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Conditions of Directed Attention Inhibit Recognition Performance for Target-Aligned Stimuli

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Abstract

Watanabe, Náñez & Sasak (2001) demonstrated that the perceptual learning of task-irrelevant items was enhanced under conditions when attentional resources were diverted away from the irrelevant stimuli. However, the current study suggests that when attention is depleted, recognition for task-irrelevant items is *impaired* in a subsequent recognition task. Participants were presented with a stream of simultaneously presented written words and line drawings, and required to respond to immediate repetitions in either the word or picture stream. A surprise recognition test measured performance for the words. When analyzing word recognition performance after attention had been directed to the pictures, words that had previously appeared when attention was most depleted (i.e., with a picture repetition in the primary task) were recognized at levels significantly *below* chance. This novel finding suggests that information that is actively ignored when appearing in conjunction with an attended stimulus is subsequently inhibited in a recognition task.

Introduction

The role of attention in human perception has been investigated extensively through the better part of experimental psychology's history (e.g., Ahissar & Hochstein, 1993; Broadbent, 1953; Cherry, 1953; James, 1890; Mack & Rock, 1998; Moray, 1954; Seitz & Watanabe, 2005; Sinnett, Costa & Soto-Faraco, 2006; Triesman, 1960). A number of findings converge on the notion that explicit perception requires, at least a certain degree of attention (Mack & Rock, 1998; Rees, Russell, Frith, & Driver, 1999). Indeed, this has been demonstrated even for cognitive processes that have been considered at one point to proceed in an obligatory or automatic fashion. For instance, written word recognition, audiovisual integration in speech perception, and motion detection have all been empirically supported to require explicit attention in order for perception to occur (Alsius, Navarra, Campbell & Soto-Faraco, 2005; Rees, Frith & Lavie, 1997; Rees et al., 1999).

Despite numerous examples suggesting that visually presented words are processed automatically (see, e.g., Lupker, 1984; Stroop, 1935), Rees et al (1999) demonstrated that when attentional reservoirs were depleted, written word perception was interrupted. In their experiment participants viewed a rapid serial visual presentation (RSVP) of written items (words or non-words), superimposed on top of a stream of pictures. The primary task was to detect immediate repetitions in either the picture or the word stream. Directly following this task, participants were given a word recognition test for the words that had previously been presented. Behavioral findings suggested that performance was significantly better (i.e., more words were correctly recognized) after directly attending to the words. Furthermore, after attending to the picture stream, participants were just as likely to incorrectly affirm that a non-presented foil word had in fact been presented as they were to correctly identify words that had been originally presented in the repetition detection task.

While the findings of Rees et al (1999) suggest that attention plays a critical role in word recognition, one could make the claim that the words were indeed perceived, but quickly forgotten because a stabile memory code could not be formed. However, the authors also compared brain activations via functional magnetic imaging (fMRI) between the presented non-words (consonant streams) and words in the repetition detection task. Importantly, and discrediting any memory based explanation, while attending to the picture stream, words and non-words failed to show different levels of activation in word processing brain areas, such as the posterior basal temporal region, an important area associated with word identification (Buchel, Price & Friston, 1998). Essentially, a string of consonants (e.g., BCRTM) was treated the same as a word (e.g., HOUSE) when attending to the picture stream (Rees et al., 1999). These results demonstrate that the processing of a written word requires that attentional resources be directed towards that word.

Rees and colleagues have also demonstrated a decrease in visual processing for motion when attentional resources were depleted (Rees et al., 1997). That is, when attention was diverted to a difficult task, a reduction in visual motion perception occurred. In this experiment participants performed linguistic judgment tasks of varying difficulty superimposed over a visual motion background while brain activity was measured with fMRI. The findings suggested that as the difficulty of the linguistic task increased, brain activity in an area associated with the processing of motion (V5; Tootell, 1995) diminished when compared to the easier task. The authors posited that as task difficulty increases, attentional resources that could otherwise be used to process task irrelevant stimuli are recruited for the more difficult task, resulting in a reduction in perception for task irrelevant events (Rees et al., 1997; see also Lavie, 1995; 2005 for a description of attentional load theory).

Despite a multitude of findings suggesting that perception levels diminish as attentional resources are depleted (see

Ahissar & Hochstein, 1993; Lavie, 2005; Mack & Rock, 1998; Rees et al., 1999; Sinnett et al., 2006), Watanabe et al. (2001; see also Seitz & Watanabe, 2003, 2005) demonstrated—in direct contrast to the results described above by Rees et al. (1997)—that the perception of irrelevant motion can actually be *increased* under situations when attentional resources are depleted. Indeed, they showed that participants' detection performance for task irrelevant motion stimuli improved under conditions when attention was directed to a separate task. Moreover, the improvement was only seen when the irrelevant motion was temporally aligned with targets occurring in the attention demanding task. This is surprising as it demonstrates a situation where improved perception is observed during moments when attention is arguably most depleted (i.e., when required to detect and respond to a target).

Watanabe et al's. (2001) participants took part in a series of experiments in which they were repeatedly exposed to a background motion signal that was set at either 5% or 10% coherent motion (see also Seitz & Watanabe, 2003; 2005 for further examples using the same task). When asked to determine the direction of coherent motion by choosing one of eight possible directions, participants performed at chance levels for the 5% condition, but above chance levels for the 10% motion condition (suggesting that the motion was subthreshold in the former, but not the latter, condition). The same task was also performed when engaged in a simultaneously presented attention-demanding task. An RSVP of letters was superimposed over the background motion, and participants were required to report the identity of white target letters that occurred in a sequence of black distractor letters. It is important to note that when the superimposed white target letter appeared (i.e., the task-target), the same subthreshold coherent motion direction was present every single time (i.e., the task-irrelevant target).

Upon completion of this task, participants were again shown the weak background motion signal and asked to indicate the direction of the motion by choosing from an array of eight directions (depicted as arrows). While the 5% coherent motion condition remained at chance performance before and after exposure, the 10% coherent motion condition showed significant improvements in perceptual performance for the coherent motion, but only for the specific motion that was synchronized with the presentation of the white target letter during exposure. Note, this result is surprising as it shows that an implicitly presented motion can have a later effect on behavior.

Watanabe and colleagues (2001; 2003; 2005) postulated that the improved motion perception is due to the temporal relationship between the task-relevant stimulus (presence of white letter) and the task-irrelevant stimulus (background motion). It was hypothesized that if these two stimuli were presented simultaneously, then the learning associated with attention being directed to the task-relevant features would also be applied to the task-irrelevant stimulus, despite attention being explicitly directed away from the motion stimulus. These findings are even more surprising when one considers that significant improvements in performance only occur when irrelevant stimuli are paired with the most demanding aspect of a secondary task (i.e., when attentional reservoirs are depleted, but directed to a temporally aligned target).

The findings of Watanabe and colleagues (2001; 2003; 2005) seemingly suggest that directed attention is not a necessary condition for the perceptual learning of irrelevant targets. While the results are ostensibly robust, their conclusions stand contrary to the wealth of research that suggests that these findings would be unlikely to occur; most research would indicate that perception for irrelevant stimuli would be diminished under conditions where attention is utilized in a separate task and not explicitly directed to the irrelevant stimuli (see for example Rees et al., 1997).

The present study aimed foremost to investigate the robustness of Watanabe and colleagues' claims and expand their findings to a different type of stimulus; explicitly presented written words, using a different paradigm. Accordingly, task-relevant items (visual pictures) were temporally aligned with task-irrelevant (written words) items in a RSVP stream to see if this synchronization would lead to enhanced recognition levels of the task-irrelevant items. Based on the findings of Watanabe et al. (2001), enhanced performance would be predicted for task-irrelevant words that appear at the same time as a target picture when compared with words that do not.

Method

Participants.

Forty participants (n=40) were recruited from the University of Hawai'i at Manoa in exchange for course credit. Participants were naïve to the experiment and had normal or corrected to normal vision.

Materials.

A total of 150 pictures were selected from the Snodgrass and Vanderwart (1980) picture database. The pictures (on average 5 to 10 cm's) were randomly rotated +/-30 degrees from upright so as to ensure the difficulty of the task in each version of the experiment (see also Rees et al., 1999). Each of these pictures was combined with 150 one to two syllable, high-frequency English words (average length of 5 letters; range 4-6) selected from the MRC psycholinguistic database (Wilson, 1988). The overall average frequency of the 150 selected words was 120 per million, ranging between 28 and 686. The words were displayed in bold, capitalized letters in Arial font at a size of 24 points. Each word was superimposed over a picture and the picture-word stimuli did not exceed 10 cm horizontally or vertically. Care was taken to ensure that picture-word combinations did not have any semantic relationship.

Two streams of picture-word stimuli were created. In one stream, 50 pictures were selected from the database, 25 of which were pre-selected, duplicated and paired with their match. These repeated pictures acted as targets as each pair occurred in the visual presentation as an immediate repetition. The remaining 25 pictures were also duplicated, but their positioning in the stream of stimuli never allowed for an immediate repetition. Together this created a block size of 100 items. A second block of 100 items was created in which the 25 pictures not immediately repeated in the first block now served as the pictures that were immediately repeated. Therefore, across both blocks, each picture was displayed a total of four times (once as a repeat and then two other times as non-repeats in the complementary block). The same principle was used when making streams of items when the words were repeated (attending to words condition). To ensure an enhanced level of randomization, three different groups of 50 words and pictures were created and randomized in the aforementioned fashion, creating six different versions of the picture-word superimposed stimuli for use in the attending to pictures condition as well as the attending to words condition.

The surprise recognition test administered after the completion of the repetition detection task, consisted of 100 words from both the previously viewed visual stream (50) as well as never seen before foil words (50). The foils were words that were used in a different version of the experiment as repeated words (fully randomized). The 50 non-foil words presented in the surprise recognition test were words that were either temporally aligned with the task-relevant target, (i.e., superimposed over the immediate repetition of a picture), or were not temporally aligned with the task-relevant target (i.e., superimposed over non-immediately repeating pictures). Words synchronized with task-relevant targets have been given the nomenclature of *target-aligned* words and those not aligned with task-relevant targets have been named *non-aligned* words (see Table 1).

Table1: Description of *Target-Aligned* and *Non-Aligned* words.

Word Type	Synchronized Temporal Pairing with Task-Target of Immediately Repeated Pictures	Synchronized Temporal Pairing with Non-Task Target of Non-Immediately Repeated Pictures
Target-Aligned	Yes	No
Non-Aligned	No	Yes

Both the repetition detection and word recognition tasks were randomized and presented on a computer screen one at a time, in bold, capitalized letters in Arial font at a size of 24 points, just as they were displayed in the previous stream. The words in the recognition test remained on the screen until a response was made.

Procedure.

Participants were randomly assigned to one of two conditions. One group was required to attend to the picture stream (i.e., ignore the superimposed words) and respond to immediate picture repetitions, while the other group was required to respond to immediate repetitions in the word stream. Participants responded to the repetitions by using the 'G' key on the keyboard.

Each item in the picture-word presentation was presented for 350 ms with a 150-ms inter-stimulus interval (ISI; blank screen) between each item for a stimulus onset asynchrony (SOA) of 500 ms (see Figure 1). Before the first experimental block, a training block of eight trials was given and repeated until participants were familiar and comfortable with the task.

Immediately after the repetition detection task, a surprise word recognition test was administered to all participants. Words were displayed individually on the center of the screen in the same size and font as previously presented in the repetition detection task, and remained on the screen until the participant made a response. Participants were instructed to press the "B" key if they had seen the word during the repetition detection task or, instead, the "V" key if they had not seen the word before. Within each group, half of the participants (n=10) were presented with foils and target-aligned words, while the other half were presented with foils and non-aligned words.

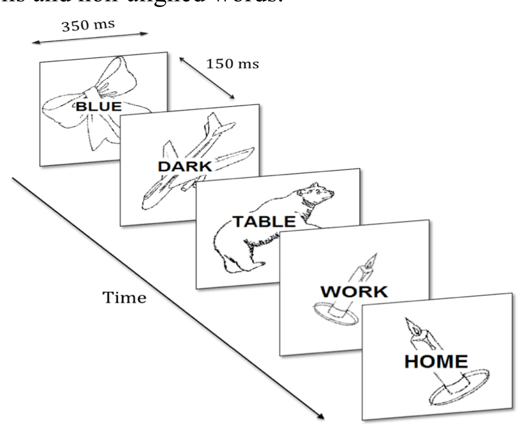


Figure 1. Rapid Serial Visual Presentation sequence employed. Each picture–word stimulus was presented for 350 ms and was then replaced by a blank screen for 150 ms before the next stimulus. Both the word-monitoring task and the picture-monitoring tasks were performed on the same streams. Note that in the present example, the word "HOME" serves as a *target-aligned* word.

Results

Overall surprise recognition performance.

The results of the surprise recognition test were analyzed in order to compare between conditions (attending pictures vs. attending words), and also against chance levels. Overall, recognition performance was significantly better after attending to the words when compared with after attending to the pictures (59.4%, *SE*=1.08 vs. 46.7%, *SE*=2.12, $t(19)=3.94$, $p=0.001$; see Figure 2). Performance after attending to the words was significantly better than chance ($t(19)=5.19$, $p<0.001$) while performance after attending to the picture stream was not significantly better than chance ($t(19)=1.52$, $p= 0.143$).

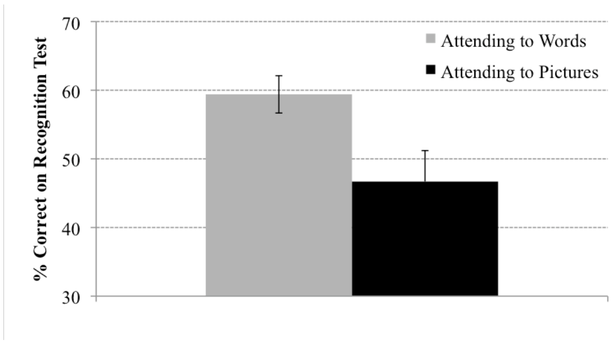


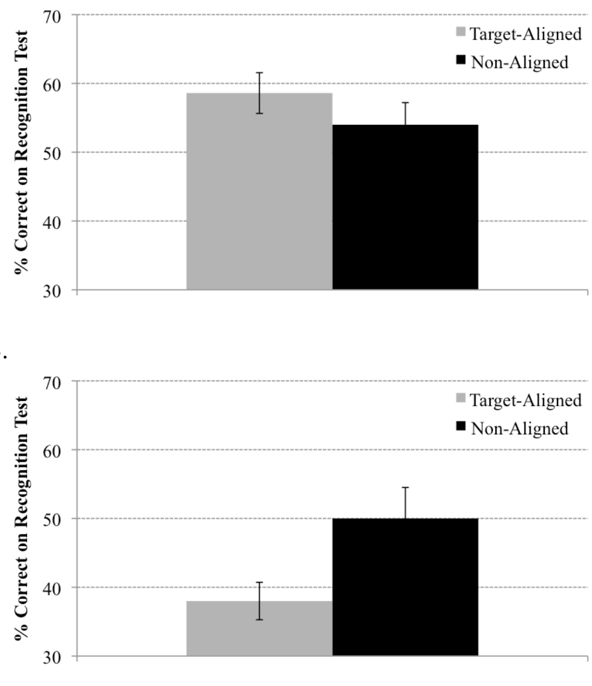
Figure 2. Overall recognition percentages and standard error bars for correct identification of words in the surprise word recognition test after attending to either the word stream (grey bar) or the picture stream (black bar).

Target-aligned word recognition.

In order to address the question at hand, that is, if performance is enhanced for words appearing with a picture repetition, recognition performance for *target-aligned* words was compared with *non-aligned* words and also against chance. When attending to words in the repetition task, subsequent recognition for *target-aligned* words (words immediately repeated) was significantly better than chance performance (59%, $t(9)= 2.67$, $p=.025$), while recognition for *non-aligned* words (not immediately repeated) was not statistically different from chance (54%, $t(9)= 1.35$, $p=.210$). There were no significant differences between *target-aligned* and *non-aligned* word performance after attending to the words ($t(9)=1.30$, $p=.224$; see Figure 3a). Analysis of recognition performance after attending to the picture stream demonstrated that participants were not better than chance at recognizing *non-aligned* words (50%, $t(9)= 0.08$, $p=.931$). Interestingly, performance was significantly different from chance at recognizing *target-aligned* words (38%, $t(9)= 4.54$, $p=.001$).

However, the direction of this significance was the opposite of what was expected, with performance significantly worse than chance (see Figure 3b). When compared to each other, recognition for *non-aligned* words was significantly better than *target-aligned* words ($t(9)= 2.34$, $p=.044$).

A.



B.

Figure 3. Recognition percentages and standard error bars for Target-Aligned (grey bar) and Non-Aligned (black bar) words in the surprise word recognition test after attending to either the word stream (A) or the picture stream (B).

An analysis was also conducted on the accuracy of the primary task of immediate target repetition detection. Overall, subjects were able to accurately detect target repetitions (75% hit rate vs. 25% miss rate, $t(9)= 21.69$, $p<.001$, see also Sinnett et al. 2006 for similar hit rates using the same paradigm). In addition, a significant negative correlation was found between target detection accuracy and recognition performance for *target-aligned* words ($r\ (10) = -.69$, $p = .02$), further suggesting that target-aligned words are inhibited in the recognition task.

Discussion

There are three main findings for the current experiment. First, we have replicated previous findings on inattentional blindness showing that word recognition is significantly better after attending directly to the word stream as opposed to attending to a distracting stream of pictures (see also Most, Simmons, Scholl, Jiminez & Chabris, 2001, Rees et al., 1999; Sinnett et al., 2006). Second, word recognition failed to be significantly better than chance levels after attending to the picture stream. That is, participants were unable to recognize the words if their attention had been placed elsewhere, suggesting that attention may be a necessary component for word recognition (see also Rees et al., 1999; Sinnett et al., 2006). Lastly, we have shown for the first time that words that appeared with a picture repetition (i.e., target-aligned) are recognized at significantly lower than chance levels after attending to the picture stream, suggesting, perhaps, an inhibition for irrelevant information that appears simultaneously with an attended target. Furthermore, after attending to the words themselves, subsequent recognition was better than chance for words that had appeared as a target repetition (i.e., target-aligned), while at chance levels for those that had appeared elsewhere in the stream (i.e., non-target aligned). Accordingly, this suggests that words that appeared with a target repetition were either inhibited or facilitated, depending on whether attention was originally directed to the pictures or the words in repetition detection task, respectively.

The finding that there is a possible inhibition of previously viewed words that appeared with a picture target stands in direct contrast to the conclusions drawn by Watanabe and colleagues (2001; 2003; 2005). For their findings to be replicated here, an enhanced recognition performance for words synchronized with task-relevant targets should have occurred. However, while the necessary temporal synchronization between task-relevant and task-irrelevant stimuli was present, enhanced perception for task-irrelevant stimuli was not observed. In fact, the exact opposite was seen, in that there was an inhibition of performance for the recognition of words that were temporally aligned with the task-relevant target of an immediate picture detection.

The potential inhibition of the target-aligned words when attention was diverted to the picture stream is of key interest to the present findings. While it is apparent that many investigations have found that when attentional resources are depleted, unattended and irrelevant stimuli are often not perceived (Mack & Rock, 1998; Rees et al., 1999; Sinnett et al., 2006), an inhibition for these stimuli has not been observed. However, it should be noted that to the best of our knowledge, this is the first time that a distinction between irrelevant stimuli appearing with a target, or not, has been empirically investigated. When doing precisely this in the present study, an inhibition for words that appeared with repeated target pictures was observed. One possible explanation for this would be that due to focused attention being placed directly on the demanding task of detecting repetitions, thereby necessitating that the attentional system actively inhibit irrelevant information in order to facilitate goal oriented behavior.

Despite significant differences in paradigms, a possible explanation for the inhibition of *target-aligned* words after attending to pictures may be found in the inhibition of return (IOR) literature (see Klein, 2000 for a review of IOR). If a target stimulus occurring in the periphery is first cued by a salient attention grabbing event, then a facilitation is normally found for the processing of that target if the time between the cue and the target is relatively short (i.e., < 300 ms; Posner, 1980). However, if there is a longer time period between the cue and the target (i.e., after attention has been disengaged from that space), then there is a delay (i.e., inhibition) for processing of targets in the previously cued area. This might be analogous to what was observed in the present experiment: Information that was attended to is later inhibited. However, it should be noted that this comparison is difficult to make as IOR is traditionally seen in visual search paradigms and measure response latency, while the present findings result from a non-spatial paradigm measuring accuracy. Nevertheless, the present findings could be viewed as an instantiation of a non-spatial, accuracy based inhibition for ignored stimuli.

As the comparison between visual search and the present paradigms can be viewed as difficult at best, perhaps a stronger explanation for the present results can be drawn from research on negative priming (see Milliken, Joordens, Merikle, & Seiffert, 1998; Tipper, 1985; Tipper & Driver, 1988). Typically, in negative priming experiments observers are presented, for instance, with two overlapping streams of object outlines with each stream printed in a different color (i.e., green and red). Participants would be required to name items in one stream (green objects) while ignoring stimuli in the other stream (red objects). Interestingly, response latencies are slower for objects that had appeared previously in the ignored stream (i.e., the to-be- ignored color), than for objects that participants did not have to ignore previously. Accordingly, this suggests that while selecting and naming one picture, the other (simultaneously displayed but not selected) object seems to be processed as well, at least to the extent that it influences naming latencies in the following trial. The theoretical implications of this could quite obviously be supported by the present findings, as behavioral responses to the ignored items here were inhibited in the form of response accuracy.

The significant negative correlation between target detection accuracy and recognition performance for *target-aligned* words further illustrates the possibility of negative priming. That is, while there was a high level of accuracy for immediate picture repetition detection, performance was decreased for recognition of *target-aligned* words superimposed over the target pictures. Perhaps, as occurs in the aforementioned negative priming paradigms, the accurate detection of the primary target is related to decreased recognition accuracy (rather than a response latency) for the ignored *target-aligned* words.

Performance on the surprise word recognition after attending to the word stream was comparable to that of previous findings, suggesting that if attention is directed to words, they are recognized at both better than chance levels and better than after attending to the picture stream. While this is not surprising, there is one noteworthy finding: Overall better than chance performance is driven by *target-aligned* words (words immediately repeated and serving as task targets). That is, recognition performance for *non-aligned* words was not better than chance. Arguably, an increased amount of attention is allocated to target detection, thereby potentially facilitating memory consolidation and subsequent performance in the word recognition task (see Craik & Lockhart, 1972 for a discussion on levels of processing theory). Accordingly, the present findings suggest an inhibition for target-aligned words when attention was directed to the picture stream, but a trend in the data (59% *target-aligned* vs. 54% *non-aligned*) for a facilitation of target-aligned words when attention was directed to the words themselves.

It is important to take into consideration significant procedural differences between the present study and the works by Watanabe and colleagues (2001; 2003; 2005). A detailed analysis of Watanabe et al's. (2001) original paradigm shows that a total of 960 trials, in which 120 consisted of the paired task-relevant and task-irrelevant stimuli, were presented daily for 20 days (i.e., nearly 100 times the amount here). In addition, the 120 paired task-relevant/-irrelevant stimuli always had the same direction in the coherent motion background. This would be equivalent to presenting only one specific word to appear with picture repetitions in the present study. Therefore, it might be possible that perception for irrelevant information paired with task-relevant information in the Watanabe et al. studies was an artifact of prolonged exposure in addition to the temporal synchronization (although this may be negated by an increased perception for the coherent motion paired with the task relevant target only). Future research could employ the paradigm from the present study to investigate prolonged exposure rates through the utilization of a larger number of trials and a smaller number of *target-aligned* words to see if perception is enhanced, rather than inhibited.

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