Target-Distractor Phase and Selective Attention:

Idle Resources do the Devil's Work?

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Abstract

Four experiments tested the hypothesis that exclusion of irrelevant stimuli is more effective when attentional resources are engaged in processing task-relevant stimuli than when they are idle. Subjects (university students) attended to a series of target words while attempting to ignore distractor words and then recalled the targets. Distractors were presented either in phase with targets (when attentional resources are presumably occupied with target processing) or out of phase (when resources are relatively idle). When distractors occurred in the same modality as targets (auditory in Experiment 1, visual in Experiment 2), recall accuracy was lower with out-of-phase distractors, consistent with the hypothesis. However, when distractors occurred in a different modality than targets (auditory distractors with visual targets in Experiment 3, vice versa in Experiment 4), there was no difference between the phase conditions, although both were inferior to the no-distractor control condition. The interaction between phase and modality is consistent with largely modality-specific processing resources.

People have an impressive ability to exclude irrelevant stimuli from processing. This article asks under what conditions these stimuli are more likely to capture attentional resources and thus more difficult to ignore. Several authors have suggested that the ability to ignore irrelevant stimuli (hereafter referred to as distractors) depends on the momentary processing demands imposed by relevant stimuli (targets). This idea presumes that processing targets requires and engages some amount of the limited resources. When the resources are engaged in processing the target, they are not available for processing the distractor. If, however, they are not engaged in target processing, then they are "idle" and susceptible to capture by the distracting stimuli, resulting in their processing. The adage "the Devil makes work for idle hands" captures the spirit of this hypothesis: when resources are idle, they are susceptible to capture by distractors and thus are more prone to process the distractors, despite the observer's desire to ignore them. We term this the "idle attention hypothesis" (IAH).

This idea appears to have been first explicitly proposed by Treisman (1969), who hypothesized that there are a number of different perceptual "analyzers," each of which computes a set of mutually exclusive descriptions of any given stimulus. When a stimulus is selected for processing along one dimension, the other dimensions are also processed because "no economy can be achieved by leaving some [analyzers] unused" (p. 287). The only time these analyzers would not process a given input would be if they were "already fully occupied with other tests and inputs" (p. 296).

Around the same time, Moray (1969) also hinted that the processing of an item depends on current demands on processing resources. Referring to the relative timing of dichotic messages (one message to each ear), Moray wrote: "There is no doubt that, if all else is equal, the one of a pair of messages which starts earlier has a very high probability of being selected. During the period before the second message starts it is virtually, perhaps completely, impossible to avoid hearing the message which has begun" (p. 49).

Kahneman (1970) also suggested that an irrelevant items are harder to ignore – and thus cause more distraction – when the primary task that the person is engaged in is relatively easy. To test this, Kahneman and G. Ben-Shachar (cited in Kahneman, 1970) had subjects perform arithmetic calculations (addition and subtraction) involving auditorily presented digits. Subjects performed this task under two conditions: with lyrical music playing in the background (distraction condition) and in quiet (control condition). Accuracy was higher for the addition task, from which the authors inferred that it was easier, and performance was poorer in the distractor condition than the control condition for both tasks. Consistent with Kahneman's hypothesis, distraction reduced performance more for the easier addition problems (89% correct under quiet, 82% correct under distraction) than for the subtraction ones (77% correct under quiet, 74% correct under distraction).

Although the observed interaction of problem difficulty and distraction conditions certainly seems consistent with the IAH hypothesis, such an interpretation appears subject to scaling problems: one must assume that the larger difference in the response measure (percent correct) under the easy-task condition reflects a greater change in the psychological component of interest (distractibility). As has often been noted, inferences of this kind are questionable (see Loftus, 1978, for discussion).

More recently, Lavie and colleagues (Lavie, 1995; Lavie and Tsal, 1994; Lavie and Cox, 1997) also suggested that a reduced processing load results in less effective selective attention. Lavie (1995) tested this hypothesis using the so-called

Eriksen flanker task (Eriksen and Eriksen, 1974), where subjects make a speeded response based on the identity of a target letter appearing in the center of a display, attempting to ignore flanking letters. Reaction times (RTs) to respond to the central letter are longer when the flankers are associated with a different response than the target compared to no response at all. This difference in RT, referred to as the "compatibility effect," is taken to illustrate that the distractor letter was processed. Lavie predicted that the compatibility effect should arise only when the main task does not require all processing resources. In Experiment 1, she varied the target processing load by manipulating the number of letters that appeared with the single target letter. In the low load condition, only a single distractor letter appeared near the target; in the high load condition, five "neutral" letters (letters not mapped to any response) appeared in addition to the distractor. A significant compatibility effect was observed under the low load condition (40 ms) but not under the high load one (4 ms). Lavie interpreted the absence of the compatibility effect in the high load condition as evidence that the distractor was not processed, whereas the presence of the compatibility effect in the low load condition implied that it was.

While consistent with the hypothesis, these results, too, seem open to various interpretations. Suppose there is enough processing capacity to handle the target along with, say, one other item. In the low load condition, that other item will always be the distractor because that is the only other item in the display. We should therefore expect a compatibility effect. In the high load condition, however, the additional item that is processed will only rarely be the distractor and most of the time it will be a neutral letter. We should then expect a reduced compatibility effect, perhaps too small to detect.

Whereas Lavie manipulated processing load in Experiment 1 by varying the number of items presented with the targets, in Experiments 2 and 3 she instead varied the amount of processing by using a go/no-go task (where a symbol's identity indicates whether the subject is to respond or not). The discriminability of the symbol was relatively easy in the low load condition (featural discrimination in Experiment 2; detection of a symbol in Experiment 3) as compared to the high load condition (conjunction of features in Experiment 2; identification of symbol in Experiment 3). Compatibility effects were again found in the former but not latter condition.

Although consistent with the IAH hypothesis, this interpretation seems less than compelling. First, in Experiment 2 compatible responses in the high load condition were slower than neutral or incompatible ones (by 28 and 35 ms, respectively). Lavie attributed this unexpected finding to a speed-accuracy tradeoff. Second, RTs in the high load condition were approximately 1000 ms (959-994 ms in Experiment 2; over 1100 ms in Experiment 3), over 300 ms slower than in the low load conditions. This disparity raises the possibility that in the high load condition the distractor was in fact processed, but its effects had dissipated by the time the response was selected (J. Miller, personal communication). The plausibility of such an interpretation is increased by findings of Hommel (1994), who noted that the magnitude of the Simon effect is altered by manipulating the target discriminability. When discriminability was easy, Hommel found, overall RTs were fast and the Simon effect was obtained. However, when it was difficult, overall RTs were slower and the Simon effect was not observed. He concluded that the failure to observe the Simon effect in the latter condition is because it had already dissipated by the time the (slower) responses were made. The strong possibility of dissipation somewhat weakens the Lavie et al data as evidence for the IAH hypothesis.

In a later study, Lavie and Cox (1997, Experiment 1) tested the load hypothesis using a visual search task. Subjects searched circular arrays of letters for one of two targets (the letters X and N) and the load was manipulated by the difficulty of the search. In the hard-search condition, the nontarget letters, like the targets, were composed of straight line segments (e.g., H's and K's) whereas in the easy-search condition, the nontarget letters were composed of curved lines (e.g., O's). A single distractor letter appeared outside the circular array. Consistent with the load hypothesis, the compatibility effect was obtained in the easy-search condition (about 25 ms, as estimated from Figure 2) but not in the hard-search one. Unfortunately, Lavie and Cox did not report the RTs for the three compatibility conditions of each search type, but they can be approximated[1] based on the overall RTs of the easy and hard conditions (478 and 720 ms, respectively) and Figure 2. From this, we see that the slowest RT in the easy search condition was under 500 ms, whereas the fastest RT in the hard search condition over 700 ms. Thus, the timing issue noted above is a concern here as well.

Overview of the experiments.

We tested the IAH hypothesis with a method that does not appear subject to the same limitations as the studies noted above and might therefore provide converging evidence for IAH. The experiments used a short-term memory task: Subjects were asked to attend to a series of targets (words) presented to one channel

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[1] From fig. 2, we estimate for the easy condition that the RTs for the neutral and compatible conditions are the same, and that the incompatible condition is 25 ms slower than the neutral one. Because the overall RT in the easy search condition was 478, then it must be that: $(x + x + x+25)/3 = 478$. Therefore, the group RTs are around 470, 470, and 494, respectively. For the hard search condition, we estimate from the figure that there is no difference among the three conditions, so the RT of each group must be the same as the group average, or 720 ms.

(e.g., the left ear) while attempting to ignore a series of distractors (different words) presented to a different channel (e.g., the right ear). They then performed an unspeeded vocal recall of the targets. The processing load was manipulated by varying the relative phase of targets and distractors: distractors were presented either in phase (simultaneously with targets) or out of phase (during the blank interval between them). Previous studies have demonstrated the interfering effect of irrelevant stimuli on this task (Colle and Welsh, 1976; Salamé and Baddeley, 1982, 1987). The goal of this research was to investigate whether the amount of interference by the distractors depends upon target-processing demands. It is presumed that resources are more heavily engaged in target processing during presentations as compared to the interval between presentations. If resources are more susceptible to capture when idle, then it should be more difficult to ignore distractors occurring out of phase with targets. Distractors in this condition should be processed more than those in the inphase condition and thus cause more interference with the memory task. Recall accuracy should therefore be lower in the out-of-phase condition than in the inphase one.

The basic design of the first two experiments is very simple – so simple that it seems surprising that it was not examined during the era when dichotic listening studies were relatively popular (the late 1950s and early 1960s). As far as we can tell, however, no such results were reported. The design does not have the limitations of the studies described above. First, unlike the Lavie studies (Lavie, 1995; Lavie and Cox 1997), only targets and distractors are presented; the processing load is manipulated without presenting additional stimuli such as neutral letters or go/no-go symbols. Second, recall accuracy serves as the main dependent variable, thereby avoiding the difficulties of comparing effects on RTs that differ greatly in magnitude.

Third, the key test employed here seems not subject to the sort of scaling problems note in relation to the study by Kahneman (1970).

Experiments 1 and 2 explore within-modal distraction whereas Experiments 3 and 4 examine crossmodal distraction. In Experiment 1, targets and distractors were presented dichotically over headphones. In Experiment 2, targets and distractors were displayed on a computer monitor: Targets were presented in the central region while distractors were presented both above and below this region. In Experiment 3, targets appeared on the monitor while distractors were presented over headphones. In Experiment 4, the presentation modality of the stimuli was swapped: targets were presented over headphones while distractors were presented on the monitor.

Experiment 1

All stimuli were presented auditorily over headphones. Subjects were instructed to attend to a series of targets (words) presented to one ear and to ignore a series of distractors (different words) presented to the other ear. Subjects then verbally reported the targets. Distractor presentation was manipulated between blocks: inphase with targets, out of phase, or not at all (control condition). The dependent measures were recall accuracy and percentage of intrusions (mistakenly reporting distractors as targets).

Method

Subjects. Female and male undergraduate subjects (n=18) participated in exchange for partial course credit. All reported normal hearing.

Stimuli. Stimulus items were recordings of 19 one-syllable words (letters and digits) by one male and one female native English speakers. In an effort to avoid auditory confusions, words that sounded similar were not used (see appendix for listing of stimuli). SoundFx-Pro software was used for analogue-to-digital sound recording and editing, and the average length of each recording was 363 ms (SD=31, with a range of 311- 454 ms.). The items were recorded with a microphone and presented through headphones at normal conversational levels. The sound intensity of all the recordings was subjectively judged to be comparable.

On each trial, 12 items were randomly selected without replacement. Half were assigned to be targets and presented to the ear to be attended (hereafter, attended ear) in the male voice at a rate of one item/1100 ms while the remaining items, assigned to be distractors, were presented to the ear to be ignored (hereafter, ignored ear) in the female voice at the same rate.

Apparatus. An OEI Electronics 486 Turbo Personal Computer (PC), allowing for millisecond timing, was equipped with a Silicon Shack LTD 1988 SoundCard and controlled the presentation of auditory items through standard personal-stereo headphones.

Design. The primary within-subjects variable of phase had three levels and was varied by block. In the inphase condition, the onset of a distractor was synchronous with the onset of a target. In the out-of-phase condition, a distractor occurred during the silent interval between targets. Specifically, the onset of a distractor was 500 ms after the onset of a target. In the control condition, no distractors were presented (subjects nonetheless wore the headphones). Each condition was presented once every three blocks; the order of conditions in each three-block cycle was randomly determined. Subjects were not informed which phase condition they were about to be presented.

The secondary within-subjects variable was the attended ear. Half of the subjects began the experiment attending to the left ear (ignoring the right one), while the other half did the opposite. The attended ear was switched at the conclusion of every three-block cycle, and in order to help remind subjects which ear was currently the attended ear, they placed their ipsilateral hand on the desk located in front of them.

There were six three-block cycles, with five trials per block, in the session. Before the session commenced, subjects first practiced with three trials per phase condition. The practice and experimental session lasted under one hour.

Procedure. Subjects, tested individually, were seated in a quiet room and wore headphones. They were instructed to attend to the six items presented to the attended ear and to ignore the items presented to the other ear. The trial began with a key press, and the first target was presented 2000 ms later. Subjects were allowed to use rehearsal strategies and were encouraged to recall targets in the same order in which they were presented. They were told to respond "blank" if they could not recall a particular target. Subjects were allowed to begin vocalizing their responses immediately upon the conclusion of stimuli presentation. The experimenter, seated in the experimental room, wrote down the responses. At the end of each block, subjects were allowed to rest, and when ready, pressed a key to resume the experiment. At the end of each three-block cycle, subjects were instructed to attend to the other ear.

The subjects' responses were scored at the conclusion of the experiment. Each item in the response was sorted into one of three categories: correct response (regardless of the serial order in which it was reported), intrusion (a reported distractor), or miscellaneous error (a reported item that was neither a target nor a distractor). The number of each type was summed for each trial and then averaged across the entire session for each phase condition.

Results

Two subjects were unable to complete the experiment satisfactorily. One became excessively drowsy and another complained of hearing difficulty in one ear during the experiment. Data for these two subjects were discarded. All dependent measures were analyzed with a two-way Analysis of Variance (Anova) with phase condition and attended ear as the within-subjects variables and with an alpha level of .05. For pairwise comparisons, Fisher's Least Significant Difference (LSD) was used as suggested by Howell (1997) for good statistical power among three groups.

Correct responses. Table 1 presents the mean percent correct of responses by phase and attended ear conditions. There was a main effect of phase condition, $F(2, 30) = 46.145$, $p < .001$, $MSE = 0.0117$. The percentages (with standard error) of targets reported for the inphase, out-of-phase, and control conditions were 78.9 (2.5), 71.9 (2.8), and 87.2 (2.0), respectively. Accuracy differed in all pairwise comparisons. The comparison most relevant to the IAH, inphase versus out-of-phase conditions, showed that subjects obtained significantly lower accuracy in the out-of-phase condition, $q_{.05}(2, 30) = 4.375$, $q_{crit} = 2.89$. Subjects' performance was better in the control condition compared to both the inphase and out-of-phase conditions, $q_{.05}(2, 30) = 5.21$, $q_{crit} = 2.89$; and $q_{.05}(3, 30) = 9.58$, $q_{crit} = 3.49$, respectively.

There was no difference in recall performance depending on which ear subjects attended to, $F(1, 15) = 0.532$, $p < .47$, $MSE = 0.1394$. The percentages of targets reported when presented to the left and right ears were 78.9 (2.3) and 79.8 (2.1), respectively. The phase condition X attended ear interaction was also not significant, $F(2, 30) = 1.226$, $p < .30$, $MSE = 0.1208$.

Intrusion responses. Table 2 presents the mean percent of intrusion responses by phase and attended ear conditions. Because no distractor items were presented in the control condition, there is intrusion data only for the inphase and out-of-phase conditions. There was no significant difference by phase condition, $\underline{F}(1, 15) = 0.188$, $\underline{p} < .67$, $\underline{MSE} = 0.0426$, and the percentages of intrusions for the inphase and out-of-phase conditions were 5.5 (0.8) and 5.9 (0.6), respectively. The main effect of attended ear, on the other hand, was significant, $\underline{F}(1, 15) = 4.815$, $\underline{p} < .05$, $\underline{MSE} = 0.0111$. The percentage of intrusions was greater when subjects attended to the left ear (6.2, $\underline{SE} = 0.7$) than to the right one (5.3, $\underline{SE} = 0.7$). The phase condition X attended ear interaction was not significant, $\underline{F}(1, 15) = 0.278$, $\underline{p} < .605$, $\underline{MSE} = 0.0237$. We also tested the simple effect of attended ear at the inphase level, but this was not significant, $\underline{F}_{.05}(1, 15) = 2.06$, $\underline{F}_{crit}(1, 15) = 4.54$.

Miscellaneous errors. Miscellaneous errors are defined as reported items that were neither targets nor distractors. Because in the control condition no distractors were presented, all non-target responses were classified as miscellaneous errors. However, not all non-target responses in the inphase and out-of-phase conditions were classified as such; indeed, some were intrusions. Therefore, a straightforward comparison of the percent of miscellaneous errors among the three conditions would be misleading. Instead, we made two separate comparisons. First, we compared the miscellaneous error data between the two distractor conditions only. Then, in order to compare the miscellaneous error data from the control condition (that is, non-target responses) with the non-target responses from the two distractor conditions, we first combined the intrusion and miscellaneous error data for each distractor condition and then made the comparison among the three groups. We refer to these combined data as “non-target” responses.

Consider first the miscellaneous errors data from the two distractor conditions. These data are presented in Table 3 by phase condition and attended ear. There was no main effect of phase condition, $\underline{F}(1, 15) = 3.448$, $\underline{p} < .083$, $\underline{MSE} = 0.0031$. The percentages of these responses for the inphase and out-of-phase conditions were 1.8 (0.3) and 2.3 (0.4), respectively. The main effect of attended ear was not significant, $F(1, 15) = 0.060$, $p < .81$, $MSE = 0.0142$. The percentages of miscellaneous errors were 2.4 (0.3) and 3.0 (0.4) when subjects attended the left and right ears, respectively. Finally, phase X attended ear condition interaction was also not significant, $F(1, 15) = 0.010$, $p < .92$, $MSE = 0.0151$.

Now consider the non-target response data. These data are presented in Table 4 by phase condition and attended ear. There was a main effect of phase condition, $F(2, 30) = 10.763$, $p < .001$, $MSE = 0.0100$. The percentages of responses for the inphase, out-of-phase, and control conditions were 7.4 (0.9), 8.2 (0.9), and 4.0 (0.5), respectively. Fisher's LSD tests revealed that there were fewer non-target responses in the control condition compared to either the inphase or out-of-phase conditions, $q_{.05}(2, 30) = 3.54$, $q_{crit} = 2.89$, and $q_{.05}(3, 30) = 4.39$, $q_{crit} = 3.49$, respectively. The two distractor conditions, however, did not differ significantly, $q_{.05}(2, 30) = 0.875$, $q_{crit} = 2.89$. As with the miscellaneous error data for the two distractor conditions, the main effect of attended ear was not significant, $F(1, 15) = 1.619$, $p < .223$, $MSE = 0.0186$. The percentages of responses when subjects attended the left and right ears were 6.6 (0.7) and 6.5 (0.7), respectively. Finally, the phase X attended ear condition interaction was not significant, $F(2, 30) = 1.550$, $p < .229$, $MSE = 0.0123$.

Discussion

The purpose of this experiment was to test the IAH in the auditory modality with a short-term memory task. Targets were presented to one ear and distractors presented to the other, either in-phase of out of phase with targets. The primary prediction of the IAH hypothesis was supported: Fewer targets were recalled when distractors were presented out of phase rather than in phase. Additionally, the standard Irrelevant Speech Effect (ISE) was obtained: subjects recalled fewer items in the presence of irrelevant speech – regardless of phase – compared to the no-distractor control condition. There was no difference in recall performance, however, depending on which ear subjects attended to, and this factor did not interact with the phase manipulation.

The effect of phase was not significant for the secondary dependent measures, however. The percent of intrusions and miscellaneous responses were both quite low (under 6% and 3%, respectively). The lack of a significant phase effect for the percent of intrusions is not necessarily inconsistent with the IAH. After all, distractors processed more thoroughly (in the out-of-phase condition, according to the IAH) would not necessarily be reported as targets. If the distractors were correctly "tagged" as such, then they would not be reported. Thus, it is possible that distractors were indeed processed more extensively when presented out of phase but they were correctly assigned the property of being a distractor. They would therefore not be reported as targets and so would not affect the intrusion score. On this account, we would expect to observe an effect of distractor processing on the correct response data, which was indeed obtained.

The attended ear factor was significant for the intrusion data: more were reported when they occurred in the right ear (and thus subjects were attending to the left ear). The phase X attended ear interaction, however, was not significant. The main effect of attended ear is consistent with previous findings of the so-called right ear advantage (REA), where a processing benefit (such as faster responding) is often found when linguistic stimuli are presented to the right ear compared to the left (Kimura, 1961). This advantage is thought to stem from the more direct (contralateral) connections between the right ear and language processing centers in the left cerebral hemisphere. The finding of more intrusions from the right ear implies that the distractors enjoyed a processing “benefit” (in this case, were more difficult to ignore) when they occurred in the right ear compared to the left, consistent with the REA.

What sort of interference do the distractors cause? One possibility is that the processing of the distractors causes some sort of general confusion, making it difficult to distinguish whether a presented item was a target or distractor. If this were the case, then some combination of targets and distractors would be maintained in short-term memory and reported as targets. Because the short-term memory store has limited capacity, maintaining a distractor in memory would exhaust some of this capacity, resulting in less capacity for targets. One outcome we would then expect is lower target recall. This was observed. A second outcome would be more intrusions in the out-of-phase condition. This was not found. Not only was there no significant difference in the percentage of intrusions by phase condition, but in both conditions the rate was quite low, under six percent. Thus, the overall pattern of data argues against a general confusion account of distraction.

Baddeley’s (1990) model of working memory may be useful in considering what effect distractors are having. The model proposes that the loop is composed of two components: a phonological store and an articulatory control process. The phonological store, which has limited capacity, holds phonological codes of items that remain until they decay over time or are replaced by other codes. The articulatory control process refreshes these codes in order to counter their decay and can also recode non-auditory codes (e.g., visual codes) to phonological ones. Codes enter the store either via this articulatory control process (for non-auditory items) or have “obligatory access” in the case of auditory codes. Because in the present experiment distractors were presented auditorily, we focus on the former method of entry: obligatory access.

Baddeley does not elaborate on whether the access requires attentional resources, but we can certainly infer from the word "obligatory" that all auditorily presented items must enter the loop. The model predicts, at least on first approximation, that all distractors should cause interference, regardless of the phase in which they occur. Therefore, there should be no differential effect of phase presentation. However, distractors presented out of phase were found to interfere more than those presented in phase, a finding not obviously predicted by this model.

How might this model account for these findings? First, we note that many of the studies Baddeley conducted with auditory distractors used visually presented targets. In this case of crossmodal presentation of stimuli, attending to the visual targets apparently was not sufficient to prevent the auditory distractors from causing interference, presumably due to their entering the loop. However, in the present experiment, both targets and distractors were presented auditorily. Perhaps this case is qualitatively different, and so attending to auditory targets might affect the access of distractors into the loop. Indeed, this is related to the hypothesis we are testing. Therefore, obligatory access by auditory distractors might depend on the modality of the target presentation. We will consider this further in Experiment 3.

In the meantime, is it possible for Baddeley's model to account for the data without considering the modality of target presentation? One possible explanation might be to shift the focus of contention away from obligatory access into the loop and onto the amount of processing of the items once already within the loop. That is, while the model in its current form must predict that distractors from both phase conditions have obligatory access to the loop, it could be that they are processed to varying degrees, depending on the attentional demands for target processing at the time of access. It could be that out-of-phase distractors form stronger memory traces than inphase ones because the former are formed when there is no competition for attentional resources. Distractors presented in phase with targets, on the other hand, would gain access to the loop, but because resources at this time are required for target processing, these distractors would be processed less, resulting in a weaker code. As a result, distractors presented inphase would cause less interference. This account is thus a synthesis between Baddeley's model of obligatory access and the IAH.

Experiment 2

The purpose of this experiment was to test the idle attention hypothesis in the visual modality. The experiment was divided into two parts. In Part 1, subjects performed a STM task similar to Experiment 1 except that the stimuli -- both targets and distractors -- were presented visually. Subjects were instructed to attend to the targets, presented one at a time at the central region of the computer monitor, and to ignore the distractors presented one at a time near the targets some time during their presentation. Subjects attempted verbal recall of the targets at the conclusion of each presentation. The main manipulation again was the phase of the distractors. In Part 2, after the conclusion of the STM task, subjects were presented a surprise recognition-memory test. They were asked to indicate which words on a list had been presented during the STM task (as either a target or a distractor). If out-of-phase distractors are indeed processed more than inphase ones, then we might expect two outcomes. First, the recognition rate of targets presented in the out-of-phase condition should be lower than those presented in the inphase condition because these targets were presented under the hypothesized more-distracting condition. Second, the recognition rate of distractors in the out-of-phase condition should be higher than that of the inphase condition because the former are hypothesized to be processed more than inphase distractors.

Method

Subjects. Male and female students (n=21) from the psychology department subject pool participated in exchange for partial course credit. All reported normal or corrected to normal vision.

Apparatus. The PC from Experiment 1 controlled the presentation of the visual stimuli on an NEC Multisync 2A 13” color monitor.

Stimuli. Stimuli were nouns, four to six letters in length, selected from a word corpus (Kucera and Francis, 1967). Each was randomly assigned to be a target (n=630), distractor (n=630), or foil (n=108). Targets and distractors were then separately listed in a fixed order so that words were presented in the same order for all subjects. Targets, colored red, appeared in the central region of the monitor, which was circumscribed by a red rectangular outline measuring 4.0 wide x 2.0 high cm. Distractors, colored blue, appeared outside of the outlined region. The same distractor was presented simultaneously in two locations: directly above and below the target region. The vertical distance between the center of the targets and the center of the distractors was 2.0 cm, subtending 1.91 visual angle from a viewing distance of 60 cm. The stimuli were presented in lower case font and measured 2.0 – 3.5 wide x 1.5 high cm, subtending 1.91-3.34 x 1.43 visual angle. The background color of the monitor was gray. No word was presented in more than one trial.

Design. The single within-subjects variable of phase condition had three levels and was varied between blocks. In the inphase condition, a distractor was presented and removed synchronously with a target. In the out-of-phase condition, a distractor appeared at the offset of a target. Finally, in the control condition, no distractors appeared. Each condition was presented once every three blocks; the order of each three-block cycle was randomly determined, and subjects were not informed which phase condition they were about to experience. Because target and distractor words were presented in the exact same order across all subjects, the random order of phase conditions insured that targets and distractors were presented under varying phase conditions across subjects. There were five trials per block and six three-block cycles per session. A subject-paced rest period occurred after every block.

Procedure. There were two parts to this experiment. In Part 1, subjects were instructed to fixate and attend to the central region of the monitor. On each trial, seven target words were sequentially presented for 400 ms each at a rate of one target/1100 ms (see figure 2). Seven distractor words were also sequentially presented for 400 ms each at the same rate. The task was to remember the targets and vocalize them aloud upon hearing a computer-generated beep, which occurred 700 ms after the offset of the last target. Subjects were instructed to report the targets in the same order in which they were presented and were told to respond “blank” for items they could not recall. The experimenter, seated in the experimental room, recorded the responses.

In Part 2, immediately following Part 1, a surprise recognition memory test was administered. Subjects were given two sheets of paper that listed 288 words. Seventy-two had been presented in Part 1 as targets, 72 as distractors, and 144 had not been presented (foils). This list was constructed by randomly sampling four targets and six distractors[2] from every block in Part 1. These words, along with the foils, were then listed in a completely random order, and all subjects saw the exact same list. Subjects were instructed to circle words – both targets and distractors – that had been presented in Part 1. Subjects, run individually, completed Parts 1 and 2 in less than one hour.

Results

All dependent measures were analyzed with a one-way Anova with phase condition as the within-subjects variable and an alpha level of .05. Due to a procedural error, an incorrect recognition-memory word list was mistakenly presented to the first six subjects. Analyses were therefore limited to the remaining 15 subjects.

Part 1.

Responses were scored as in Experiment 1. For the correct responses, there was a main effect of phase condition, $F(2, 28) = 4.538$, $p < .02$, $MSE = 0.0208$. The percentages (with standard error) of correct responses for the inphase, out-of-phase, and control conditions were 58.8 (2.3), 56.9 (2.3), and 59.0 (2.3), respectively. In the pairwise comparison most relevant to the IAH, Fisher's LSD test revealed that more words were correctly recalled in the inphase condition than the out-of-phase one, $q_{.05}(2, 28) = 3.47$; $q_{crit.} = 2.92$.

For intrusions, the effect of phase was not significant, $F(1, 14) = 0.789$, $p < 0.389$, $MSE = 0.0008$. In fact, the percentages were quite low in the inphase and out-of-phase conditions, 0.2 (0.1) and 0.3 (0.1) respectively. Similarly, for the miscellaneous errors, the effect of phase was not significant, $F(2, 28) = 1.556$, $p <$

[2] This resulted in 24 targets from each of the three phase conditions and 36 distractors from the two distractor conditions. The reason why there were equal total numbers of targets and distractors in Part 2, even though an unequal number were sampled from each block in Part 1, is because in the control blocks, the words assigned to be distractors were not presented. The words sampled from these blocks, along with other words not presented in Part 1, served as foils in Part 2.

.229, MSE = 0.0072. The percentages in the inphase, out-of-phase, and control conditions were 4.8 (0.8), 4.2 (0.7), and 4.1 (0.8), respectively.

Part 2

Probability of target recognition. The overall probability of target recognition by phase condition was computed for each subject based on whether a recognized target in Part 2 was recalled or not in Part 1.[2] The effect of phase was not significant, $F(2, 28) = 0.074$, $p < .929$, $MSE = 0.0087$. The overall probabilities of recognition (with standard error) for the inphase, out-of-phase, and control conditions were 35.3 (3.9), 34.5 (3.6), and 35.7 (4.4), respectively. These probabilities are well below 50 – the guess rate – so it appears that subjects were conservative in responding.

Successfully recalling a word in Part 1 probably results in an increased likelihood of its recognition in Part 2. Indeed, when the data are collapsed across all phase conditions, the percentage of recognized targets was significantly greater for those that were recalled (43.9, SE = 2.9) compared to those that were not (22.6, SE = 2.5), $F(1, 14) = 28.473$, $p < .001$, $MSE = 0.036$. Therefore, we might expect higher rates of recognition in the inphase condition than the out-of-phase one because the former had a higher rate of recall in Part 1. However, this expectation is qualified because only a random sample of targets was included on the recognition list, not all targets. Hence, it is possible that the targets that were recalled in Part 1 did not appear on the recognition list in Part 2. We therefore separately inspected the two conditional probabilities of recognition. For the conditional probability of recognition given the target was recalled in Part 1, there was no difference by phase condition, $F(2, 28) = 1.124$, $p < .339$, $MSE = 0.0164$. These conditional probabilities for the

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[2] Hence, the overall probability of recognition equaled the Pr(recognition in Part 2 | recalled in Part 1) x Pr(recall in Part 1) + Pr(recognition in Part 2 | not recalled in Part 1) x Pr(not recall in Part 1).

inphase, out-of-phase, and control conditions were 40.0 (4.7), 46.8 (5.0), and 44.8 (5.5), respectively. For the conditional probability of recognition given the target was not recalled in Part 1, on the other hand, the phase manipulation was marginally significant, $F(2, 28) = 2.639$, $p < .089$. These conditional probabilities for the inphase, out-of-phase, and control conditions were 28.3 (5.0), 17.0 (3.1), and 22.4 (4.5), respectively. The comparison most relevant for the IAH – between the two distractor conditions – showed a significant difference, $F(1, 14) = 5.428$, $p < .035$, with a lower probability of recognition for the out-of-phase condition.

Probability of distractor recognition. The percentage of distractor words recognized did not differ by phase condition, $F(1, 14) = 0.005$, $p < .944$, $MSE = 0.0026$. The percentages for the inphase and out-of-phase conditions were 11.3 (3.2) and 11.2 (3.8), respectively. The percentage of foils mistakenly marked – the false alarm rate – was 9.8 (2.6). There was no significant difference in the recognition rate of the distractors among the two distractor conditions and the false alarm rate, $F(2, 28) = 0.430$, $p < .655$, $MSE = 0.0025$.

Discussion

The purpose of this experiment was to test the IAH in the visual modality. In Part 1, using a STM task, fewer words were recalled in the out of phase condition, consistent with the IAH. There was no effect of phase, however, on either the intrusion or miscellaneous error response data. In fact, the percent of both types of responses was quite low (under 1% and 5% for the intrusions and miscellaneous error responses, respectively). In Part 2, where subjects were given a surprise recognition-memory test of words presented in Part 1, there was no effect of phase on the overall probability of recognition or the conditional probability of recognition given the targets were successfully recalled in Part 1. However, for the conditional probability given the targets were not recalled in Part 2, a pairwise comparison found significantly lower performance in the out-of-phase condition than the inphase one. The recognition rate of distractor words was quite modest (around 10% in each condition) and there was no significant difference among the two distractor conditions and the false alarm rate (percent of foils marked), implying that distractors were not recognized with any probability greater than chance.

There are two results that argue that out-of-phase distractors interfere more with target processing than inphase ones. First, from Part 1, we see that performance on the STM recall task is worse with out-of-phase distractors than inphase ones, just as was found in Experiment 1 with auditory attention. Thus, out-of-phase distractors appear to affect more strongly some aspect of target processing involved in recall performance. Second, from Part 2, we see that the conditional probability of recognition for targets that were not recalled in Part 1 is lower in the out-of-phase than inphase condition. Interestingly, there is no effect of phase for the conditional probability of target recognition for those targets that were correctly recalled in Part 1.

The differential effect of phase on the two conditional probabilities implies that if a target was sufficiently processed to be recalled, then the phase of the distractor does not affect the likelihood that it will be subsequently recognized (perhaps because the recognition is based as much on the recall as on the original presentation). However, if a target was not sufficiently processed to be recalled – implying that it suffered more from the effects of distraction – then the phase of the distractor does affect the probability of recognition. For the targets that were not recalled, the out-of-phase distractors caused more interference on the recognition task than the inphase ones. Of course, the distractors might affect the same underlying process used for both recall and recognition memory. The important observation is that the data offer two pieces of evidence that out-of-phase distractors cause more interference with target processing.

We note that there is no evidence that the distractors themselves are processed more in the out-of-phase condition. If this were the case, then we might expect two findings. First, we might expect the intrusion rate in Part 1 to be higher in the out-of-phase condition. Second, we might expect more distractors from this condition to be recognized in Part 2. However, neither was found.

Experiment 3

The results of the two within-modality experiments support the IAH: recall performance was worse when distractors were presented out of phase with targets than in phase. Experiments 3 and 4 studied crossmodal distraction in order to explore whether it functions similarly to within modal distraction. Does focusing resources on target processing affect ignoring distractors when they occur in a different modality?

The IAH makes differing predictions on recall performance depending on different models of attentional resources. Some authors have proposed that there is a single, undifferentiated pool of resources (Kahneman, 1973) for processing all stimuli, regardless of the modality in which they occur. Many others have instead posited (at least relatively or partially) modality-specific processing resources (e.g., Wickens, 1984; Duncan, Martens, and Ward, 1997). These models make different predictions on the effect of distractors, so below we consider each in turn.

If processing depended on just a single undifferentiated pool of resources, crossmodal distraction should function similarly to within-modal distraction. There should be no difference in the ability of a distractor to capture resources as a function of whether it occurs in the same or different modality than the target. Thus, on the IAH, focusing resources on a target in one modality should prevent capture of resources by a distractor occurring in a different modality, just as was found in Experiments 1 and 2.

On the other hand, if there are modality-specific pools of processing resources (as most attention theorists believe), the effect of phase on recall performance might take several forms. One possibility would be that the distractors have no effect on target processing because whatever resources would be used for distractor processing are separate from those used for target processing. In this case, perhaps resources of the modality in which the distractor appears can be sequestered since they cannot be used for target processing. This would be akin to "shutting off" these resources. On this account, then, not only should there be no effect of the phase manipulation, but target processing should be unaffected by the presence of distractors. Thus, there would be no difference in recall accuracy among the no-distractor control and the two distractor conditions. A second possibility, given modality-specific processing resources, would be that resources could not be shut off in the modality in which the target does not appear. We would therefore expect distractors to be processed and exert some interference in the target task if, for instance, the processed distractors enter a short-term store, thereby interfering with processed targets. However, we would not expect there to be an effect of the phase manipulation because processing the distractors would be independent of processing the target.

Like the two previous experiments, subjects in this experiment performed a STM task, but here distractors were presented in a different modality than the targets. Specifically, targets were presented visually while distractors were presented auditorily. We employed the same phase manipulation as in the previous experiments.

Method

Subjects. Female and male undergraduate students (n=24) participated in exchange for partial course credit. All reported normal or corrected to normal vision and hearing.

Apparatus. The same equipment from Experiments 1 and 2 were used.

Stimuli. Stimuli were from the same set of items used in Experiment 1, and the assignment of stimuli to be targets and distractors followed the same procedure used there. The six targets appeared in the center of the monitor one at a time for 400 ms each at a rate of one target/s. Targets were colored white and presented against a blue background. Letters were presented in uppercase font and each target measured approximately 0.5 cm wide x 1.5 cm high, subtending 0.48° x 1.43° visual angle from a viewing distance of 60 cm. The six distractors were presented in stereo one at a time at the same rate as targets. Only recordings in the male voice from Experiment 1 were used.

Design. The design was the same as Experiment 1 except that attended ear was not a factor.

Procedure. The same procedure was used as in Experiment 1 except where otherwise noted. Subjects were instructed to attend to the visual targets and ignore the auditory distractors. At the start of each block, the word “ready” appeared in the center on the monitor for 1000 ms. Upon its offset, the computer emitted two beeps to warn the subjects that the trial was about to commence. Target presentation began 1000 ms later.

Results

Data analysis followed that of Experiment 2. There was a main effect of phase condition on target recall, $F(2, 46) = 7.415$, $p < .002$, $MSE = 0.063$. The percentages (with standard error) of correct responses for the inphase, out-of-phase, and control conditions were 81.1 (1.5), 80.5 (1.6), and 84.8 (1.3), respectively. However, the comparison most central to the IAH, inphase versus out-of-phase conditions, revealed no significant difference, $q_{.05}(2,24) = 0.780$, $q_{crit(2,40)} = 2.92$. Also, a one-way Anova on the intrusion data revealed a significant difference by phase condition, $F(1, 23) = 4.389$, $p < .047$, $MSE = 0.0021$. The percentage of intrusions was greater in the out-of-phase condition (2.1, $SE = 0.4$) than the inphase one (1.6, $SE = 0.3$).

We performed two separate analyses on the miscellaneous error data following the same logic outlined in Experiment 1. In both cases, the effect of phase was not significant. For the two distractor conditions only, miscellaneous errors did not differ significantly by phase condition, $F(1, 23) = 0.243$, $p < .627$, $MSE = 0.0002$. The percentages of responses for the inphase and out-of-phase conditions were 1.9 (0.4) and 2.2 (0.5), respectively. Similarly, for all three conditions, the effect of phase was not significant, $F(2, 46) = 1.248$, $p < .297$, $MSE = 0.0005$. The percentages of responses for the inphase, out-of-phase, and control conditions were 3.6 (0.6), 4.2 (0.9), and 3.2 (0.5), respectively.

Discussion

The purpose of this experiment was to test the IAH with crossmodal presentation of stimuli. Subjects performed a STM task, attempting to recall the visually presented targets and ignore the auditorily presented distractors. As in Experiments 1 and 2, there was an overall main effect of the phase manipulation among the no-distractor control condition and the two distractor conditions. However, unlike those within modality experiments, performance here was not significantly worse with out-of-phase distractors compared to inphase ones. While one must always be cautious in interpreting a null finding, it seems unlikely that this finding can be attributed to a lack of statistical power. After all, the omnibus Anova showed that the experiment was sensitive enough to detect a significant effect. The finding of no difference between the two distractor conditions is theoretically interesting and we will explore its meaning below.

The pattern of data seems inconsistent with two models of attentional resources: a single, undifferentiated pool of processing resources for all stimuli, regardless of the modality in which they occur, and modality-specific resources, where the resources in the "nontarget" modality can be sequestered. On the other hand, the pattern of results is most consistent with a different version of the modality-specific model, one where modality-specific resources cannot be "shut off" even though targets are not presented in this modality. Hence, these resources are used to process items (distractors) when they occurred in this modality, resulting in worse performance compared to the no-distractor control condition. However, the phase in which distractors are presented in relation to targets should have no bearing on the amount of distractor processing since the resources for target and distractor processing are independent. We therefore expect no effect of the phase manipulation on target performance.

There were more intrusions in the out-of-phase condition than the inphase one. We might be tempted to interpret this to mean that distractors presented out of phase were processed more but this interpretation must be tempered. The percent of intrusions was quite low (around 2% in each condition), and there was no difference among the two distractor and the control conditions for the combined intrusion and miscellaneous error responses. Thus, it is clear, based on the low percentage of intrusion and miscellaneous error responses, that the distractors did not cause overwhelming confusion in performing the task. Instead, it appears that subjects were able to comply with instructions: they typically reported targets or refrained from making a response.

What is the locus of the distraction effects? We can at least speculate. In STM tasks, subjects often subvocally rehearse targets. On Baddeley's model of the articulatory loop, rehearsal of visually presented targets forms phonological codes, thereby allowing the use of the phonological store (Baddeley, 1990). Distractors in Experiment 3, like those in Experiment 1, were presented auditorily, and thus had obligatory access to the phonological loop. They therefore should cause interference in the capacity-limited short-term store. However, unlike Experiment 1, the phase of distractor presentation did not result in differential target recall performance, suggesting that distractors were processed to the same degree regardless of the phase in which they were presented. Thus, in the case of crossmodal distraction, target processing does not seem to affect the ability to ignore distractors as it does in within modal distraction. We note in close that the results of this experiment are consistent with Salam’ and Baddeley (1982), who manipulated the phase of distractor presentation between experiments.

Experiment 4

Experiment 4 was the complement of Experiment 3 in that the modality of stimulus presentation was swapped: targets were presented auditorily whereas distractors were presented visually. The purpose, structure, and predictions of this experiment were the same as that of Experiment 3.

Methods

Subjects. Female and male undergraduate subjects (n=24), who had not been in Experiment 3, participated in exchange for partial course credit. All reported normal or corrected to normal vision and hearing.

Apparatus. The same equipment from Experiment 3 was used.

Stimuli. The same stimuli from Experiment 3 were used but now the targets were the auditory recordings and the distractors were the visual items. The only stimulus addition were four white dots in the central region of the monitor, one dot appearing in each corner of an imaginary square measuring 2.5 x 2.5 cm, subtending 2.39° x 2.39° visual angle from a typical viewing distance of 60 cm. The distractors appeared within this region. The purpose of the dots, which remained on the monitor continuously throughout the trial, was to provide subjects a placeholder in which to direct their gaze. The rate of presentation and the duration of visual stimuli were the same as Experiment 3.

Design. The design was the same as in Experiment 3.

Procedure. The procedure followed that of Experiment 3 except for the following. Subjects were instructed to attend to the auditory targets and to recall them at the end of stimulus presentation. They were also instructed to maintain their gaze at the central region of the computer monitor -- demarcated by the four dots -- but to ignore the items appearing there. They were asked not to employ any strategy to impair their visual acuity. The research assistant, seated next to the subjects, monitored their eyes throughout the trials in an effort to confirm that subjects complied with the instructions.

Results

Data analysis followed that of Experiment 3. The one-way Anova revealed a main effect of phase condition, $F(2, 46) = 7.175$, $p < .002$, $MSE = 0.0005$. The percentages of correct responses (with standard error) for the inphase, out-of-phase, and control conditions were 87.8 (1.1), 88.5 (1.1), and 90.3 (1.1), respectively. The comparison most central to the IAH, inphase versus out-of-phase conditions, revealed no significant difference, $q_{.05}(2, 24) = 1.16$, $q_{crit} = 2.92$.

There was no significant effect of phase condition for any of the remaining dependent variables: for intrusions, $F(1, 23) = 1.038$, $p < .319$, $MSE = .0001$, and the percentages for the inphase and out-of-phase conditions were 2.1 (0.5) and 1.8 (0.4), respectively; for miscellaneous errors in the distractor conditions only, $F(1, 23) = 0.005$, $p < .942$, $MSE = .0001$, and the percentages for the inphase and out-of-phase conditions were 2.0 (0.4) and 2.1 (0.4), respectively; finally, for non-target responses, $F(2, 46) = 2.477$, $p < .095$, $MSE = .0002$, the percentages for the inphase, out-of-phase, and control conditions were 4.1 (0.8), 3.8 (0.7), and 3.2 (0.6), respectively.

Discussion

The purpose of this experiment was to test the IAH with crossmodal distraction with the reverse stimulus-modality mapping of Experiment 3: targets were presented auditorily whereas the distractors were presented visually. The same STM task and phase manipulation were used as in the previous experiments. In general, the same pattern of results was found in this experiment as in Experiment 3. For correct responses, there was an overall main effect of phase condition among the three conditions but there was no significant difference for the pairwise comparison most central to the IAH: inphase versus out-of-phase condition. Just as in Experiment 3, this null finding is probably not due to a lack of statistical power as the omnibus

Anova detected an overall significant effect. The finding of no difference between the two distractor conditions is theoretically interesting and we will explore its meaning below. For the other dependent variables (intrusion, miscellaneous, and non-target responses), there was no effect of phase condition.

The pattern of results in this experiment is consistent with the model of attentional resources argued for at the conclusion of Experiment 3: modality-specific processing resources, where resources of the modality in which the distractors occur cannot be shut off. The obtained results for the correct response data are not consistent with the two other models of attentional resources considered in Experiment 3 for the same reasons outlined earlier. For the other types of responses (intrusion, miscellaneous, and non-target responses), the same pattern of results was obtained as in Experiment 3, even approximately to the same degree. Interpretation of these results is similar to that experiment and will not be repeated here.

We now speculate as to the cause of the distraction by the visual items. We begin with the assumption, following Baddeley's model, that for this STM task, subjects made use of the phonological loop. Because the targets were (linguistic) auditory items, they had obligatory access into the loop. In addition, to the extent that these items were rehearsed, representations of these items were refreshed and possibly strengthened.

One possibility for the source of distraction is that even though subjects attempted to ignore the visual distractors, phonological representations of these items were formed, thereby interfering with the codes for the targets in the phonological loop. This account presumes not only that a phonological code is formed for a visually-presented item (Booth, Perfetti, and MacWhinney, 1999; Humphreys, Evett, and Taylor, 1982; Hillinger, 1980; Tanenhaus, Flanigan, and Seidenberg, 1980), but also that the formation of the code occurs even when one attempts to ignore the item. In a sense, this explanation of visual distractors is the complement to Baddeley's account of "obligatory access" by auditory (linguistic) ones.

Baddeley has argued, based on the negligible effect of white noise on recall performance, that only linguistic auditory distractors, as opposed to all sounds, have access to the loop (hence, a phonological, not acoustic, loop). If this account applies to visual as well as auditory distractors, then phonological codes will only form for visual items that have a linguistic label, and thus interference will only occur for these types of distractors. This account makes a testable prediction: visual distractors lacking any linguistic label (e.g., letters from an unfamiliar foreign alphabet) or not readily described semantically (e.g., unusual polygons) should not cause interference. An alternative account of the results is that subjects employed a particular strategy that is more effective in the control condition than in the others. Perhaps subjects formed visual codes of (some of) the auditory targets in order to make use of the putative visual short-term store (Scarborough, 1972). The load of remembering the targets would then be shared across two memory systems instead of just one. It seems plausible that this strategy could be more effectively employed in the absence of visual distractors (as in the control condition) than in their presence, since visual items probably have access to this store, particularly if they are presented at fixation and visual attention is not focused on a different visual item. Both explanations of the locus of distraction – in the phonological loop or the visual short-term store – are consistent with the modality-specific model of attentional resources. In either case, attending to the auditory targets does not seem to affect distractor processing (i.e., affect the ability to ignore them), as appears to be the case in within-modality distraction.

The finding of visual distraction in a crossmodal attention design is noteworthy because almost all distraction studies have focused on auditory distractors (Driver and Baylis, 1993; Schriefers and Meyer, 1990; Shimada, 1990; Cowan and Barron, 1987; Salame and Baddeley, 1987, 1982) with only a few examining visual distractors (MacDonald and McGurk, 1978; Langton, O'Malley, and Bruce, 1996). The bias against studying visual distractors probably reflects methodological considerations (namely, the concern that people may employ non-cognitive strategies to avoid processing visual distractors, e.g., not fixating on them).

General Discussion

Four experiments were conducted to test the hypothesis that it is easier to ignore distracting stimuli when attentional resources are engaged in and occupied with processing task-relevant stimuli rather than idle. The logic underlying this hypothesis, which we termed the Idle Attention Hypothesis (IAH), is that if the resources are engaged in target processing, then they are not available for processing an irrelevant stimulus. However, if processing resources are idle, then they are susceptible to capture by distracting stimuli. As a result, the distractors will be processed, thereby causing more interference. This hypothesis -- or ideas similar to it -- has been proposed by several researchers (e.g., Treisman, 1969; Kahneman, 1970; Lavie, 1995), but it was suggested in the Introduction that previous empirical evidence for this hypothesis have not been terribly compelling. We therefore set out to perform a stronger, or at least converging, test.

In all of the experiments, subjects performed a short-term memory task, attending to a series of target words presented to one channel (say, the left ear) while attempting to ignore a series of distracting words presented to a different channel. The main manipulation was the relative phase in which distractors were presented:

either in phase or out of phase with targets. It was presumed that processing resources are (at least relatively) idle during the “blank” interval between consecutive targets. Therefore, on the IAH, distractors presented during this time (i.e., out of phase with targets) should be harder to ignore and thus processed more than distractors presented in phase, when resources are engaged in target processing. As a result, the out-of-phase distractors should have a greater interfering effect on the memory task than inphase ones.

The first two experiments studied within modal distraction. In Experiment 1 targets and distractors were both presented auditorily, each to different channels (i.e., the left and right ears), while in Experiment 2 targets and distractors were both presented visually, each to different locations on the computer monitor. The two experiments showed a similar pattern of results: recall accuracy suffered more when distractors were presented out of phase with targets than in phase, as predicted by the IAH. In addition, in Part 2 of Experiment 2, where subjects performed a surprise recognition-memory test, the conditional probability of target recognition for words not successfully recalled in Part 1 was lower in the out of phase condition than the inphase one.

The last two experiments studied crossmodal distraction. In Experiment 3 targets were presented visually and distractors were presented auditorily while in Experiment 4 the targets were presented auditorily and distractors were presented visually. Again, the results of the two experiments were similar to each other. There was no significant difference in recall performance between the inphase and out-of-phase conditions, but both conditions resulted in poorer performance than the no-distractor control condition. Thus, a differential effect of the phase manipulation was found only when the distractors occurred in the same modality as the targets.

This interaction is predicted by a model of attentional resources where there are separate pools of resources for each modality (or at least for the auditory and visual modalities, the ones tested here). The results from Experiments 1 and 2 imply that when distractors occur in the same modality as targets, resources are more susceptible to capture by distractors when they are idle rather than engaged in processing targets. However, the results from Experiments 3 and 4 imply that when distractors occur in a different modality than targets, the susceptibility of resources to capture by distractors is not affected by whether target-processing resources are idle or engaged.

The results of the two crossmodal experiments dovetail nicely with the findings of two studies that compared unimodal and bimodal presentation of stimuli. Treisman and Davies (1973) found a clear advantage for detecting simultaneously presented targets when each occurred in a different modality (visual and auditory) than both in the same one. Similarly, Duncan, Martens, and Ward (1997) found that detection and reporting of two targets occurring in the same modality suffered when they were presented nearly simultaneously (within a few hundred milliseconds of each other) compared to longer temporal intervals. However, when each target was presented to a different modality, there was no performance decrement at short temporal intervals. These authors conclude that there are processing limitations within but not between modalities. Thus, both studies are consistent with a modality-specific model of processing resources.

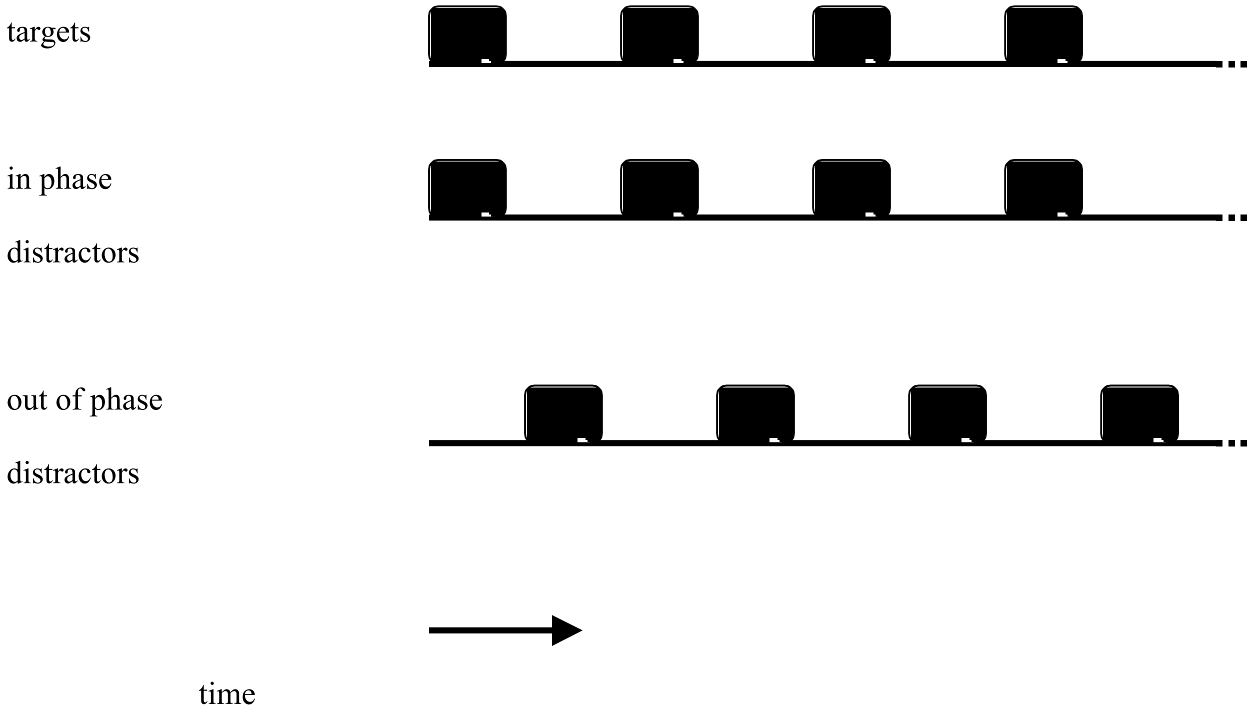
targets
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Figure 1

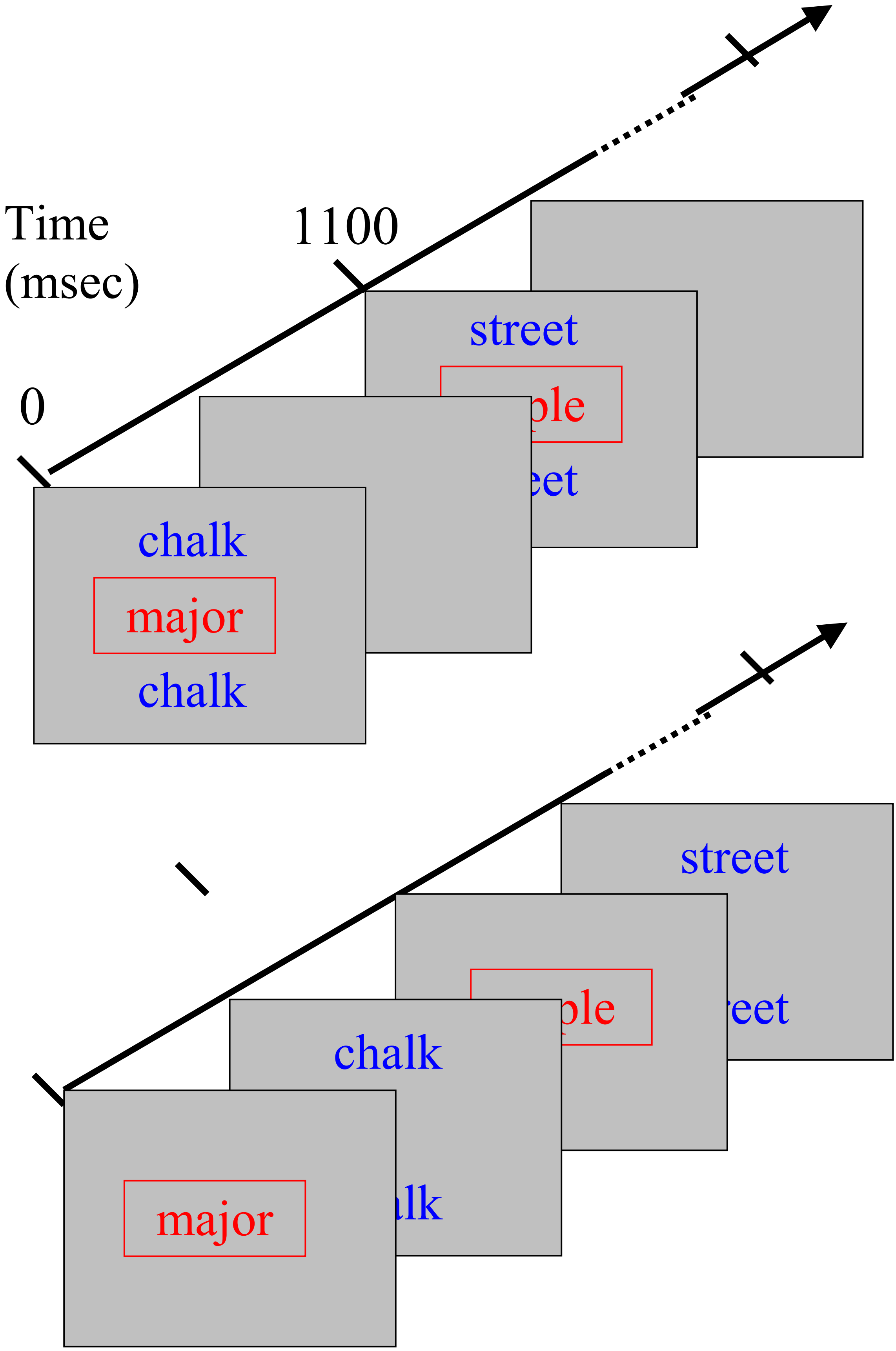
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Figure 2

Table 1

Percentage of correct responses by attended ear and phase condition, Experiment 1

	Left		Right	
Phase condition	M	SE	M	SE
inphase	78.3	3.5	79.5	3.7
out-of-phase	70.4	4.1	73.4	3.9
control condition	87.9	3.0	86.5	2.7

Table 2

Percentage of intrusion responses by attended ear and phase condition, Experiment 1

	Left		Right	
phase condition	M	SE	M	SE
inphase	6.2	1.0	4.9	1.1
out-of-phase	6.3	0.9	5.6	0.9

Table 3

Percentage of miscellaneous errors by attended ear and phase condition

(two distractor conditions only) , Experiment 1

	Left		Right	
phase condition	M	SE	M	SE
inphase	1.7	0.4	1.9	0.4
out-of-phase	2.2	0.5	2.3	0.6

Table 4

Percentage of miscellaneous/non-target errors by attended ear and phase condition (all three conditions), Experiment 1

	Left		Right	
phase condition	M	SE	M	SE
inphase	8.0	1.2	6.8	1.2
out-of-phase	8.5	1.3	7.9	1.2
control condition	3.3	0.7	4.8	0.9

Appendix

Stimulus items

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2

3

4

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6

8

9

F

H

J

L

N

O

P

Q

R

S

X

Figure captions

Figure 1. Schematic timeline of stimuli presentation. Because the precise timing of stimuli presentation varied slightly by experiment, this figure conveys only the general methodology used. Each box represents a stimulus item.

Figure 2. Example of visual stimuli for the inphase and out-of-phase conditions (no-distractor condtrol condition not shown).

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