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TESTING LOAD THEORY OF ATTENTION: IGNORING IRRELEVANT DISTRACTOR[1]

Abstract: Load theory of attention suggests that insufficient capacity for processing prevents subjects from perceiving irrelevant distractor in high perceptual load tasks (LaVie et al, 2004). The aim of our research was to test the proposed theory in visual search task, sinceLavie et al used choice response task in their research. Participants were asked to search for the oblique line among horizontal or vertical ones, while ignoring irrelevant distractor. The independent variables were target presence, task difficulty (depending on the angle of rotation of the target), distractor (there was either no distractor, or the distractor was oriented in the same direction as the target or in the opposite direction) and set size. The dependent variable was reaction time. Only target-present sets were analyzed. Significant effects of the task difficulty ($F(1,11)=118.05$, $p=.000$) and distractor ($F(2,22)=17.436$, $p<.01$) factors were obtained, as well as significant interaction of task difficulty and distractor ($F(2,22)=17.281$, $p<.01$). Analysis showed that in simple tasks there was no effect of irrelevant distractors. In difficult tasks, reaction times were the shortest when there was no irrelevant distractor and the longest when the distractor was rotated in the opposite direction from that of the target. The obtained results suggest that irrelevant distractor disturbs performance only in high perceptual load task, which is not in line withthe assumptions of the load theory.

Key words: Visual search, perceptual load, task difficulty, irrelevant distractor.

Introduction

Visual information selection is one of the major topics in cognitive psychology literature. Most of the authors find visual attention to be the most important cognitive process that constitutes the cognitive basis for visual selection. Since the 1980s, first in an article and then in a theory by Treisman known as the Feature Integration Theory of Attention, visual attention has been recognized as one of the supporting mechanisms of visual selection, as well as the basis for perceptual processing of objects in general (Treisman & Gelade, 1980). The basic idea

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proposed within this theory describes the perception processas one consisting of phases. Namely, it is seen as divided into two functionally discrete wholes, which are distinguished based on whether or not object perception requires attentional processing. Inspired by the findings in the field of neuroscience, primarily those by Zeki, Hubel & Wiesel, regarding the functional specialization of neural structures and the organization and the citoarchitecture of the visual cortex, Triesman claims that these neurophysiological data offer an explanation for the results obtained within the visual search task (Zeki, 1976, Hubel & Wiesel, 1959; Livingstone & Hubel, 1988). The data in question are among the most consistently replicated experimental findings in cognitive psychology that served as grounds forthe construct of preattentive, early vision. In a typical visual search task, the participant is required to detect the presence or absence of the critical stimulus (target), whose specific features make it different from the rest of the visual field comprised of stimuli with different features (distractors). If the target differs from the rest of the set in only one feature,there is no increase in search time depending on the number of the elements. On the other hand, if the target is defined in terms of features shared by the distractors, the search time gradually increases with an increase in the number of elements (distractors) surrounding the target. Such pattern of results has yielded the concept known in the literature as attentive vision (Treisman & Gelade, 1980; Sagi & Julesz, 1986; Wolfe, 1994). However, studies investigating the pop out search phenomena and paradigms within the early vision phenomena are far more common. One of the factors that have most certainly influenced the shaping of such a trend is the bias toward focusing on the target features which constitute the so-called parallel search. Still, one of the highly influential works which investigate the influence of distractor composition on the efficiency of visual search is the paper by Duncan and Humphreys, which, among others, inspired authors to come up with a highly specific theoretical solution (Duncan & Humphreys, 1989, Lavie et al, 2004). According to the Load Theory of Attention, goal-directed behavior is regulated by two psychological mechanisms.The first is a perceptual selection mechanism, which is relatively passive and enables successful visual search by extracting the important information (the target) from the rest of the visual field (distractors). The second mechanism is active and it relies on attention control, which enables the exclusion of irrelevant distractors in searches in which it is presumed that the distractors are perceived despite being less relevant. This mechanism is controlled by a higher cognitive function, working memory, whose supervision is necessary in order to maintain the order of processing of high-priority events within the cognitive system.That way, especially by ignoring the less relevant information, the working memory system secures the optimal functioning of the cognitive system. Conversely to perceptual load, great cognitive load burdens and diminishes the disposable capacity of active control, which leads to the processing of insignificant information such as irrelevant distractors(Lavie et al, 2004).

The literature on this topic includes various reports of the effects of perceptual load during distractor perception. During the period when selection theories were divided into early and late selection theories, several interesting studies appeared. In the auditory domain, by applying dichotic stimuli presentation, it was established that directed attention can efficiently prevent the processing of irrelevant stimuli(Treisman, 1969). Similar ideas are proposed by supporters of late selection, who claim that attention acts as a mediator in the memorization of stimuli during and at the moment of providing response (Duncan, 1980).

Similar findings are reported regarding the problem of unperceived visual information.In brief, information outside attention focus remains unnoticed, as reported in studies about the Inattentional blindness paradigm (Neisser & Becklen, 1975; Rock & Gutman, 1981; Mack & Rock, 1988; Treisman & Geffen, 1967).

Lavie et al propose a hybrid model which combines elements of both early and late selection approaches. According to their model, when the perceptual load regulated by the demand of the task is high enough, it exhausts the disposable resources, which results in insufficient capacity for distractor processing. Conversely, in cases of lower load, the entire remaining capacity is directed toward irrelevant stimuli processing. In one of their studies, the authors of this model describe a direct manipulation of perceptual load. They introduced variations into the letter stimuli set used in visual search task in order to measure the effects on distractor processing. Results showed that perceptual load significantly modifiedoperating, as well as that the final result of perceptual load could be the full use of attention resources, which results in blocking irrelevant distractor processing (Lavie & Tsal, 1994).

The aim of our research was to test the model in the context of parallel search of basic stimuli features. In order to do so, we attempted to answer the following research question: Can the Load Theory of Attention be applied to simple feature search?

Experiment

The aim of the present experiment was to indicate the interdependence between perceptual load and visual search efficiency. In order to test the hypothesized difference between higher and lower perceptual load conditions, we used a visual search task in which the target was defined in terms of line orientation.

Method

Design

We employed a four-factor within-subject design.The first factor, target presence, had two levels. Half of the trials consisted of sets containing the target, while in the remaining half of the sets the target was not present. The second factor, task difficulty, had two levels. The first level comprised trials including the target, vertical line rotated by 45°, while the second level trials included targets rotated by 10° relative to the vertical position. The third factor, distractor, had the following levels: no distractor, distractors oriented in the same direction as the target (compatible) and distractors oriented in the opposite direction from that of the target (incompatible). Finally, the fourth factor was set size, with four values: 18, 21, 24 and 27 elements.

Participants

A total of 12 subjects participated in the experiment. The participants were first-year psychology students at the Faculty of Philosophy, University of Belgrade. All participants had corrected to normal vision.

Stimuli

Visual search sets included varying number of lines. In half of the cases, the target was a line rotated by 45° or 10° relative to the vertical position (Figure 1), while the second half comprised identically oriented lines.

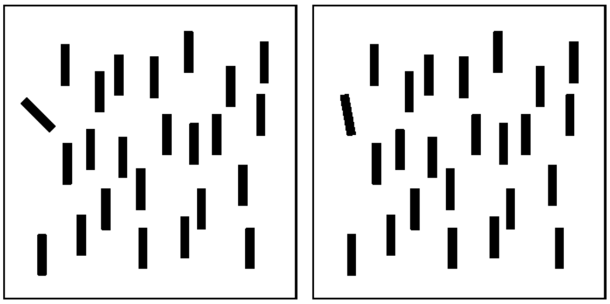

Figure 1: Two visual search displays with different targets. Easy task contained line rotated by 45 (left) and difficult task contained line rotated by 10° (right).

The perceptual load of the set was manipulated using three levels of distractor composition: no distractors, identical-orientation distractors and different-orientation distractors (Figure 2).

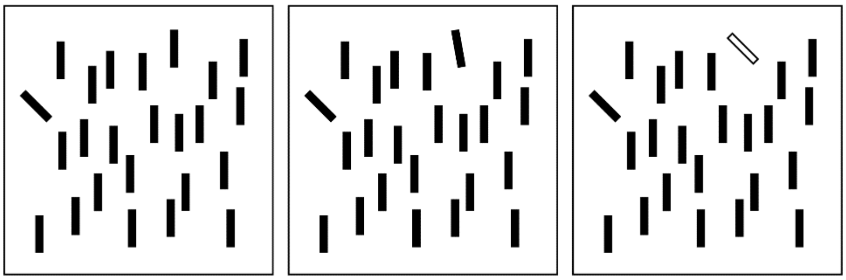

Figure 2: Three visual search displays: no distraction (left), distractors similar as a target (middle) and different distractors (right).

The target, an oblique line, lied in between vertical or horizontal distractors. Target position within the set was balanced. Each experimental conditionwas presented 16 times, meaning that every participant searched a total of 768 sets.

Procedure

The search sets were displayed on a 22-inch screen. Participants sat approximately 57 cm from the screen. All stimuli were displayed randomly. Prior to the experiment, the subjects were presented with a 16-trial training. *SuperLab for Windows* (Cedrus Corporation, 2010) software package and response box RB-530 were used for displaying stimuli and data collection.

Results

We conducted a repeated measures ANOVA, with reaction times as dependent variables. The analysis revealed that the first factor, target presence, was significant: $F(1,11)=36.70$, $p<.01$ and that the positive sets were searched faster in comparison to negative sets. The second factor, task difficulty, was also significant, $F(1,11)=81.54$, $p<.01$ and showed that sets with a more salient target are searched more efficiently than those with a less salient target. The analysis further showed that the absence of distractors leads to the most efficient search; searching is somewhat less efficient in the presence of distractors oriented in the same direction as the target and least efficient in the presence of distractors oriented in the opposite direction from that of the target, as suggested by the significant effect of distractor factor: $F(2,22)=33.43$, $p<.01$. Finally, the analysis showed that an increase in the number of elements also significantly affected visual search time, $F(3,33)=7.49$, $p<.01$. Partial analysis of positive sets showed that sets with a more salient target were searched faster in comparison to sets with a less salient target; that is, that the task difficulty factor was significant: $F(1,11)=118.05$, $p<0.1$. Similarly, it was found that search time increases with distraction level, $F(2,22)=17.43$, $p<0.01$. Sets with no distractors were searched fastest, followed by sets with moderate distraction level, while the sets with the maximum distraction level were searched slowest. The expected set size effect was also confirmed, $F(3,33)=2.32$ and revealed that search time varies linearly (increases) with an increase in set size.A significant interaction of task difficulty and set composition factors was found, $F(2,22)=17.28$, $p<0.01$, as well asan interaction of task difficulty and set size factors, $F(3,33)=1.65$, $p<0.01$. Figure 3 shows triple interaction of task difficulty, distractor and set size factors.

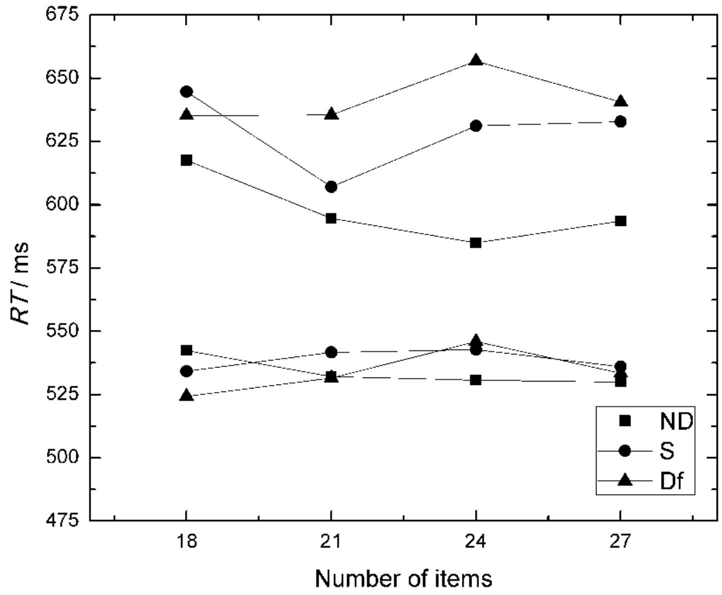

*Figure 3:*Relation showing reaction time vs. number of items in difficult (upper) and simple tasks(lower) in three different conditions: no distraction (ND), distractors similar as a target (S) and different distractors.

Figure 3 shows that search time varies linearly depending on set size in difficult tasks only, that is, when the target does not pop out. When searching is performed under higher perceptual load, that is, on sets with low-saliency targets, the effect of distractor factor is more effective, as it speeds up the search as the distraction level decreases.In other words, visual search is most efficient in the absence of distractors (ND), somewhat less efficient when the distractors are differently oriented than the target (Df) and least efficient when the distractors are identically oriented as the target (S).

Discussion

The aim of the present experiment was to testthe link between perceptual load and visual selection mechanisms hypothesized by the Load Theory of Attention. In line with the findings reported by Lavie & Cox (1997), direct manipulation of task type was expected to result in interference of incompatible distractors with the efficiency of task solving in easier tasks. On the other hand, in line with the theory predictions, it was expected that both distractor classes will be excluded in more difficult tasks with high perceptual load.

The results of the experiment showed that this relation was not found in visual search tasks involving basic stimuli feature search. It seems that in simple tasks, the search operates in accordance with the basic search mechanisms, with no effects of the irrelevant distractors. In cases of higher perceptual, i.e. cognitive load, distractor composition proved significant, since its effects impede the search in cases when distractors share certain features with the target.

Such pattern of results suggests that the given results can more readily be explained by some of the existent visual search models which primarily rely on the effects of background elements, in accordance with the Gestalt grouping principles, rather than by resource loading from higher cognitive mechanisms in the domain of working memory, as suggested by the Load Theory of Attention.

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ТЕСТИРАЊЕ ТЕОРИЈЕ ОПТЕРЕЋЕЊА ПАЖЊЕ: ИГНОРИСАЊЕ ИРЕЛЕВАНТНОГ ДИСТРАКТОРА

Апстракт: По теорији оптерећења пажње , недовољни капацитет обраде спречава субјекте у опажању ирелевантних дистрактора током визуелног претраживања поља у захтевним задацима. Циљ нашег истраживања био је да испита предикцију ове теорије у задацима визуелне претраге јер је она пре свега настала из емпиријског контекста задатка принудног избора. Испитаници су имали задатак да идентификују дијагоналну линију међу вертикалним игноришући притомирелевантедистракторе. Коришћен је четворофакторски нацрт поновљен по субјектима. Варирани су: тип сета, тежина задатка, састав дистрактора и обим сета. Време реакције је била независна варијабла. Анализа је показала одсуство ефекта ирелевантног дистрактора у једноставним задацима претраживања, док то није био случај у захтевнијим задацима . Добијени резултати упућују на то да ирелевантни дистрактори ометају претрагу само у захтевним задацима што није у складу са предвиђањем теорије оптерећења пажње. Постојећи резултати пре се могу интерпретирати у оквирима постојећих модела визуелног претраживања.

Кључне речи: визуелна претрага, перцептивно оптерећење, захтевност задатка, ирелевантни дистрактор