A Window of Perception When Diverting Attention? Enhancing Recognition For Explicitly Presented, Unattended, and Irrelevant Visual Stimuli by Target Alignment

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Abstract

Irrelevant, but overtly presented, stimuli that are temporally aligned with an attended target in a separate task are later inhibited in a recognition task (Dewald, Doumas, & Sinnett, 2011). This is contrary to findings in the perceptual learning literature where facilitation has been observed for later recognition of irrelevant motion stimuli, albeit after extensive exposure rates. Here, we adapted previous work to include higher exposure rates, and subsequently observed a reversal in inhibition in favor of enhanced recognition performance. Participants responded to immediate picture repetitions in a stream of line drawings while ignoring simultaneously presented superimposed words. A surprise test measured recognition for the unattended words. Words that had previously appeared simultaneously with a repeated picture were recognized significantly *more often* than words that had appeared with non-repeating pictures. The findings suggest that the exposure rate and the quantity of irrelevant stimuli can have a significant impact on whether perception is inhibited or facilitated.

Introduction

Throughout the past decade, researchers have explored how information is processed when it is explicitly or implicitly presented, and the fate of this information when it receives or does not receive direct and focused attention (Dewald, Sinnett, & Doumas, 2011; Mack & Rock, 1998; Rees, Russell, Frith, & Driver, 1999, Seitz & Watanabe, 2003, 2005; Sinnett, Costa, & Soto-Faraco, 2006, Tsushima, Sasaki, & Watanabe, 2006; Tsushima, Seitz, & Watanabe, 2008, Swallow & Jiang, 2010). For instance, several investigations have shown significant perceptual learning enhancements in the absence of focused attention for stimuli that are, in fact, presented below the threshold for visual awareness (i.e., implicitly presented) (Seitz & Watanabe, 2003; 2005; Watanabe, Náñez, & Sasaki, 2001). More recently and contrary to these findings, Tsushima and colleagues (Tsushima et al., 2006; Tsushima et al., 2008) presented evidence suggesting that when the implicit stimulus is made explicit (i.e., observable), a later inhibition is observed. Thus, it would appear that facilitation or inhibition is dependent on whether or not stimulus presentation is sub- or suprathreshold. Furthermore, all of these investigations purport that a synchronous temporal relationship between the irrelevant stimulus (motion in these investigations) and a separate but attended target in the exposure stage is critical to observing these facilitatory or inhibitory effects in a later recognition task (i.e., the nonsynchronous condition is baseline).

Demonstrating learning enhancements for irrelevant stimuli, Seitz and Watanabe (2003) had participants take part in a series of experiments in which improved motion perception for an irrelevant, subthreshold motion, was postulated to be due to the establishment of a temporal relationship between task-relevant and task-irrelevant stimuli (Seitz & Watanabe, 2003; 2005, see also Watanabe et al., 2001 for a further example using a similar paradigm). Briefly, participants were required to identify a differently colored letter in a rapid serial visual presentation of letters. This primary task was superimposed over an irrelevant background motion stimulus that involved an array of moving dots, of which a small subset moved in coherence. Note that the coherently moving dots (5%) were implicit in nature, demonstrated by chance motion discrimination during pre-testing. While every letter was accompanied with an array of moving dots, the direction of the subthreshold coherent motion was always the same for the target letters of the primary task, while remaining random for non-target letters. The implicit motion synchronized with the presence of the task- target (the different colored letter) was later identified significantly more often than the other motions (i.e. those accompanying non-target letters) in a motion detection task (see, Seitz and Watanabe, 2003). It was hypothesized that when the irrelevant motion and task-target were presented simultaneously during exposure, the learning associated with attention being directed to the detection of the task-relevant features of the task-target would also be applied to the task-irrelevant stimulus of background motion, despite the motion being subthreshold and attention being explicitly directed towards the primary attention-demanding task. Further bolstering this account is the fact that significant improvements in the motion discrimination task were observed only for the motion direction that was paired with the presence of the task-target (i.e., simultaneously presented). However, it is important to recall that the irrelevant stimuli temporally aligned with the presence of the task-target were subthreshold in nature.

Given the differences in perception for subthreshold and suprathreshold information, a logical ensuing question would be to explore what happens when above threshold irrelevant motion stimuli are presented during the exposure stage.

Addressing this very question, Tsushima et al (2008) conducted a similar experiment using explicit rather than implicit motion. Specifically, their experiment included a condition with suprahreshold motions (i.e., 50% coherence) during the primary task (i.e., exposure stage), in addition to a subthreshold motion condition (i.e., 5% coherence). Although one might perhaps expect that higher motion coherence would lead to stronger learning effects (when compared to lower motion coherence signals) due to an arguably strengthened perceptual signal (Britten, Shadlen, Newsome, & Movshon, 1992), the opposite occurred. Facilitation was found only for the subthreshold stimulus levels, while an inhibition was observed for suprathreshold exposure (i.e., explicit presentation). Combined, these findings suggest that strong (overt) target-aligned irrelevant features are subject to attentional inhibition, as the initial task requires attention to be directed to the letter stream. This possibly prevents the strong, but irrelevant, feature from being learned. However, subthreshold motion is not subject to this same inhibitory control, and might therefore be learned and facilitate later perceptual performance.

Other experimental paradigms have utilized different approaches and stimuli to further investigate the way information is processed during dual-task performance. Interestingly, despite the explicit presentation of their stimuli, opposite findings from Tsushima et al (2006) have been observed, with a facilitation for overt stimuli that was presented simultaneously with an attended target from a separate task. For instance, Swallow and Jiang (2010; see also Lin et al., 2010 for a similar example of a paradigm utilizing temporally aligned targets) completed a series of experiments suggesting an "attentional boost" (i.e., facilitation) for simultaneously presented information in a dual-task paradigm, rather than an inhibition as witnessed by Tsushima et al (2006; 2008). In their experiment, participants monitored a stream of pictures of various scenes. A series of distractor items (small black superimposed squares) were simultaneously paired with the presentation of each picture. Participants were required to remember as many of the presented scenes as possible, in addition to monitor the distractor stream for the presence of an "odd-ball" color change (i.e., the presence of a white square rather than a black square). In a subsequent forced choice recognition test for the picture scenes, an enhanced recognition for pictures that had been presented simultaneously with the presence of the target (i.e., the 'odd-ball' color change) in the distractor stream was observed (i.e., an attentional boost).

Of particular note to Swallow and Jiang's (2010) findings is that participants were required to attend to both streams of information simultaneously (encode the pictures as well as detect an "odd ball" target). Recall that in the paradigm utilized by Seitz and Watanabe (2003) as well as Tsushima et al (2008), participants were instructed to detect a target in one stream (i.e., identify a differently colored letter) while being exposed to the background coherent motion, but not actively attend to the background motion (i.e., the motion was in fact irrelevant at this stage in the experiment). Regardless of these procedural differences, it is important to note that Swallow and Jiang's (2010) findings are based on the presentation of above threshold stimuli, much like the 50% coherent motion in the Tsushima et al (2008) paradigm. A second important difference is the nature of the stimuli. Swallow and Jiang used pictures (see also Lin et al., 2010) while irrelevant motion was used in the other examples. It is likely that explicitly presented pictures are processed much differently than irrelevant and implicitly presented motion. Combined, the procedural differences between these two paradigms may be a contributing reason as to why a contradictory pattern of results has been observed (i.e., facilitation for Swallow & Jiang, 2010 and inhibition for Tsushima et al., 2008).

Recent work from our laboratory (Dewald et al., 2011) examined the temporal pairing of highly salient and overtly presented task-relevant and task-irrelevant stimuli with an adapted inattentional blindness (IB) task (see Rees et al., 1999; Sinnett et al., 2006 for similar examples), requiring participants to monitor a stream of pictures with synchronized superimposed words, and respond to immediate repetitions in the picture steam while ignoring the word stream. Following the picture repetition detection task, participants were administered a surprise recognition test for the (ignored) words that had been superimposed over the pictures during the repetition detection task. Words that had been temporally aligned with the presence of a task-target (i.e., an immediately repeating picture) were subsequently recognized significantly below chance levels (i.e., inhibited), while words that had been temporally aligned with non-targets (i.e., a non repeating picture) were recognized at chance levels. These findings dovetail with the conclusions of Tsushima et al (2006, 2008) and suggest that suprathreshold presented stimuli will be inhibited rather than facilitated if presented simultaneously with an attended target from a separate task.

Critical the experiment presented here, a key component of the paradigm used by Tsushima et al (2006, 2008) and Seitz and Watanabe (2003, 2005) is that the exposure rates of implicit and explicit motion were extremely high, often including multiple days of exposure including thousands of trials. On the other hand, our previous research included a mere 200 total trials lasting approximately 10 minutes. Furthermore, while our research (see also Swallow & Jiang, 2010) paired many different irrelevant stimuli (i.e., words) with the relevant task target (picture repetition), the sub- and superthreshold motion paradigms paired only a single motion direction with all targets in the primary task. This important point is explained further below. The present investigation therefore aims to further extend this research by exploring whether recognition for a highly salient stimulus will in fact be facilitated if presented more

frequently, and without other competing stimuli. That is, it will address the question of whether using a higher frequency of presentation for a salient irrelevant stimulus could in fact modulate the previously observed inhibition and lead to facilitation effects (i.e., akin to the attentional boost effect; see Swallow & Jiang, 2010).

There are a number of possible outcomes in the present investigation. First, based on the conclusions of Seitz and Watanabe (2003), in regards to the temporal pairing of task-relevant stimuli (e.g., immediate picture repetitions) and task-irrelevant stimuli (e.g., superimposed words), it could be predicted that this synchronization will at the least establish a relationship that will affect perception for task-irrelevant stimuli aligned with task-relevant targets. It should be noted however, that studies by Tsushima et al (2006; 2008) as well as Dewald et al. (2011) suggest that if an irrelevant stimuli is explicitly presented (rather than implicitly, as used by Seitz & Watanabe, 2003), the temporal relationship between task-relevant and task-irrelevant stimuli may lead to an inhibited performance in a later recognition task for the irrelevant items. Critical to the question at hand, our previous demonstration used 50 different words rather than a single word (i.e., akin to a single motion; see Dewald et al., 2011). This increased quantity of words could have augmented the salient nature of the stimuli, thereby necessitating that they be ignored in order to complete the primary task of detecting picture repetitions, and consequently lead to inhibitory effects. To better approximate the conditions used by Seitz and Watanabe (2003), in the present experiment we utilize only one high-level irrelevant stimulus (a specific written word) that may lead to an enhanced performance rather than inhibited. This would therefore be analogous to the same unchanging suprathreshold motion always paired with the presence of the task-target in Tsushima et al (2008). We argue that although explicit and suprathreshold in nature, coherent motion detection fails to be processed to the same level as semantic words (see Borst & Egelhaaf, 1989 for a review of visual motion detection). Therefore, it can be predicted that the repeated exposure of a single word that is temporally aligned with an attended target will lead to a later facilitation in recognition for that word when compared to words that were not temporally aligned with an attended target (i.e., similar to the attentional boost, see Swallow & Jiang, 2010). We predict that these results will surface due to a synergy of higher salience for words along with increased exposure levels to the word that is temporally aligned with the presence of a task-target (note, all words were presented in equal frequency).

Method

Participants. Sixteen participants (n=16) 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 50 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 eight 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 eight selected words was 361 per million, ranging between 135 and 782. 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.

A stream of 960 picture-word concatenated items was created. Repeated pictures acted as the task relevant-targets. The presentation stream was broken into eight blocks of 120 trials in which an immediate picture repetition occurred on average of one out of every eight trials, equating to an average of 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).

Eight words were selected to be superimposed over the 960 trial picture stream. This was done to parallel the quantity of items and exposure to irrelevant stimuli as well as mimic the dependent measure employed by Watanabe et al. (2001; see also Seitz & Watanabe 2003, 2005). The eight selected words can be thought of as the eight coherent motions. That is, the same single word was always temporally aligned with the presentation of an immediately repeated picture target. All eight words were presented equally. 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. This single word was randomized between the eight words between participants (2 participants per word) so as to control for any possible differences that may have existed regarding particular word saliency.

A surprise recognition test was administered after the completion of the repetition detection task. The test consisted of a total of sixteen words from which half came from the previously viewed visual stream, while the other half consisted of foil words that had never been seen before. The foils were words that had never been used in the exposure stage of the experiment, but were taken from the same database and had an average frequency of 236 per million with a range of 165-399. The eight non-foil (previously seen in the picture repetition task) words 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). For ease of explaining and reference, words synchronized with task-relevant targets will be referred to as *target-aligned* words and those not aligned with task-relevant targets will be referred to as *non-aligned* words (see also Dewald et al., 2011).

Both the repetition detection and word recognition tasks were randomized and presented by DMDX software (http://www.u.arixona.edu/jforster/dmdx.htm) one at a time, written in bold, capitalized letters in Arial font at a size of 24 points, in an identical fashion 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 required to attend to the picture stream (i.e., ignore the simultaneously presented superimposed words) and respond to immediate picture repetitions by pressing the 'G' key on the keyboard of the computer. 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.
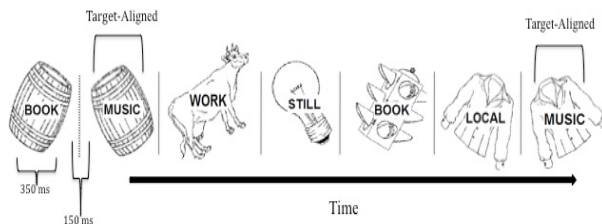

Figure 1. Each picture–word stimulus was presented for 350 ms and then replaced by a blank screen for 150 ms before the next stimulus. The task is to respond to picture repetitions and ignore the words, for which a surprise recognition test is later given. Note that the *target-aligned* word (in the present case 'MUSIC') remains the same across all repetition trials.

Immediately after the repetition detection task, the 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.

Results

Overall task performance for word recognition was 78%, which was significantly above chance levels (t (15) = 6.58, $p < .01$). In order to address the question at hand, that is, if recognition performance is enhanced for words that had appeared with a picture repetition, the average correct recognition score for *target-aligned* words (words superimposed over immediately repeated pictures) and *non-aligned* words was compared against chance, and also against each other. In this case, recognition for *target-aligned* (87.5%, SE=.85) and *non-aligned* words (68.4%, SE=.37) was significantly better than chance (t (15)= 10.91, $p < .001$ and t (15)= 4.89, $p < .001$ respectively). Most importantly, recognition for *target-aligned* words was significantly better than performance for *non-aligned* words (t (15)= 2.31, $p = .03$; see Figure 2).

Additionally, the correct rejection of foil words was compared with overall performance for *target-aligned* and *non-aligned* words. No significant differences between recognition for *target-aligned* words and correct rejections surfaced (*target-aligned*: 87.5%, SE=.85 vs. *CR*: 88.6%, SE=.03, $t(15)$=-.07, p=.994). There was a significant difference between correctly recognizing *non-aligned* words and correctly rejecting foil words (*non-aligned*: 68.4%, SE=.37 vs. *CR*: 88.6%, SE=.03, $t(15)$=3.69, p<.002). Further demonstrating the overall accuracy of word recognition, there were significantly fewer false alarms (FA) (i.e., incorrectly identifying a foil word as having been present during the picture repetition task), when compared with correct foil rejections (*FA*=10.4% vs. *CR*=88.6%, $t(15)$=17.08, p<.001), *target-aligned* words (87.5%, $t(15)$=17.65, p<.001), and *non-aligned* (68.4%, $t(15)$=13.79, p<.001) words as well as significantly fewer false alarms than to be expected by chance ($t(15)$=19.11, p<.0001).

Lastly, confirming that participants were able to successfully perform the initial repetition task, an analysis was also conducted on the accuracy of the primary task of detecting immediate target repetitions. Overall, participants accurately detected target repetitions (**Hits:** 75%, *SE*=0.20 vs. **Misses:** 25%, *SE*=0.79, $t(15)$=11.83, p<.001).
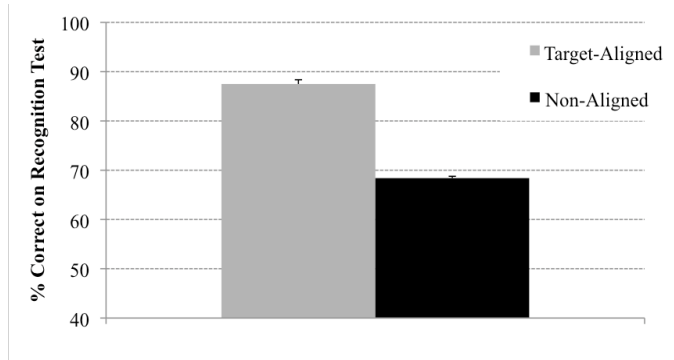

Figure 2. Recognition percentages and standard error bars for Target-Aligned (grey bar) and Non-Aligned (black bar) words in the surprise word recognition test after attending to the picture stream.

Discussion

The present findings extend investigations exploring how above threshold, but unattended information is processed

when it appears simultaneously with an attended target (Dewald et al, 2011; Lin et al, 2010; Seitz & Watanabe, 2003, 2005; Swallow & Jiang, 2010; Tsushima et al., 2006, 2008). Critically, despite all task-irrelevant words being recognized better than chance, words that were temporally aligned with a picture target (i.e., repetition) were recognized at significantly higher rates when compared with words that did not appear with a picture target. Specifically, performance for both the *target-aligned* (88%) and *non-aligned* (68%) words was significantly better than chance, but *target-aligned* words were recognized significantly better than *non-aligned* words. Accordingly, this suggests that, at least in the present case, temporally pairing explicitly presented irrelevant stimuli with relevant target stimuli facilitates subsequent recognition of the irrelevant stimuli.

Performance on the ability to correctly reject foil words further bolsters the notion that target-alignment is critical for enhanced perception. Participants were significantly more accurate at correctly rejecting foil words in the recognition test than they were at correctly identifying *non-aligned* words (88% vs. 68%, respectively), while no significant differences were observed when comparing performance for rejecting foils with accuracy for *target-aligned* words (88% vs. 87%). These data suggest an "attentional boost" (see Swallow & Jiang, 2010) for irrelevant stimuli as long as the stimuli were presented simultaneously with a target in the picture repetition task, despite not receiving direct attention.

The superior recognition of *target-aligned* words is analogous to the enhanced motion detection for coherent motion displays aligned with relevant task-targets observed by Seitz and Watanabe (2003). Interestingly, this enhancement was found only after exposure to implicitly presented motion directions. When explicitly presented (i.e., suprathreshold) an inhibition was observed for motion recognition, rather than a facilitation (see Tsushima et al., 2006; 2008). These findings would seemingly indicate that the enhancement or inhibition of performance is contingent on whether the initial irrelevant but target-aligned stimulus was implicitly or explicitly presented. The present findings fail to support either notion. That is, *facilitation* for target-aligned stimuli was observed, despite all irrelevant stimuli being overtly presented.

Aligning with our result, other recent investigations have observed an "attentional boost" (i.e., facilitation) for simultaneously and overtly presented information in a dual-task paradigm (Lin et al., 2010; Swallow & Jiang, 2010). However, significant procedural differences warrant discussion. Specifically, Swallow and Jiang's (2010) task (see also, Lin et al, 2010) required participants to attend to both the irrelevant and relevant streams of information, rather than only one stream as done here (see also Seitz & Watanabe, 2003; but see Swallow & Jiang, 2011, discussed below). Thus, the key distinguishing feature between the respective paradigms is whether or not attention was simultaneously directed to both streams of information or if only a single stream receives attention while the other is ignored.

Addressing the differing approaches, Swallow and Jiang (2011) required to only attend to one stream of information while ignoring the other. In this case, participants were required to direct their attention to the detection of the "odd ball" target only and not required to pay attention to the concurrently presented picture scenes (i.e., the images were now *irrelevant* to the task). A surprise recognition test administered for the pictures (task-irrelevant) revealed that the attentional boost effect did not occur when the background scenes were made task-irrelevant, thereby suggesting that temporal alignment was not sufficient to foster the attentional boost of target-aligned irrelevant stimuli.

This elimination of the attentional boost seemingly contradicts the present findings demonstrating an enhanced performance for the recognition of target-aligned stimuli. A potential explanation for this could be found in the differing amounts of irrelevant stimuli utilized in each respective paradigm. For instance, in Swallow and Jiang's (2011) experiment over 100 different stimuli (pictures) served as the irrelevant items, while presently there was only one target-aligned stimulus and seven non-aligned items (i.e., analogous to Tsushima et al., 2008). This considerable difference in stimulus set size could be why we observed an attentional boost (despite attention not being directed to both streams). Note, the elimination of the attentional boost effect is actually a null effect when comparing aligned with non-aligned items, therefore it is difficult to make a strong claim regarding these findings.

Further support for the speculation that the quantity of irrelevant items modulates whether the boost is observed or not, comes from previous research conducted by our laboratory (Dewald et al., 2011). In this work, the paradigm was identical to the present (i.e., detect picture repetitions followed by a word recognition test), but an inhibition for target-aligned stimuli was observed. Importantly, the number of irrelevant items (50) was more in line with Swallow and Jiang's (2011) recent work. Furthermore, as stated before, using semantic words rather than pictures could also be a contributing reason why we continue to see an attentional boost here, despite attending to only one stream of information (pictures).

Setting aside the null effect found by Swallow and Jiang (Experiment 4, 2011), studies involving a specific analysis of recognition performance for target-aligned vs. non-aligned stimuli show recognition for target-aligned stimuli to be either *inhibited* (i.e., recognized significantly below chance levels) or facilitated, with a key difference being whether the target stimulus was implicitly or explicitly presented. It is evident that in the present experiment, words were recognized at high levels (78% of the time), and when accounting for target alignment, those synchronized with repetitions were indeed better recognized (a 20% improvement). In fact, when attention was most utilized in the repetition detection task, subsequent performance for the

target-aligned word was best. Recall however, that Tsushima et al. (2008) observed an inhibition for target-aligned, suprathreshold irrelevant stimuli. Although both Tsushima et al. (2008) and the present investigation utilized an above threshold, irrelevant stimuli (written words/ high motion coherence, respectively), it may be that the increased saliency and frequency of presentation of the written words lead to a facilitation rather than an inhibition.

Combined, the present findings and previous research offer insight into how irrelevant information is processed when it is presented simultaneously with an attended target. Under certain circumstances, unattended stimuli can be perceived and affect behavior (see also Dewald et al., 2011; Seitz & Watanabe, 2003; Tsushima et al., 2008). When using a low salience, irrelevant stimulus, there appears to be a relationship between explicit or implicit presentations, fostering either an inhibition (Tsushima et al., 2008), or facilitation (Seitz & Watanabe, 2003) respectively. Regardless of the explicit or implicit nature of the stimuli presentation, synchronization of task-relevant and task-irrelevant signals is crucial to establishing a relationship that will affect perception for task-irrelevant stimuli aligned with task-relevant targets, however, this relationship can be modulated when dividing attention across streams of information (Swallow Jiang, 2010, i.e., a facilitation is observed for explicitly presented stimuli). Most importantly to the present investigation however, when using a high exposure rate to salient, explicitly presented irrelevant stimuli in a limited stimulus set a perceptual window is created in which an "attentional boost" (Swallows & Jiang, 2010) surfaces for stimuli that do not receive direct and focused attention as long as they are presented simultaneously with the relevant target of a separate task.

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