Speed Facilitation In The Absence Of Enhanced Recognition For Target-Aligned But Irrelevant Stimuli Under Cross-modal Presentations

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Abstract

An ignored stimulus is later recognized at enhanced levels if it had previously been aligned with a target from a separate task. This has been demonstrated using both visual and auditory presentations. Here we extend these findings to multisensory conditions. Participants were required to detect immediate repetitions in a sound or picture stream while ignoring superimposed words presented in the opposite modality (either written or spoken, respectively), and then underwent a surprise recognition test for these words. Contrary to the previous unisensory examples (Dewald, Sinnett, & Doumas, in press; Dewald & Sinnett, 2012), a significant difference between recognition rates for target-aligned and non-aligned words was not observed. However, a highly significant difference in response latency was observed, with target-aligned words being responded to much more quickly. This finding was robust and observed when the surprise test was presented in either the visual or auditory modalities, as well as across modalities.

Key words: Attention, Multimodal Presentation, Response latency, Cross-modal processing.

Introduction

Investigations of the relationship between attention and perception have demonstrated significant learning enhancements for certain stimuli in the absence of focused attention (Seitz & Watanabe, 2003, 2005; Watanabe, Náñez, & Sasaki, 2001). However, in order to observer these enhancements a number of compulsory prerequisite conditions were required. These included extended exposure rates of unattended stimuli (a random dot motion display) that were presented below threshold (a subset of dots moved coherently and subliminally) and also temporally aligned with a target from an attended secondary task. Under such conditions, enhanced learning performance was observed for the unattended stimuli in later motion discrimination tasks (see, Seitz & Watanabe, 2003, 2005; Watanabe et al., 2001). Curiously however, when presenting the same type of stimuli (coherent motion) under the same conditions, but at levels that are easily perceptible (i.e., suprathreshold), the aforementioned learning enhancements vanish (Tsushima, Sasaki, & Watanabe, 2006; Tsushima, Seitz, & Watanabe 2008). Thus, it appears that the relationship between whether or not learning enhancements occur for irrelevant stimuli is dependent on whether the initial presentation is sub- or suprathreshold. It is important to note that the investigations that collectively posit this idea have exclusively used random-dot, coherent motion displays (Seitz & Watanabe, 2003, 2005; Watanabe et al., 2001; Tsushima et al., 2006; Tsushima et al., 2008). A natural ensuing question, therefore, would be whether these findings apply to stimuli that arguably demand a higher level of processing?

Directly addressing this question, Dewald, Sinnett, and Doumas (in press) adapted Seitz and Watanabe's (2003, 2005, see also, Watanabe et al., 2001) motion detection task to include a high-level irrelevant semantic stimulus (words) in an inattentional blindness paradigm (see Rees et al., 1999 for a similar example of the paradigm). Specifically, participants were required to respond to immediate picture repetitions in a stream of serially presented line drawings, while at the same time ignore a simultaneously presented stream of superimposed words. The irrelevant word stream contained a single, unchanging word aligned with the presence of an immediate picture repetition (i.e., target-aligned) as well as seven additional words that were superimposed over the non-repeated pictures (non-aligned; i.e., analogous to exposure frequencies used by Seitz & Watanabe, 2003). The findings demonstrated that, despite attention being directed away from the task-irrelevant items (i.e., the words), subsequent recognition of these previously irrelevant items was nevertheless *enhanced*. Critically, this enhancement only occurred for words that had been presented simultaneously with a task-target in the previous task (i.e., target-aligned) when compared to non-aligned irrelevant words.

Similar enhancements for target-aligned stimuli have been observed when measuring recognition performance for irrelevant pictures that had appeared with targets (geometric shapes) in a separate task (e.g., the *attentional boost* effect; see Swallow & Jiang, 2010). Collectively, the findings by both Dewald et al. (in press) and Swallow and Jiang seem to paint a different picture than what was described earlier. That is, explicit presentations lead to an enhancement in recognition performance for previously target-aligned items. This is the exact opposite of the inhibited performance observed when explicit motion presentations were used as the irrelevant stimulus (see Tsushima et al., 2006; Tsushima et al., 2008). Dewald et al. argue that the high saliency of the irrelevant stimuli (i.e., written words rather than a lower level stimulus) likely underpins the difference in findings, assuming that the previous requisite condition of simultaneous presentation is met.

Regardless of the direction of learning effects, the critical component appears to whether the irrelevant stimulus is temporally aligned with a task-relevant target in a previous task (Seitz & Watanabe, 2003). As these investigations have largely been conducted only in the visual modality, it is important to extend these findings to other sensory modalities in order to determine whether they extend beyond the visual domain. Our recent work (Dewald & Sinnett, 2012) recently explored this very question by presenting an analogous paradigm using spoken words and sounds (i.e., rather than pictures). A facilitation for target-aligned irrelevant stimuli was observed. Interestingly however, the enhanced performance occurred only when the surprise recognition task was presented in either the same modality as the initial presentation (audition) or across modalities (i.e., audiovisual presentations).

Despite vision being the dominant sense in humans (Chandra, Robinson, & Sinnett, 2011; Colavita, 1974; Posner, Snyder, & Davidson, 1980; Sinnett, Spence, & Soto-Faraco, 2007), it is clear that the human perceptual experience is multisensory in nature. Thus, it is important to explore if the learning effects for irrelevant stimuli within the same sensory modality extend across modalities, as this will further inform how information is processed as a consequence of attentional allocation both within, and across modalities. Generally, performance improves when comparing multisensory to unisensory presentations (see for example Duncan, Martens, & Ward, 1997; Sinnett et al., 2006; Toro, Soto-Faraco, & Sinnett, 2005; Wickens, 1984).

The enhanced recognition performance for cross-modal presentations, when compared to unimodal presentations, can be explained by numerous findings that suggest that the capacity of the attentional system is increased if a demanding unisensory task is divided across multiple sensory modalities (i.e., multiple resources theory, see Wickens, 1984). For instance, Sinnett et al. (2006) demonstrated that under multimodal presentations, inattentional blindness for words was ameliorated (i.e., perception improved) when compared with unimodal conditions, regardless of the modality of word presentation (see also Toro et al., 2005 for a similar example involving statistical learning). These findings seem to provide support for an attentional system that is segregated, such that each sensory modality has access to individualized attentional resources (Wickens, 1984, see also Duncan et al., 1997 for an example using the attentional blink)

In the present investigation, we extend unimodal examples of learning enhancements for task irrelevant but target-aligned stimuli, to multimodal presentations. As increased performance has been observed for such presentations (see Duncan et al., 1997; Sinnett et al., 2006), we would expect an overall increase in recognition performance for both target-aligned and non-aligned items if they are presented in a separate sensory modality from a temporally aligned task-relevant target (e.g., more attentional resources will be available for non-aligned words). Of particular interest is whether or not the comparatively higher scores for target-aligned words will persist under cross-modal presentations. Interestingly, this could possibly jettison the enhancement associated with target-alignment if performance for non-aligned words increases substantially (i.e., a ceiling effect). We presented participants with multisensory visual and auditory streams (adapted from those used in the unimodal conditions in Dewald et al., in press and Dewald & Sinnett, 2012). This resulted in one of the streams including spoken words with distracting pictures, and the other having written words with distracting sounds. The task was to respond to repetitions in the target stream (i.e., sounds or pictures) and then to subsequently recognize as many words that had been previously presented (i.e., ignored) in the repetition detection task.

The present study also investigates the nature of the surprise recognition task. With the exception of our previous work in the auditory modality (Dewald & Sinnett, 2012), all research involving this paradigm has presented the recognition task in the visual modality, regardless of whatever modality it was presented in during the repetition detection task. As irrelevant stimuli in the exposure portion of the experiment will be presented in either the auditory or visual sensory modalities, it is necessary to examine if subsequent recognition of these items is affected by whether presentation is in a congruent modality. Our previous work (Dewald & Sinnett, 2012) did precisely this and systematically manipulated the modality of presentation between exposure and recognition tests. Not surprisingly, when irrelevant items were presented for recognition in the same modality as the exposure (i.e., both visually or both auditorally), learning effects were observed. However, when irrelevant stimuli were presented for recognition in an incongruent modality from their initial exposure, learning enhancements failed to surface for irrelevant items that had been temporally aligned with task-relevant targets (Dewald & Sinnett, 2012). Lastly, cross-modal presentations lead to the greatest magnitude of enhancement for the previously aligned words in the surprise recognition test. This latter outcome dovetails with previous investigations of attentional allocation across sensory modalities in perceptual and recognition tasks, suggesting that cross-modal presentations generally lead to superior performance when compared to unimodal presentations (Dewald & Sinnett, 2011; Duncan et al., 1997; Sinnett et al, 2006; Toro et al., 2005). Accordingly, in the present experiment we also presented the surprise recognition tests in the same or different sensory modality, or across modalities. If primary and secondary task modality congruence is a factor as it was in Dewald and Sinnett (2012), then we expect improved results for congruent matchings vs. incongruent matchings between exposure and recognition tasks, and potentially an additional enhancement for multimodal presentations (simultaneous visual and auditory presentation of the stimulus in the recognition test) given that performance is generally enhanced for multisensory presentations (see Driver & Spence, 2004). Note, these modality specific enhancements were only seen for target-aligned items.

Method

Participants. Seventy-four participants (n=74) were recruited from the University of Hawai'i at Manoa in exchange for course credit. A total of 46 participants were assigned to the visual words and sounds condition and a total of 28 participants assigned to the auditory words and pictures condition. The uneven distribution of participants across all conditions was a consequence of convenience sampling. Participants were naïve to the experiment and had normal or corrected to normal vision and hearing. Written informed consent was obtained before participation in the experiment occurred.

Materials. The exact same stimuli and design to create streams were used here as in Dewald et al. (in press, for visual stimuli) and Dewald and Sinnett (2012, for auditory stimuli) except now with multimodal presentations (i.e., pictures presented with spoken words or sounds presented with written words).

Attending to pictures with spoken words. A total of 50 pictures were selected from the Snodgrass and Vanderwart (1980) picture database. Each of the pictures (on average 5 to 10 cm, rotated +/-30 degrees from upright so as to ensure difficulty) was combined with eight one-to-two syllable, high frequency English words (average length of five letters; range 4–6) selected from the MRC psycholinguistic database (Wilson, 1988). The overall average frequency of the eight selected words was 361 per million, ranging between 135 and 782. For the auditory presentation of the words, a native English speaker's voice was recorded reading the list of selected words three times. Three blind listeners chose the best exemplar of each spoken word, with a fourth listener deciding which one was best in the event of a tie. The selected recordings were edited using sound editing software so that all items were the same presentation length (350 ms) and average amplitude.

A stream of 960 picture-spoken word concatenated items was created, with repeated pictures acting as task relevant-targets. The presentation stream was broken into eight blocks of trials (120 each) in which an immediate picture repetition occurred on average one out of every eight trials, equating to 15 task-relevant target repetitions per block, for a total of 120 trials of exposure to a task-relevant target (and specific word, see below). Only eight total words were superimposed over the 960 pictures. Note then that all word types (aligned or non-aligned) were presented in equal proportions (120 times each). This was done to parallel the number of different motions used in Watanabe et al, (2001; see also Seitz & Watanabe, 2003, 2005), so as to expose the participants to an unchanging, single, irrelevant word, although also having seven additional irrelevant words all exposed at the same frequency. The same single word was always temporally aligned with the presentation of an immediately repeated picture target. The presentation was pseudorandomized so that on average one out of every eight trials was an immediate picture repetition (and, therefore, the presentation of the same superimposed task-irrelevant target word). Only one superimposed word was aligned with all of the immediately repeated pictures for each participant.

Attending to sounds with written words. The exact same procedure as above was employed but now with sounds, instead of pictures, serving as the task-targets, and visually presented words as the irrelevant stimuli. The sound stimuli were extracted from a database of 100 familiar sounds and were also edited to 350 ms and similar average amplitude (see Sinnett et al., 2006). All other aspects were identical to the previous condition (pictures and spoken words).

Surprise recognition task: For both conditions, a surprise recognition test for the presented words was administered after the completion of the repetition detection task. The test consisted of a total of sixteen words (i.e., half came from the previously presented words, while the other half consisted of foil words that had never been presented before, average frequency of 236 per million with a range of 165-399. The word recognition tasks were randomized and presented by DMDX software (http://www.u.arixona.edu/jforster/dmdx.htm) one at a time, in either the visual or auditory modality, or across modalities. For the visual presentation the words were written in bold, capitalized letters in Arial font at a size of 24 points, and remained on the screen until a response was made. For auditory presentations the words were spoken just as they were in the initial repetition detection task. Cross-modal presentations involved the written word on the screen with the spoken word presented simultaneously.

Procedure

Participants were required to attend to the sound (or picture) stream (i.e., they were explicitly instructed to ignore the simultaneously presented, overlaid written/spoken words) and respond to immediate repetitions by pressing the 'G' key on the keyboard of the computer. Each item in the sound-word (or picture-word) presentation was presented for 350 ms with a 150-ms inter-stimulus interval (ISI; silence) for a stimulus onset asynchrony (SOA) of 500 ms. 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, the surprise word recognition test was administered to all participants (modality type of surprise task dependent on condition). Participants were instructed to press the "B" key if they had heard the word during the repetition detection task or, instead, the "V" key if they had not heard the word before.

Results

Target detection accuracy in the repetition detection task. Overall performance accuracy (across all conditions) of immediate target repetition detection revealed that participants were successful at detecting target repetitions in the primary task, (72% hit rate vs. 28% miss rate, $t(73)= 14.67, p<.001$).

Overall recognition accuracy. Across all conditions, participants were accurate in recognizing the unattended words (both target-aligned and non-aligned) displayed during the repetition detection task at better than chance levels (86.1% *SE* = 1.47, t (73) = 17.35, p < .001). A three-factor mixed design ANOVA was used to analyze overall (across all conditions) recognition performance for all words. Surprise test modality (auditory, visual, or cross-modal) and exposure modality (visual words vs. auditory words) were between-subjects factors, and target alignment (target-aligned or non-aligned) was a within-subjects factor. There were no main effects for target alignment (F (1, 68) = .217, p = .643), exposure modality in the primary task (F (1, 68) = 2.68, p = .08), or surprise test modality (F (2, 68) = .548, p = .580). A planed comparison further demonstrated that target-aligned and non-aligned words were recognized at statistically indistinguishable rates, across all conditions (*target-aligned:* 89.1.0%, *SE* = 3.06; *non-aligned*: 83.8%, *SE* = 2.15, $t(68) = 1.30$, p = .195, Figure 1). Given these null results, no further analyses of recognition performance were conducted.

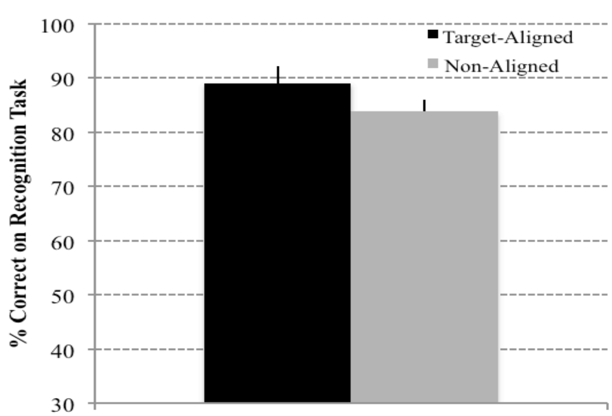

Figure 1. Recognition percentages pooled across all conditions for Target-aligned words (black bar) and Non-Aligned (grey bar) words.

Overall recognition speed. To explore if response latency to the words was modulated by target alignment or the modality of presentation of the surprise task, the same three-factor mixed design ANOVA was conducted as above, with surprise test modality (auditory, visual, or cross-modal) and exposure modality (visual words vs. auditory words) as between-subjects factors, and target alignment (target-aligned or non-aligned) as a within-subjects factor. A main effect of target alignment confirmed that overall, the speed of responding to words was significantly faster for target-aligned words (787.8 ms, *SE* = 21.8) when compared to non-aligned words (1378.2 ms, *SE*=80.2) (F (1, 68) = 52.44,p = .001) (see Figure 2). No main effects were observed for surprise test modality (F (1, 68) = .298, p = .587) or exposure modality (F (2,68) = 1.80, p = .173), nor were any interactions significant except for the three-way interaction (F (2, 68) = 3.58, p = .03). To further explore this interaction, further ANOVAs of response speed for each condition were conducted.

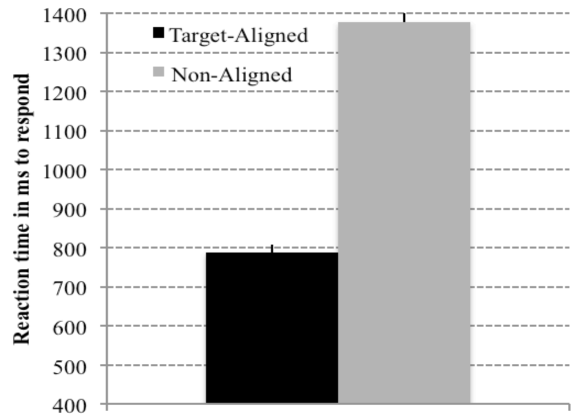

Figure 2. Response latencies pooled across all conditions for Target-Aligned (black bar) and Non-Aligned (grey bar) words.

Attending to sounds with written words. A two factor mixed design ANOVA was conducted for response latencies with surprise test modality as a between subjects factor and target-alignment as a within-subjects factor. A main effect of target alignment (F (1, 43) = 34.97, p < .001) was observed, demonstrating that participants responded more quickly to target aligned (812.2 ms, *SE* = 29.3) when compared with non-aligned words (1371 ms, *SE* = 93.8). There was no main effect for surprise test modality (F(2, 43) = .237, p = .790) nor was there a significant interaction (F(2, 43) = 1.28, p = .286. Planned comparisons also confirmed that when examining response latency in the surprise word recognition task, target-aligned words were responded to significantly faster than non-aligned words in all conditions *(Visual Presentation:* Target-aligned: 789.2 ms, *SE*=38.4 vs. Non-aligned: 1293.7, *SE* = 217.4, t (16) = 2.92, p = .02; *Auditory Presentation:* Target-aligned: 717.8 ms, *SE* = 63.4, vs. Non-aligned: 1519.2 ms , *SE* = 38.4, t (11) = 5.31, p = .001; *Multimodal Presentation:* Target-aligned: 901.9 ms, *SE* = 46.1 vs. 1320 ms, *SE* = 72.7, (t (16) = 4.86, p = .001). Further confirming the non-significant interaction, there were no significant differences in performance between conditions (all p > .58).

Attending to pictures with spoken words. The same two factor mixed design ANOVA was conducted for response latencies with surprise test modality as a between subjects factor, and target-alignment as a within-subjects factor. Again, a main effect for target alignment ($F(1, 25) = 19.57$, $p < .001$) was observed, demonstrating once more that participants responded more quickly to target aligned (747.8 ms, *SE* = 30.9) when compared with non-aligned words (1404.5 ms, *SE* = 147.2). while no main effect was observed for the modality of the recognition test ($F(2, 25) = 1.51$, $p = .239$). The interaction also failed to reach levels of significance ($F(2, 25) = 2.81$, $p = .079$). Planned comparisons also confirmed this in each modality presentation in the surprise recognition task *(Visual Presentation:* Target-aligned: 659.7 ms, *SE* = 67.8 vs. Non-aligned: 1833.9, *SE* = 368.9, t (8) = 2.84, p = .02; *, Auditory Presentation:* Target-aligned: 819.8 ms, *SE* = 44.5 vs. Non-aligned: 1159.4 ms, *SE* = 116.5, t (9) = 3.10, p = .01; *Multimodal Presentation:* Target-aligned: 755.9 ms, *SE* = 35.5 vs. 1247.3 ms, *SE* = 200.9, t (8) = 2.42, p = .04). Despite the marginal interaction, there were no significant differences in performance between conditions (all $p > .05$)..

Discussion

There are a number of outcomes that necessitate discussion, as the present findings strengthen the understanding of how unattended information is processed when it appears simultaneously with an attended target, especially when considering the multimodal exposures used here. Specifically, the findings exhibit that both presentation types (pictures with auditory words, or sounds with visually presented words) lead to learning effects, exemplified by high recognition rates in the surprise task, despite attention not being directed to the words. This is similar to analogous paradigms using only unimodal visual (Dewald et al, in press) or auditory (Dewald & Sinnett, 2012) presentations. However, both of these unimodal studies indicated enhanced recognition rates for target-aligned words when compared with non-aligned words. This was not the case with cross-modal presentations, as observed here. That is, although the recognition rates for the unattended stimuli were high, there was no difference between target-aligned and non-aligned items.

The lack of a significant difference in recognition rates based on target alignment is likely due to the cross-modal presentations used here. It is possible that the division of the task could have permitted additional attentional resources to focus on processing *all* of the words, as shown by the high recognition rates for non-aligned words here (overall 84%). While it is difficult to statistically compare this rate to our previous studies (already published), it is worth noting that, in analogous but unimodal paradigms, performance for non-aligned words was much lower in either the visual (68%, Dewald et al., in press) or auditory modality (59%, Dewald & Sinnett, 2012). Thus, it appears that by presenting the repetition detection task across modalities, additional resources were available that potentially enabled the processing of irrelevant stimuli, resulting in arguably near ceiling recognition rates for both aligned and non-aligned words. This dovetails well with other research demonstrating enhanced performance under multimodal conditions (Duncan et al., 1997; Sinnett et al., 2006), possibly indicating a segregation of attentional resources across modalities (Wickens, 1984).

Despite the lack of a recognition difference between target-aligned and non-aligned items, the former were responded to significantly faster, regardless of the modality of presentation (*target-aligned*: 787.8 ms vs. *non-aligned*: 1378.2 ms), suggesting alignment did play a role. That is, it is possible that there was improved learning of words that were temporally aligned with a task-relevant target, indicated by response latencies to target-aligned words being faster in all three recognition conditions (visual, auditory, audiovisual). This is an intriguing finding as it indicates a conceivable enhancement for target-aligned material without explicit awareness, as there were no differences in recognition performance. Although, it should be acknowledged that recognition performance might have been at ceiling levels and therefore masked any possible improvement for target-aligned words. Regardless, this finding warrants discussion, as well as further research. Indeed, of the many studies published on this topic (see, Dewald et al, in press, Dewald et al., 2011; Dewald & Sinnett, 2012; Rees et al, 1999; Sinnett et al, 2006; Swallow & Jiang, 2010; Tipper & Driver, 1988) the present experiment is the first to use response latency as a potential measure of enhancement for target-aligned material.

Also of key interest here, is that we did not observe an interaction in performance between target-alignment and the modality of the surprise test, as was observed by Dewald and Sinnett (2012). Across all conditions, regardless of the congruency between presentation and recognition task, there was no significant difference between target-aligned and non-aligned words. Accordingly, this suggests that, at least in the present case, under multimodal presentation, the modality of presentation does not need to match exposure and test conditions. This could be a byproduct of the overall enhanced recognition performance seen after cross-modal presentations. A more systematic approach manipulating presentation (unimodal vs. cross-modal) and surprise test (congruent, incongruent, cross-modal) is required before ruling out that this factor is unnecessary.

Collectively, the present findings provide insight into how irrelevant information is processed when it is presented simultaneously with an attended target across sensory modalities. If certain prerequisite conditions are met, unattended stimuli can be perceived and affect behavior, perhaps even below levels of conscious awareness. Additionally, although a significant difference was not observed here, future research should consider the congruency of modality presentation in both exposure and testing conditions.

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