceptual load (increasing display size) with the effects of sensory degradation (e.g., reducing size and contrast of a target). The major finding of this study was that while perceptual load reduced distractor interference, sensory load increased it. However, there is one clear difference between the perceptual and sensory manipulations used by Lavie and DeFockert. In increasing perceptual load additional neutral (potentially diluting) letters were added to the display, whereas in increasing sensory load the target was presented alone without the accompanying neutral letters. Hence, these results can be explained in terms of a dilution effect. That is, distractor interference is diminished only when task difficulty is increased by adding neutral letters that can dilute that interference (perceptual load), and not when task difficulty is increased but the target remains by itself (sensory degradation). Following this differences between manipulations of perceptual and sensory loads, we propose that sensory degradation and perceptual load are two aspects of the same mechanism of general task difficulty, functionally increasing distractor interference. But, only one of them, perceptual load, benefits from the factor of dilution, which influences selectivity in the opposite direction of task difficulty, thereby decreasing distractor interference. Our hypothesis leads to two predictions tested in the present study. First, if potentially diluting items are added to the degraded target, then, distractor interference ought to be reduced as in increasing perceptual load. Second, if the effect of dilution is controlled, then, increasing perceptual load should increase distractor interference similar to increases observed for sensory degradation.

The study reported here included four conditions. The first two conditions were the Low and High Perceptual Load as in previous studies: In the Low load condition the target was presented in one of six possible circular positions, and the left five circular positions remained empty. In the High load condition the five circular positions were occupied with five neutral letters. The third condition was the degraded target condition, in which the target was degraded similarly to the study of Lavie and deFockert (2003), but unlike this study, the target did not appear alone, and the remaining five positions were occupied with five neutral letters as in the High-Load condition. The last condition was a New Low-Load condition (Dilution), in which the target was surrounded by neutral letters capable of diluting distractor interference, yet the target was clearly distinguishable from the neutral letters thereby allowing for a low load processing mode. In all conditions a distractor was presented in the left or right periphery. Our first prediction was that sensory degradation will decrease distractor interference like perceptual load, if additional items are added to the degraded target. It was tested by comparing the Low Load condition to our new Sensory Degradation condition. Our second prediction was that if dilution is controlled, increasing perceptual load will enhance distractor processing like sensory degradation. It was tested by comparing the High Load condition to our New Low Load condition, which was characterized by high dilution.

Method

Participants

The participants were 19 undergraduate students from Tel Aviv University, who participated to fulfill a course requirement. All had normal or corrected-to-normal vision.

Stimuli and procedure

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. Stimuli were presented on a black background. All stimuli were light gray (color 16X8 in the palette),

except for the target letters in the Sensory-Degradation condition, which were dark gray (color 16X14 in the palette). Each display consisted of a target letter, either X or N, subtending 0.72 deg in height and 0.54 deg in width in the Low-Load and High-Load conditions, and 0.37 deg in height and 0.31 deg in width in the Sensory-Degradation condition. An irrelevant distractor subtending 1.05 deg in height and 0.75 deg in width was also presented in each display. 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 randomly presented in one of six possible locations arranged on an imaginary circle subtending 2.48 deg of visual angle. In the Low-Load condition, the target letter was presented alone and the other five locations remained empty. In the High-Load, Dilution, and Sensory-Degradation conditions, the other five locations were occupied by five different neutral letters (G, E, H, T, and A), each subtending 0.72 deg in height and 0.54 deg in width and randomly assigned to the five circular locations. In the Dilution condition the target was marked by 0.42 horizontal line appearing underneath it. The distractor was centered at random and equally often at 3.2 deg from fixation to the left or to the right of fixation. The fixation display consisted of a small central cross (0.38X0.38 deg) and six dots marking the six possible target locations.

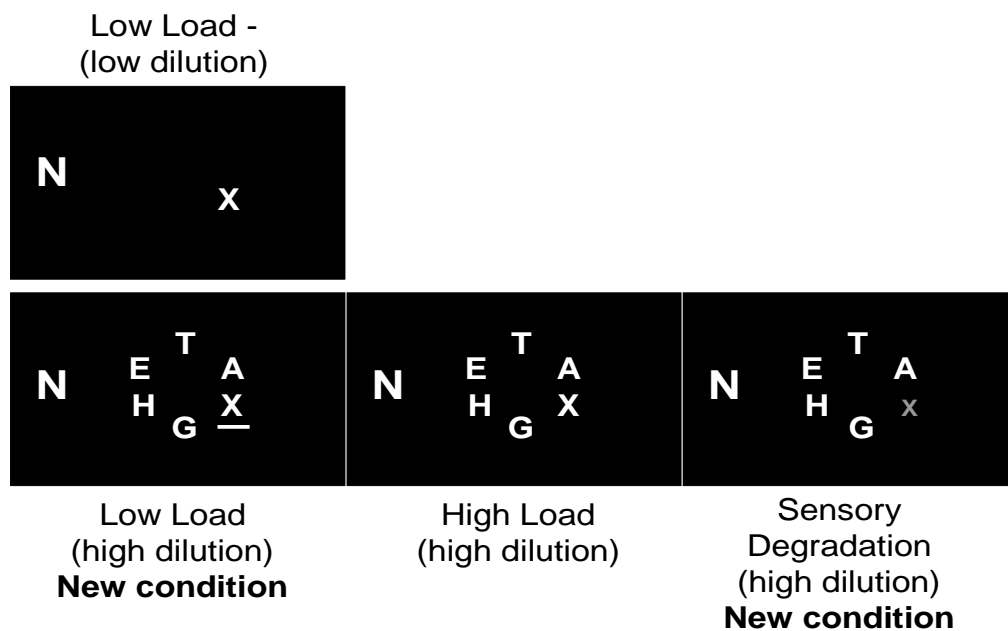


Figure 1: Examples of stimulus displays in every condition.

The order of conditions was randomized across participants. Each condition included 160 trials 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 150 msec. Error trials were followed by a feedback beep in the practice trials.

Results and Discussion

One participant was excluded from the analyses since his error rate exceeded 30%. Incorrect responses and responses deviating by more than two standard deviations from the means in every type of trials (4.0%) were removed from the RT analyses.

The Dilution Effect

A comparison between the Low Load and Low Load with Dilution conditions showed that congruent displays were responded to faster than incongruent ones ($F(1,17)=21.786, p=0.000$) and that the target was identified equally fast in the two conditions ($F(1,17)=2.983, p=0.102$). The latter result indicates that the addition of clearly distinguishable diluting items did not increase perceptual load. Most importantly, the interaction between Condition and Congruency was highly significant ($F(1,41)=23.031, p=0.000$). Further analyses of simple effects showed that distractor interference in the Low Load with Dilution condition was completely eliminated as congruent and incongruent displays were responded to equally fast ($F(1,17)=0.782, p=0.388$). This result is consistent with previous findings (Benoni & Tsal, 2009; Tsal & Benoni, 2010; Wilson et al, 2011), and lends further support to the conclusion that the traditional effect of perceptual load is due to dilution rather than perceptual load.

The Erroneous Degradation Effect

Our first prediction was tested by comparing the congruency effect between the Low-Load and the new condition of Sensory-Degradation. The analysis revealed that the two main effects were significant, thus the target was identified faster in the Low-Load Condition than in the new condition of Sensory Degradation ($F(1,17)=24.836, p=.000$), and congruent displays were responded to faster than incongruent ones ($F(1,17)=18.297, p=.001$). The interaction between these two factors reach significance ($F(1,11)=6.259, p=.023$). Thus in this experiment the new condition of *Sensory-Degradation* was found to reduce distractor interference compared to the Low-Load Condition. Analyses of simple effects indicated that the Congruency effect didn't reach significance in the New Sensory-Degradation Condition ($F(1,17) = 1.09, p=.310$). It is important to note that this comparison is not the best way to assess the degradation effect, but the important point here is that this comparison is equivalent to the comparisons in typical assessments of perceptual load effects. The conclusion that sensory degradation or perceptual load decrease interference is an erroneous conclusion, of course, in both cases. The fact that in the case of high load condition the dilution is inherent to the load, and in the case of sensory degradation the dilution seems to be artificial, does not make one case more acceptable than the other.

The Reversed Load Effect

Our second prediction was tested by comparing the congruency effect between the High-Load condition and the Low Load with Dilution Condition. This comparison assessed the true, dilution-free effect of perceptual load. The analysis revealed that the target was identified faster in the Dilution Condition than in the High-Load Condition ($F(1,17) = 6.843, p = .018$), Congruent displays were responded to faster than incongruent ones ($F(1,17) = 9.767, p = .006$), and most importantly, the interaction between Condition and Congruency was also significant ($F(1,17) = 12.953, p = 0.002$) indicating a greater distractor interference in the High-Load Condition than in the Low Load with Dilution Condition. This finding shows that when dilution is controlled for, i.e., both Low Load and High Load displays contain diluting items, *high perceptual load increases distractor interference* compared to the low load

condition, and influences selectivity similarly to sensory degradation. The Reversed Load Effect we obtained here is consistent with the reversed load effect we found in our previous study (Tsal & Benoni, 2010a).

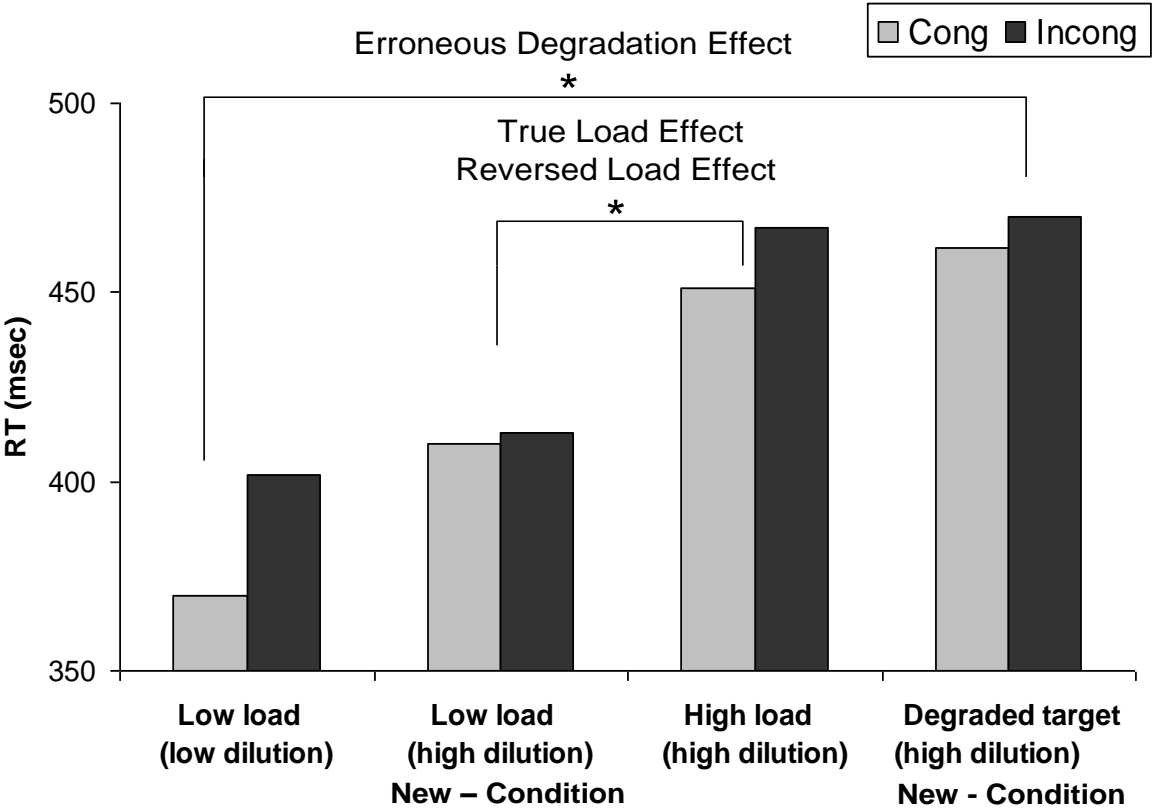


Figure 1: Congruency effect in every condition.

Perceptual Load vs. Sensory Degradation

To assess the relative effects of perceptual and sensory limitations we compared the High Load Condition with the Sensory Degradation with Dilution Condition. The main effect for congruency was significant ($F(1,17)=7.129, p = .016$), but not for condition ($F(1,17)=0.156, p = .679$). The interaction between these two factors was not significant ($F(1,17)=1.249, p = .279$). Thus, when dilution is controlled for and perceptual and sensory limitations produce similar increase in RT, they also produce similar distractor processing.

One mechanism of general task difficulty

Our results indicate that perceptual load per-se, influences selectivity as sensory degradation. Both perceptual and sensory loads increase distractor interference. It is important to note that these effects reflect the true direction of influence on selectivity. Adding diluting items causes sensory degradation to influence selectivity as perceptual load in traditional studies, namely, to decrease distractor interference. It is important to note that these effects reflect the erroneous effects on selectivity.

Following our results, and under Occam's razor principle, which draws the foundation to persimmon ontology: "Entities should not be multiplied beyond necessity", we

propose to replace two entities, perceptual load and sensory load, with one functional mechanism: *General Task Difficulty*.

References

- Benoni, H. & Tsal, Y. (2010). Where have we gone wrong? Perceptual load does not affect selective attention. *Vision Research*, *50*, 1292-1298.
- Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception & Performance*, *21*, 451-468.
- Lavie, N., & DeFockert, J. W. (2003). Contrasting effects of sensory limits and capacity limits in visual selective attention. *Perception & Psychophysics*, *65*, 202-212.
- Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, *56*, 183-197.
- Tsal, Y. & Benoni, H (2010a). Diluting the burden of load: Perceptual load effects are simply dilution effects. *Journal of Experimental Psychology: Human Perception & Performance*, *36*, 1645-1656.
- Tsal, Y. & Benoni, H (2010b). Much dilution little load in Lavie and Torralbo's (2010) response: A reply. *Journal of Experimental Psychology: Human Perception & Performance*, *36*, 1665-1668.
- Wilson, D. E, Muroi, M. & MacLeod, C. M. (2011). Dilution, not load, affects distractor processing. *Journal of Experimental Psychology: Human Perception & Performance*, *37*, 319-335.