Auditory Distractors in the Visual Modality:

No Evidence for Perceptual Load Hypothesis or Auditory Dominance

Undergraduate Research Thesis

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by

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Abstract

Attention is a valuable resource with limited capacity, so knowing what will distract us during important tasks can be crucial in life. There is a lot of support for the Perceptual Load Hypothesis (PLH) when examining visual distractibility; however, less research has examined if PLH can predict auditory distractibility. Participants in the current study completed three experiments using visual selective attention tasks while being presented with auditory and visual distractions under low/high perceptual loads. In Experiment 1, I took the visual selective attention task from Robinson et al. (2018) and shortened the stimulus presentation while adding a no distractor baseline condition. In Experiment 2, I increased auditory distractor effects by requiring participants to periodically respond to the auditory information. In Experiment 3, I added a working memory task to increase cognitive load. Results showed no support for PLH with auditory distractors in Experiments 1 or 2, and instead showed the opposite pattern, with auditory distractors having a larger effect under high perceptual load (Experiment 2). Results from Experiment 3 show that increasing cognitive load had no effect on distractibility, which suggests the results from Experiment 2 were caused by periodically responding to the auditory stimuli. These findings have important implications for our understanding of selective attention and shed light on tasks that require the processing of multisensory information.

Keywords: Selective Attention, Multisensory Processing, Perceptual Load, Cognitive Load

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There are many situations that require us to focus our selective attention on a task and ignore irrelevant information. For example, working on homework in a noisy environment and driving in heavy downtown traffic both require focused attention and poor selective attention can result in being unproductive or contributing to a deadly accident. Thus, it is important to understand what factors account for increased distractibility. While there is considerable support for the Perceptual Load Hypothesis in the visual modality (Lavie, 1995; Lavie & Tsal, 1994; see also Murphy, Groeger, & Greene, 2016, for a review), less research has examined if the Perceptual Load Hypothesis can predict the effects of auditory or cross-modal distractors on selective attention. The current study contributes to this research by examining the filtering of auditory and visual distractors under low and high load conditions while participants are performing a visual selective attention task.

The Perceptual Load Hypothesis (PLH) predicts that distractors should be more distracting under low perceptual load (when there is less information to process) than under higher load. The underlying idea is that in low load conditions participants have more available attentional resources to detect the distractors, whereas, they are less likely to see/hear distractors under high load. For example, in Lavie (1995), participants had to quickly respond to targets and ignore distractors. Distractors were either compatible (target and distractor were identical and associated with the same response), incompatible (target was associated with one response and distractor was associated with a different response), or neutral (distractors were not associated with any response). In Experiment 1, the high load condition had five non target stimuli and one target and the low load condition had just the target and one distractor. Lavie (1995) found that incompatible distractors slow response times more in the low load condition compared to the high load condition (see also Murphy, Groeger, & Greene, 2016, for a review).

Studies that have looked into auditory/cross-modal distractions have produced mixed findings (Macdonald & Lavie, 2011; Robinson, Hawthorn, & Rahman, 2018; Tellinghusien & Nowak, 2003; see also Murphy et al., 2017, for a review). For example, Macdonald and Lavie (2011) manipulated the perceptual load in the visual modality and examined auditory detection. Consistent with PLH, participants were more likely to detect the auditory stimulus under low visual load, therefore extending PLH across sensory modalities (Macdonald & Lavie, 2011). In contrast, other studies do not support PLH when examining auditory distractibility (Robinson, Hawthorn, & Rahman, 2018; Tellinghusien & Nowak, 2003). Robinson et al. (2018) and Tellinghusien and Nowak (2003) examined auditory distractibility while manipulating the perceptual load in the visual modality. These studies found that children (Robinson et al., 2018) and adults (Tellinghusien & Nowak, 2003) were more likely to be slowed down by the auditory distractors in the high load condition, which is inconsistent with PLH. Thus, previous research shows unclear answers to the issue of auditory stimuli and PLH, with research both supporting PLH (Macdonald & Lavie, 2011) and research going against PLH (Robinson et al., 2018; Tellinghusien & Nowak, 2003).

Auditory dominance research also predicts that PLH should not predict auditory distractibility (Dunifon, Rivera, & Robinson, 2016; Robinson & Sloutsky, 2010). Using variations of change detection tasks (Barnhart, Rivera, & Robinson, 2018; Dunifon et al., 2016; Robinson, Chandra, & Sinnett, 2016; Robinson, Moore, & Crook, 2018; Sloutsky & Napolitano, 2003), participants in these studies had to discriminate auditory and visual information when presented unimodally (just sounds or pictures) or when presented cross-modally (sounds and pictures were paired together). The main finding from these studies is that simultaneously presenting sounds and pictures attenuated visual discrimination and/or slowed down visual discrimination compared to the unimodal visual baseline. At the same time, pairing pictures and sounds together often had no negative effect on auditory processing. To account for this finding, Robinson and Sloutsky (2010) suggested that sensory modalities are competing for attentional resources and that auditory stimuli are favored over visual stimuli. The auditory modality may initially win the competition because auditory stimuli are often transient in nature and it might be adaptive to automatically allocate attention to this information before it disappears (Robinson & Sloutsky, 2010). Thus, based on a proposed mechanism underlying auditory dominance, auditory stimuli should be detected regardless of perceptual load, thus, PLH should not predict which auditory distractors affect processing.

The research presented here followed up on the Robinson, Hawthorn, and Rahman (2018) study where they examined if PLH could predict auditory and visual distractibility in children, young adults, and older adults. Participants in Robinson et al. (2018) were asked to complete four selective attention tasks, which involved detecting a visual target without becoming distracted by auditory and visual distractors under different levels of perceptual load. On each trial, participants were shown a bird or a dog in a box and were asked to press the corresponding button for each target. The visual distractors consisted of a bird or dog (compatible or incompatible with the target in the box) and were presented outside the box. The auditory distractions consisted of a bird chirping or a dog barking (could also be compatible or incompatible with the target). The study found that auditory distractors had a larger effect in young children, whereas, visual distractors had a larger effect in older children, which is consistent with the auditory to visual modality dominance shifts found using other paradigms

(Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). It was also shown that PLH was unable to predict performance. In contrast to PLH, auditory and visual distractors were more distracting to children under high rather than low load conditions. Finally, there was no evidence that the auditory or visual distractors slowed down adults' responses; however, this may have stemmed from using a task that was geared for young children.

The current study used a similar selective attention task from the Robinson et al. (2018) study but we made a few changes to make the task more challenging for adults. First, we shortened the stimuli to 400 ms (more consistent with previous research in adults), whereas, visual stimuli were presented until participants made a response in Robinson et al. (2018). Second, we added a no distractor baseline to assess facilitation and interference effects. If compatible distractors are facilitating processing, then compatible trials should exceed the no distractor baseline, whereas, interference was inferred if performance on incompatible trials was worse than the no distractor baseline. Shortening stimulus duration should increase auditory effects and these effects should not be predicted by PLH. Shortening the stimulus duration should also increase compatibility effects in the visual modality, and these effects should be consistent with PLH. With previous literature showing mixed findings for auditory distractibility, I adjusted Robinson et al's (2018) experiment in three different ways throughout this study to increase the difficulty for adults (Experiment 1), examine different factors that could change auditory distractibility (Experiment 2), and examine the causation for distraction (Experiment 3).

Experiment 1

Methods

Participants. Twenty-nine participants (*M* = 19.19 years, *SD* = .43 years, 20 females) from The Ohio State University at Newark participated in the experiment for course credit. One additional participant was excluded from the sample due to not completing the experiment. Tests were conducted in a quiet room in the psychology laboratory at The Ohio State University at Newark. Recruitment and experimental procedures were carried out in accordance with the guidelines and approval of The Ohio State University's Behavioral and Social Science Institutional Review Board, Protocol# 2014B0022. After instructions were given for the study, participants signed and completed an IRB approved informed consent form.

Materials and Design. DirectRT was used to present all stimuli and record all responses. The visual stimuli were constructed of six colorful cartoon animals. The stimuli were presented on a 22" Dell P2219H monitor at approximately 3.80 cm x 5.70 cm, with an approximate horizontal visual angle of 3.63° and a vertical angle of 5.44°. One of the six visual stimuli presented inside the box was either a Dog or a Bird and was chosen to be the target stimulus. In the low perceptual load condition, only the target stimulus was inside the black-lined box, while the high perceptual load condition had the target stimuli with five other non-target animals inside the box (i.e. Frog, Fish, etc.). See Figure 1 for examples of high and low load visual distractor trials. The Bird and Dog targets never appeared inside the box on the same trial, and the exact location of the target and non-targets were shuffled on each trial. The visual stimulus display was presented for 400 ms.

On each trial, the target was either presented with a visual distractor, an auditory distractor, or with no distractor (baseline control). Distractor conditions were blocked and manipulated within subjects. The visual distractors appeared outside the box, within close proximity to the box either above or below. The visual distractors consisted of the Dog or Bird but were outside the box (see Figure 1). Participants were instructed to ignore these visual distractors and report only if they saw the dog or bird inside the box. Half of the visual distractor trials had compatible distractors (the distractor matched the target) and the other half had incompatible distractors (the distractor did not match the target). I also compared performance on these trials to a no distractor baseline. Facilitation was inferred if distractor trials exceeded the no distractor baseline and interference was inferred if distractor trials were worse than the baseline.

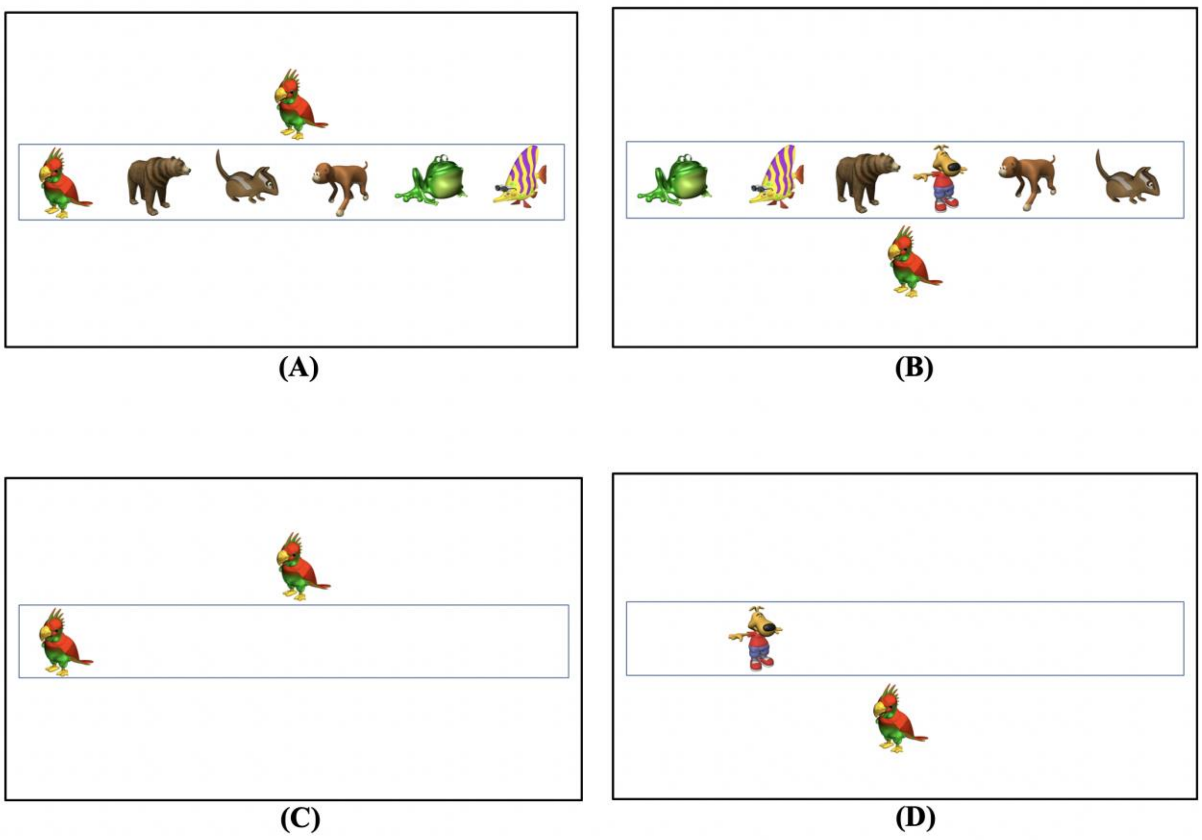

Figure 1: Examples of the high load (A & B) and low load (C & D) visual distractor trials. A & C are examples of compatible trials and B & D are examples of incompatible trials.

The auditory distractors were made up of two distinct sounds. One sound was a bird chirping, while the other was a dog barking. The animal sounds were retrieved from Marcell et al. (2000), yet shortened to approximately 400 ms using Audacity software, and saved as 44.1 kHz .wav files. Auditory stimuli were presented through the use of Kensington 33137 headphones. Each sound was approximately 65-68 dB and was presented at the onset of the visual stimulus. Auditory stimuli were presented to both ears simultaneously with equal intensity. Auditory and visual distractor trials were identical in nature, but only one distractor was presented in a single trial. As with visual distractors, the auditory distractor either matched the visual target on compatible trials (dog paired with dog bark) or it did not match the target on incompatible trials (dog paired with bird chirp). Performance on these trials was compared to the no distractor baseline.

Procedure. Participants sat approximately 60 cm from a computer monitor. The experimenter briefly described the experiment and then participants signed the consent form. Once completed, participants filled out a brief demographic form before being presented with the first set of instructions on the computer screen. Participants were shown the small black-lined box in the middle of the screen with either a dog or a bird within the box. Participants were instructed to press the corresponding key on their keyboard when they saw the bird (1 on the numberpad) or a dog (3 on the numberpad). Participants were told that the bird or dog could appear anywhere inside the box and that the bird and dog would never be presented at the same time inside the box. They were also told to respond as quickly and as accurately as possible. Participants were also told that they would only see/hear the stimulus for a half of a second before it disappeared and that the program would not move to the next trial until they responded. Finally, participants were also shown how the computer would try to “trick” them. For example, they were told that the computer may place a bird or dog above or below the box or play the sound of a dog barking or bird chirping through the headphones.

Once the initial instructions were read and the study initiated, the computer randomly started one of the six blocks (high load auditory, low load auditory, high load visual, low load visual, high load baseline, or low load baseline). The six blocks were manipulated within-subjects and each block had 48 trials (288 trials in total). In the auditory and visual distractor blocks, there were 24 compatible and 24 incompatible trials. The baseline blocks had 48 trials each, with no compatibility factor due to no distractors being in the trials. The next trial did not appear until a response was made on the previous trial. The whole experiment took approximately 30 min and response times and accuracies were collected on each trial.

Results

I examined accuracy (correct or incorrect) and response times (RT) in comparison to the no distractor baseline data. I calculated two difference scores by subtracting baseline accuracy from compatible and incompatible trials (e.g. compatible difference = compatible accuracy - baseline accuracy). Scores greater than zero showed increased performance compared to baseline and scores less than zero indicated that distractors hurt performance. See Figure 2 for means and standard errors. I submitted accuracy difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA. There was a significant effect of modality, F (1, 28) = 6.98, p = .013, η_p^2 = .20, with accuracy on auditory distractor trials (M = .04, SE = .01) being greater than on visual distractor trials (M = .01, SE = .02). The analysis also revealed an effect of compatibility, F (1, 28) = 5.14, p = .031, η_p^2 = .16, with compatible distractors (M = .03, SE = .01) increasing accuracy more than incompatible distractors (M = .01, SE = .01). There was also an effect of load, F (1, 28) = 4.67, p = .039, η_p^2 = .14, with better performance under low load (M = .05, SE = .01) than high load (M = 0, SE = .02). The load x compatibility interaction consistent with PLH was not significant, F (1, 28) = 1.30, p = .26, η_p^2 = .04

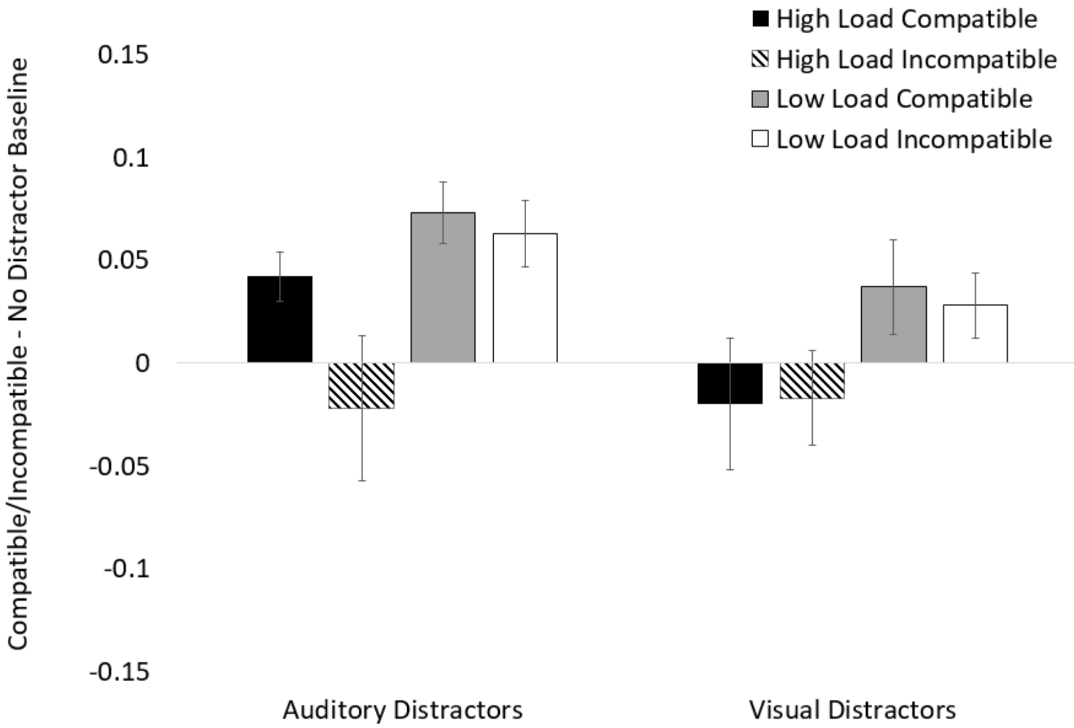

Figure 2: Accuracy difference scores across modality, compatibility, and load. Positive scores represent an increase in accuracy, whereas negative scores represent a decrease. Error bars denote Standard Errors.

On each trial, I also calculated a response time (timestamp of response - timestamp of stimulus onset). I only analyzed response times on correct trials and response times greater than two standard deviations were removed. I also calculated difference scores for response times by subtracting baseline response times from compatible and incompatible trials (e.g. compatible RT difference = compatible RT - baseline RT). Scores greater than zero showed slower responses compared to baseline (interference) and scores less than zero indicated faster responses compared to baseline (facilitation). See Figure 3 for means and standard errors.

I submitted RT difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA. There was a significant effect of modality, F (1, 28) = 5.91, p = .022, η_p^2 = .17, with visual distractors (M = 73.33 ms, SE = 18.92 ms) slowing down response times more than auditory distractors (M = 44.17 ms, SE = 16.65 ms). The analysis also revealed a significant effect of compatibility, F (1, 28) = 20.63, p < .001, η_p^2 = .42, with incompatible distractors (M =73.02 ms, SE = 16.84 ms) slowing down responding more than compatible distractors (M = 44.48 ms, SE = 16.97 ms). The load x compatibility interaction was not significant, F (1, 28) = .21, p = .654, η_p^2 = .01.

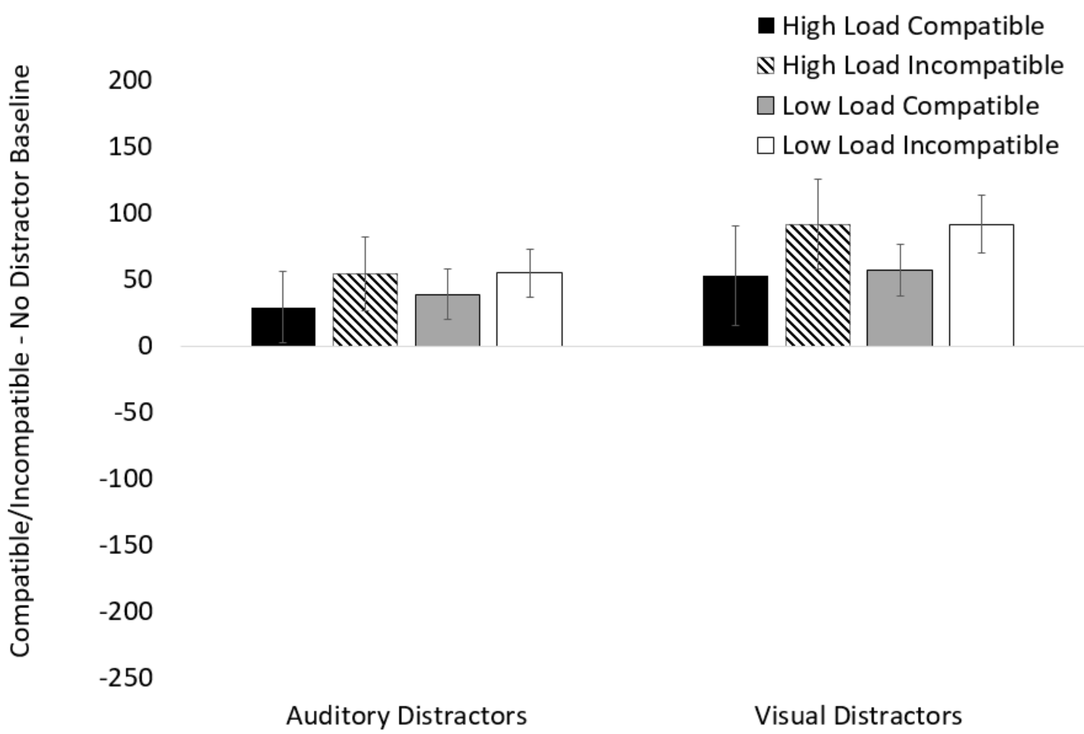

Figure 3: RT difference scores across modality, compatibility, and load. Positive scores represent a slowdown in response time, whereas negative scores represent a speed up. Error bars denote Standard Errors.

Discussion

For Experiment 1, I looked to find if shortening the stimulus duration and adding a no distractor baseline would affect auditory distractibility. I found that visual distractors tend to be more distracting than auditory distractors, and compatible distractors were more distracting than incompatible distractors. With this, the data suggests that PLH was unable to predict auditory distractibility on a visual selective attention task. It's possible that participants managed to ignore all auditory stimuli and complete the task as if they never heard anything. For the next experiment, I examine factors that may affect attention to auditory stimuli.

Experiment 2

The primary aim of Experiment 2 was to test PLH with auditory distractors and to test two hypotheses that may account for the weak auditory interference effects found in Experiment 1. First, it is possible that adults habituated to the auditory stimuli since they were presented on every trial in the auditory distractor conditions. Recall that in Experiment 1, auditory and visual distractor trials were blocked together, leaving participants able to know what type of distractor they were going to consistently encounter during a set of trials. I tested this hypothesis by intermixing auditory and visual distractor trials (intermixed conditions). Thus, on any given trial, participants had no idea if they were going to encounter an auditory distractor, a visual distractor, or no distractor. If habituation to the auditory stimuli can account for weak auditory interference, then the effects of auditory distractors should increase in the current study because the presence of auditory stimuli was less predictable.

Second, it is also possible that auditory interference was relatively weak because participants never had to respond to the auditory information, whereas, in most auditory dominance studies participants have to divide attention across sensory modalities and respond to both auditory and visual information (Barnhart et al., 2018; Dunifon et al., 2016; Robinson et al., 2016; 2018; Sloutsky & Napolitano, 2003). To test this hypothesis, I presented an eye or an ear before each trial and this indicated whether the participants should report what they saw or heard (eye/ear conditions). If weak auditory interference stemmed from never having to respond to the auditory stimuli, then distractibility should increase on the eye/ear conditions because participants had to periodically respond to the auditory information. Finally, since I also manipulated perceptual load (low vs. high), the current study will also determine if PLH can predict auditory distractibility. Based on auditory dominance research, it is hypothesized that PLH would not predict auditory distractibility because auditory stimuli should automatically engage attention and be detected under low and high load, leaving participants to be more distracted in the eye/ear condition.

Methods

Participants. Twenty-seven participants (*M* = 19.41 years, *SD* = .64 years, 18 Females) from The Ohio State University at Newark participated in the experiment for course credit. One participant was excluded because s/he did not understand the instructions in the eye/ear condition. Recruitment was conducted the same way as Experiment 1.

Materials and Design. All aspects of this experiment are the same besides the creation of the two following tasks. The first task, the Intermixed Conditions, is essentially the same as Experiment 1. The only difference is that I intermixed the auditory distractor, visual distractor, and baseline trials into one high load block and one low load block, as well as adding a fixation point “+” to the beginning of each trial. This should prevent habituation to the auditory distractors, as participants will not know when each distractor will appear. In the second task, the Eye/Ear Conditions, I took the same task from the intermixed condition and added a picture of an eye or an ear before each trial. When participants saw an eye, they were expected to report the visual target (dog or bird in box) and ignore distractors, whereas if they saw an ear, they were expected to report the auditory distractor they heard (dog bark or bird chirp) and ignore all other stimuli. This task should allow me to test if periodically responding to auditory stimuli will increase the auditory interference when responding to visual stimuli and if PLH predicts performance.

Procedure

In contrast to Experiment 1, the computer randomly started one of the four blocks (high load intermixed, low load intermixed, high load eye/ear, or low load eye/ear). The four blocks were manipulated within-subjects and each block had 120 trials (480 trials in total), with 48 visual distractor trials, 48 auditory distractor trials, and 24 no distractor trials in each block. With the auditory and visual distractor trials, half were compatible distractors and half were incompatible distractors. Second, a small fixation point "+" appeared on the screen for 300 ms prior to each intermixed trial, and the picture of the eye or the ear was presented for 300 ms prior to each eye/ear trial. Trial order (visual distractors, auditory distractors, and no distractors) was randomized for each participant.

In contrast to the intermixed conditions where there were auditory and visual distractor trials, I always presented a visual target with an auditory distractor in the eye/ear task. On the ear trials, participants reported if the auditory distractor was a bird chirp or a dog bark. These trials were only added to increase attention to the auditory modality. On the eye trials, participants reported if the visual target was a dog or a bird and they heard an auditory distractor in the background. Thus, eye trials were identical to the auditory distractor trials in the intermixed condition, however, participants in this condition had to periodically respond to the auditory distractors. The no distractor baseline trials were identical to the intermixed condition. The whole experiment took approximately 30 min and response times and accuracies were collected on each trial.

Results

In both conditions, I examined accuracy (correct or incorrect) and response times (RT). I first focus on the intermixed condition, and then we analyze the eye/ear condition.

Intermixed Conditions

As in Experiment 1, I calculated accuracy difference scores (see Figure 4 for Means and Standard Errors). I submitted accuracy difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA. There was a marginally significant effect of modality, F (1, 26) = 3.95, p = .057, η_p^2 = .13, with visual distractors (M = -.03, SE = .02) being more distracting than auditory distractors (M = -.01, SE = .01). The analysis also revealed an effect of compatibility, F (1, 26) = 5.79, p = .023, η_p^2 = .18, with incompatible distractors (M = -.04, SE = .02) decreasing accuracy more than compatible distractors (M = .00 SE = .01). The load x compatibility interaction was not significant, F (1, 26) = 1.42, p = .245, η_p^2 = .05.

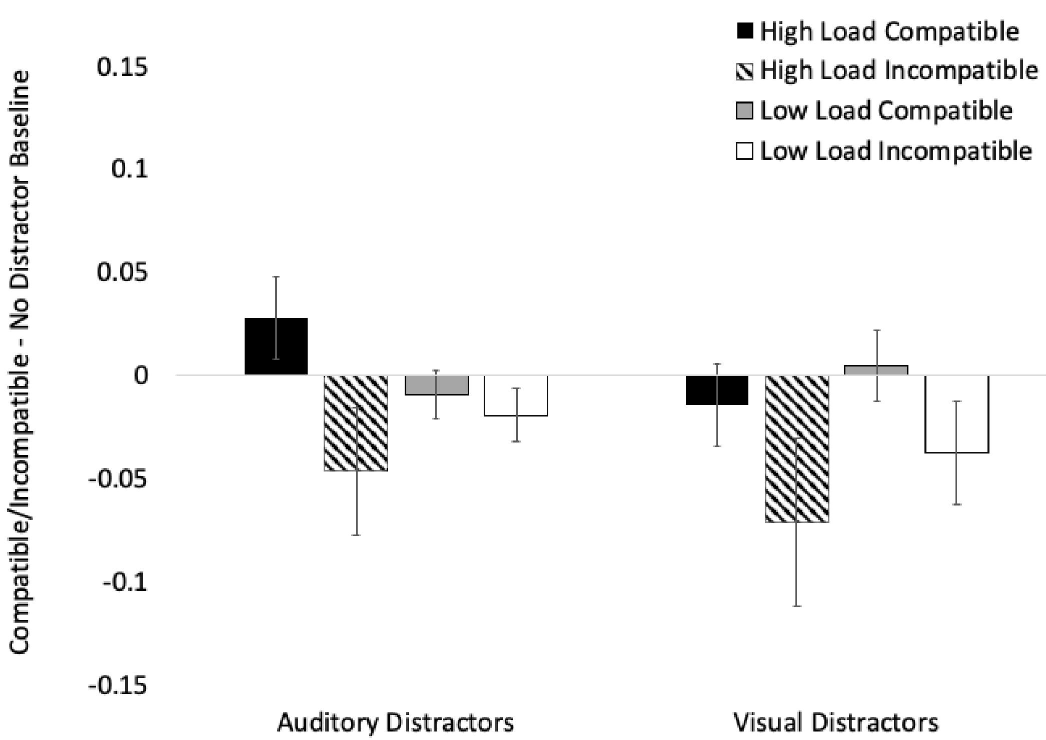

Figure 4: Accuracy difference scores across modality, compatibility, and load in the Intermixed Conditions. Error bars denote Standard Errors.

As in Experiment 1, I calculated response times difference scores (see Figure 5 for Means and Standard Errors). I submitted RT difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA. There was a significant effect of modality, F (1, 26) = 8.23, p = .008, η_p^2 = .24, with visual distractors (M = 42.61 ms, SE = 21.29 ms) slowing down response times more than auditory distractors (M = -25.41 ms, SE = 16.23 ms). The analysis also revealed a marginally significant effect of compatibility, F (1, 26) = 3.15, p = .087, η_p^2 = .11, with incompatible distractors (M = 21.85 ms, SE = 19.21 ms) slowing down responding more than compatible distractors (M = -4.65 ms, SE = 13.30 ms). The load by compatibility interaction was not significant, F (1, 26) = .33, p = .570, η_p^2 = .01.

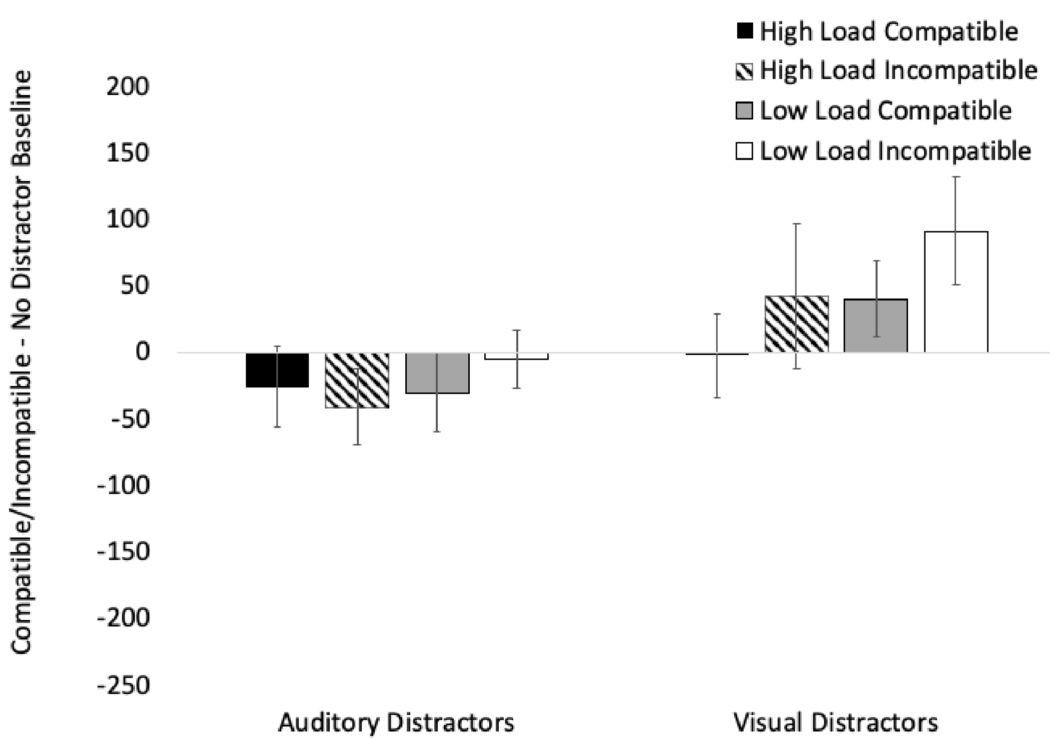

Figure 5: Response Time difference scores across modality, compatibility, and load in the Intermixed Conditions. Error bars denote Standard Errors.

Across accuracy and response time data, visual distractors were more distracting than auditory distractors and incompatible distractors were more distracting than compatible distractors. There was no evidence that auditory distractors facilitated or interfered with responding compared to the no distractor baseline, all one-sample *t*'s compared to 0, *p*s > .15. Finally, the load x compatibility interaction never reached significance, thus, providing no support for the Perceptual Load Hypothesis.

Eye/Ear Conditions

As in the Intermixed conditions, I calculated accuracy and response time difference scores. Although I had participants periodically respond to the auditory stimuli (ear trials), I was primarily interested in how increased attention to the auditory modality would affect performance while responding to visual targets. Thus, in the analyses below, I only examined accuracy and response times on the visual selective attention task (eye trials). I submitted accuracy difference scores to a 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA (see Figure 6 for Means and Standard Errors). There was a significant effect of load, F (1, 26) = 4.66, p = .040, η_p^2 = .15, with accuracy being greater under high load (*M* 0, *SE* = .01) than low load (*M* = -.05, *SE* = .02). The analysis also revealed an effect of compatibility, F (1, 26) = 20.29, p < .001, η_p^2 = .44, with incompatible distractors (*M* = -.09, *SE* = .02) decreasing accuracy compared to compatible distractors (*M* = .04, *SE* = .01). The load by compatibility interaction was not significant F (1, 26) = .06, p = .815, η_p^2 < .01.

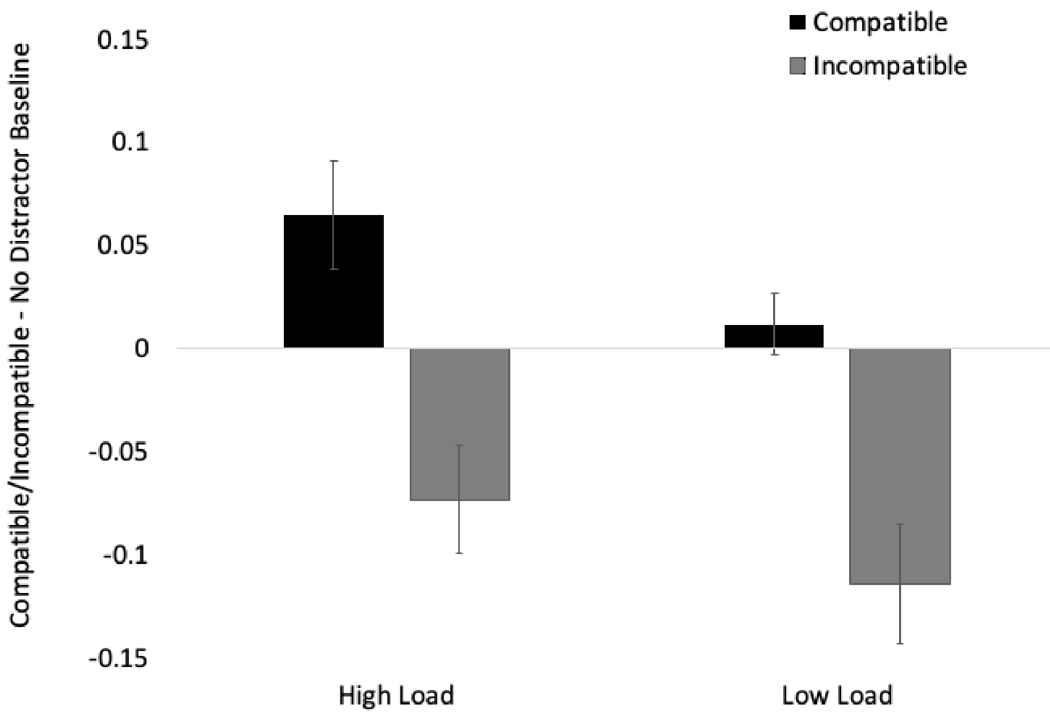

Figure 6: Accuracy difference scores across compatibility and load in the Eye/Ear Conditions. Error bars denote Standard Errors.

I also submitted response time difference scores on correct trials to a 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA (see Figure 7 for Means and Standard Errors). There was a significant effect of compatibility, F (1, 26) = 18.82, $p < .001$, $\eta_p^2 = .42$, with compatible distractors (*M* = -137.99 ms, *SE* = 36.41 ms) speeding up responses compared to incompatible distractors (*M* = -27.99 ms, *SE* = 39.09 ms). In contrast to the intermixed condition, the load x compatibility interaction was significant, F (1, 26) = 9.04 $p = .006$, $\eta_p^2 = .26$; however, the effects were inconsistent with the Perceptual Load Hypothesis, which would predict distractors being more distracting under low load. As can be seen in Figure 7, distractor compatibility only had an effect in the high load condition, paired sample t-test, t =

(26) = 4.95, *p* < .001, with compatible distractors speeding up responding and no evidence that incompatible auditory distractors significantly slowing down responding (compared to baseline).

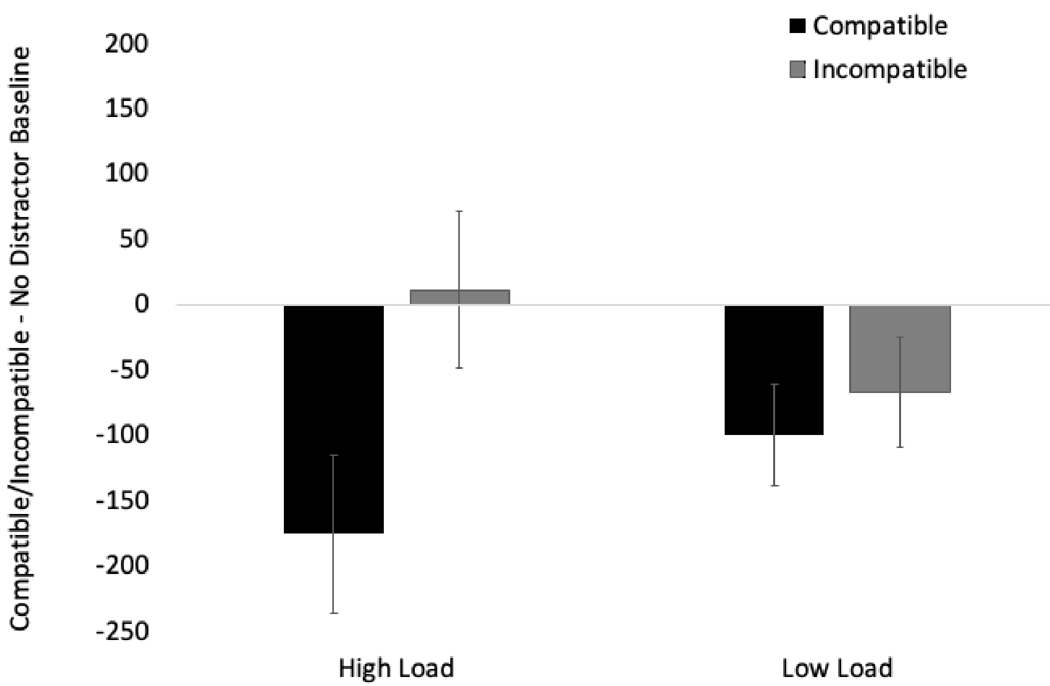

Figure 7: Response time difference scores across compatibility and load in the Eye/Ear Conditions. Error bars denote Standard Errors.

In summary, the goal of the eye/ear task was to examine the effects of increased attention to the auditory modality on visual selective attention. The attentional manipulation appeared to have an effect as increased attention to the sounds in the eye/ear task increased the effects of auditory distractor compatibility on the visual selective attention task. For example, in regard to accuracy, auditory distractor compatibility had a larger effect in the eye/ear condition (η_p^2 = .44) than in the intermixed condition (η_p^2 = .14). The same pattern can be seen when examining response times with distractor compatibility having a larger effect in the eye/ear condition (η_p^2 = .42) than in the intermixed condition (η_p^2 = .00). While the attention manipulation appeared to increase the effect of distractor compatibility, it is important to note that this effect was either comparable across perceptual load (see accuracy data in Figure 6) or resulted in stronger effects under high load (see response time data in Figure 7). Both of these findings are not consistent with PLH.

Discussion

In Experiment 2, I looked at two different sets of trials to account for different explanations as to why auditory distractors were not as distracting as visual distractors when both are compared to baseline. In the intermixed condition, I saw visual distractors still being more distracting than auditory distractors, replicating the results from Experiment 1. This therefore suggests that habituation did not appear to have an effect on auditory distractibility. When looking at the Eye/Ear condition, auditory distractors had more of an effect overall, but PLH was still unable to predict performance. This suggests that when I have participants periodically respond to the auditory stimulus, that this then affects performance in the visual modality. Why is this happening though? Is it really because participants were having to respond to the auditory stimulus, or is it because the eye/ear task within itself is a cognitively heavy task? This question leads me into my last experiment to rule out one of these reasons and get more clarity on these findings.

Experiment 3

In Experiment 3, I took the Intermixed Condition trials (where participants never responded to the auditory stimulus) and increased cognitive load by adding a short working memory task before each trial. This should help determine what is driving the increased auditory effects of auditory distractors on visual processing. If it is due to increased cognitive load, I should see similar results in this experiment to the eye/ear condition from Experiment 2 because both tasks were cognitively demanding. If the effects found in the eye/ear condition are due to periodically responding to the auditory stimulus, then the results from this experiment should be similar to the results from the intermixed condition from Experiment 2, as there was no auditory responding in this test.

Methods

Participants. Twenty-seven participants (*M* = 19.16 years, *SD* = .76 years, 14 Females) from The Ohio State University at Newark participated in the experiment for course credit. No participants were excluded from our data set. Recruitment was conducted the same way as in previous experiments.

Materials, Design, and Procedure. For this experiment, we used the intermixed condition from Experiment 2 with the addition of a short working memory task. The working memory task consisted of a six digit number presented to the participant before the beginning of a trial. Participants were instructed to memorize the number presented to them. The number only appeared for 2000 ms before disappearing. Then, a single bird/dog intermixed trial took place. After the participants responded to the trial, the six digit number would reappear, and ask the participant if this number was the same or different from the first number they saw. The number was either the same number the participant saw before, or it was different by one digit. Participants pressed 1 if the two numbers were the same and 3 if the two six-digit numbers differed. The changed digit was equally likely to appear in any location in the six-digit number. Finally, we only presented the intermixed conditions in Experiment 3. The computer randomly started one of the two blocks (high load intermixed or low load intermixed). The two blocks were manipulated within-subjects and each block had 120 trials (240 trials in total), with 48 visual distractor trials, 48 auditory distractor trials, and 24 no distractor trials in each block. All other aspects of this experiment mimicked Experiment 1.

Results

First, I looked at the data from the working memory task to check if participants were taking the task seriously. Overall, participants were accurate on 90% of the trials and there were no differences across any of the conditions (Range 89 – 91%, *p's* > .09).

As in previous experiments, I calculated accuracy difference scores (see Figure 8 for Means and Standard Errors). I submitted accuracy difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA. There was a significant effect of compatibility, F (1, 26) = 3.64, p = .013 η_p^2 = .12, with incompatible distractors (M = .01, SE = .01) decreasing accuracy more than compatible distractors (M = -.01, SE = .01). As in the intermixed condition of Experiment 2, there was no evidence that auditory distractors facilitated or interfered with responding compared to the no distractor baseline, all one-sample *t*'s compared to 0, Bonferroni corrected *p*s > .22.

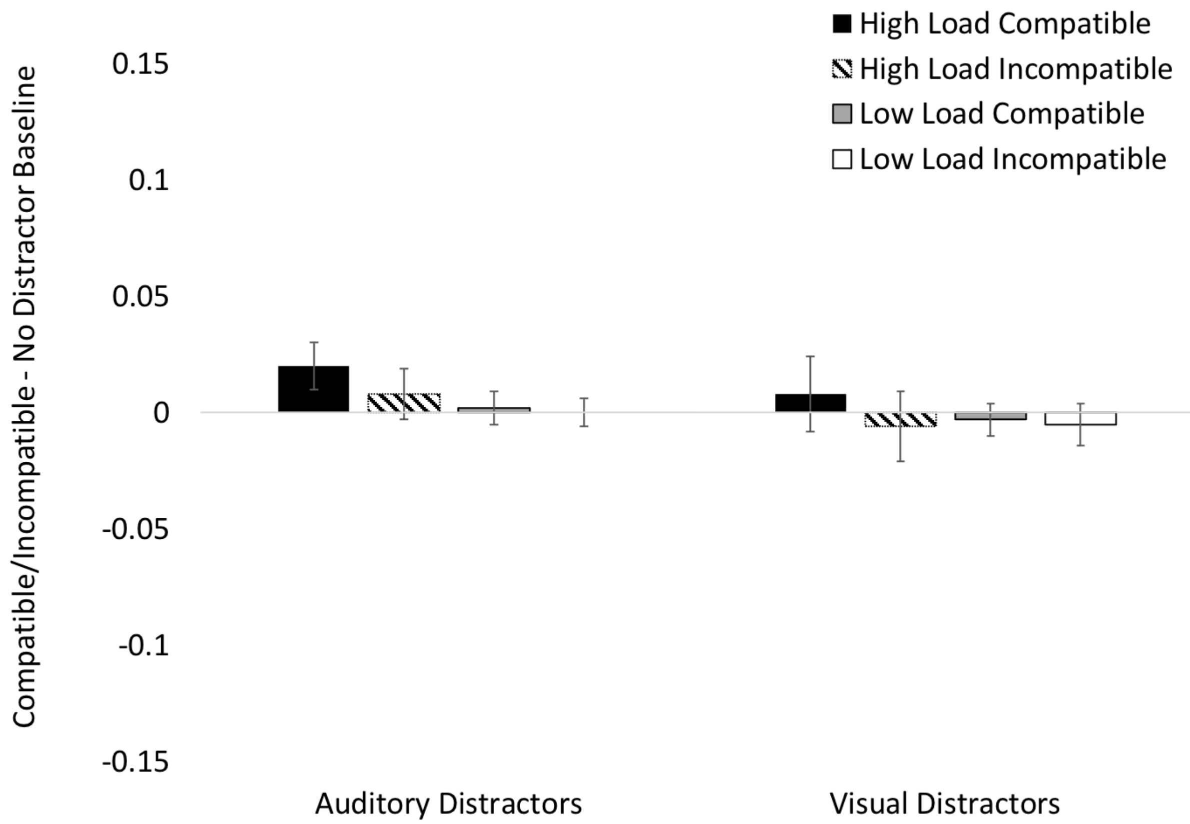

Figure 8: WM accuracy difference scores across modality, compatibility, and load in the Intermixed Conditions. Error bars denote Standard Errors.

I also submitted response time difference scores to a 2 (modality: auditory vs. visual) x 2 (compatibility: compatible vs. incompatible) x 2 (load: high vs. low) repeated measures ANOVA (see Figure 9 for Means and Standard Errors). There was a significant effect of compatibility, F (1, 26) = 15.41, p > .01, η_p^2 = .37, with compatible distractors (*M* = -12.95 ms, *SE* = 18.98 ms) speeding up responses compared to incompatible distractors (*M* = 73.18 ms, *SE* = 17.41 ms). As in the intermixed condition of Experiment 2, there was no evidence that auditory distractors facilitated or interfered with responding compared to the no distractor baseline, all one-sample *t*'s compared to 0, Bonferroni corrected *p*s > .22.

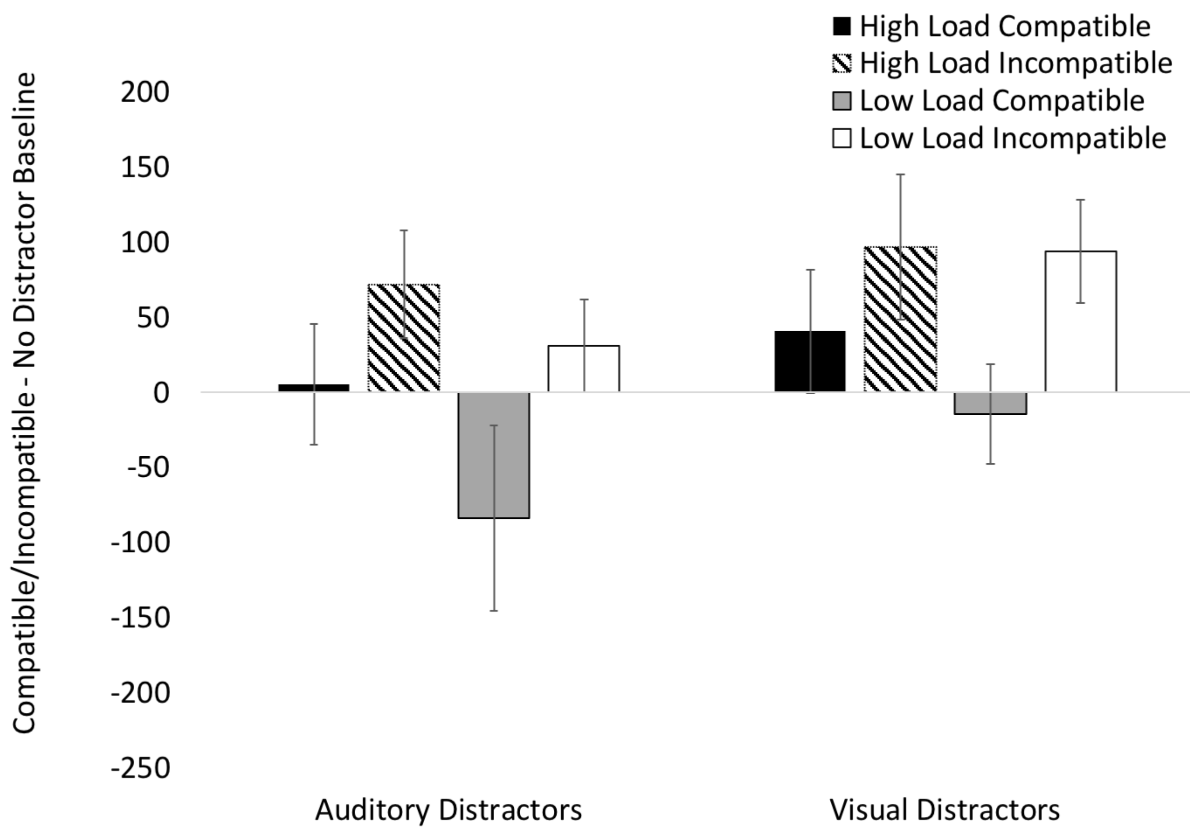

Figure 9: WM response Time difference scores across modality, compatibility, and load in the Intermixed Conditions. Error bars denote Standard Errors.

Comparisons Across Experiments 2 and 3

In order to better understand the results from both experiments, I compared performance across the auditory distractor conditions (See Figure 10 for accuracy data and Figure 11 for response time data). Auditory stimuli had no effects (compared to 0) in the two intermixed conditions, but did have an effect in the eye/ear task. This can be seen in both Figures 10 and 11, as the results from Experiment 3 resemble the results from the intermixed condition of Experiment 2. When looking at the auditory effect sizes across all conditions (η_p^2 reported above each condition in Figures 10 and 11) results show that both the Intermixed conditions of

Experiment 2 and Experiment 3 could account for around 0%-10% of the variability in the data, whereas, auditory effect sizes can account for a little more than 40% of the variability in the eye/ear task. This suggests that auditory stimuli affected the variability of the data more in the eye/ear task, potentially because participants had to pay attention to and periodically report out the auditory stimuli.

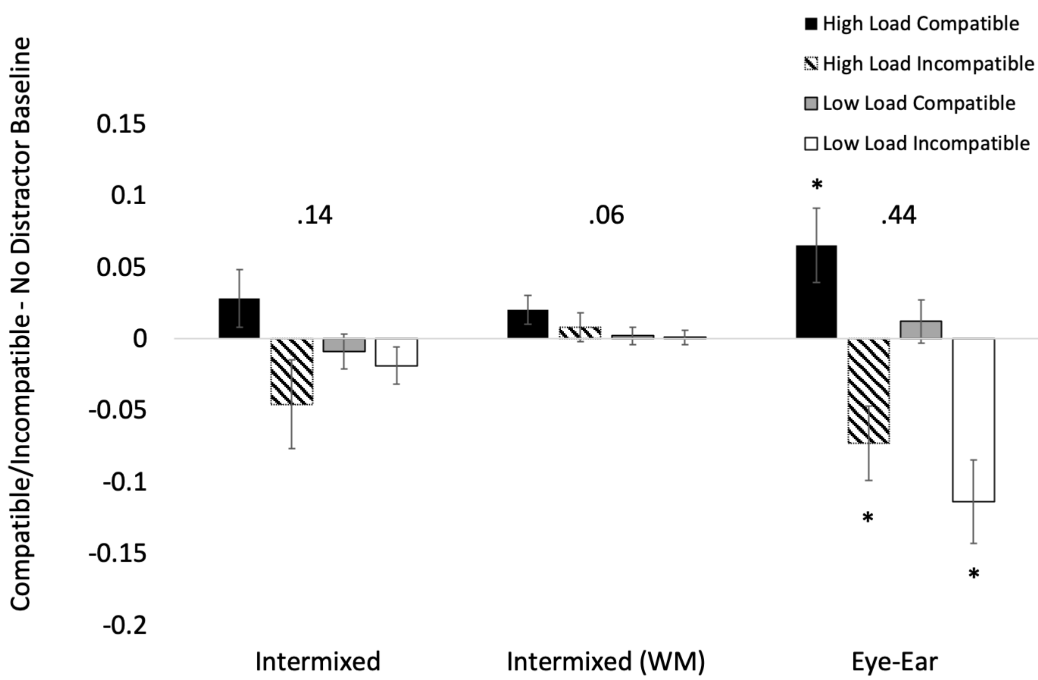

Figure 10: Accuracy difference scores in the auditory distractor conditions in Experiments 2 & 3. Error bars denote Standard Errors. Values denote effect sizes associated with the main effect of compatibility).

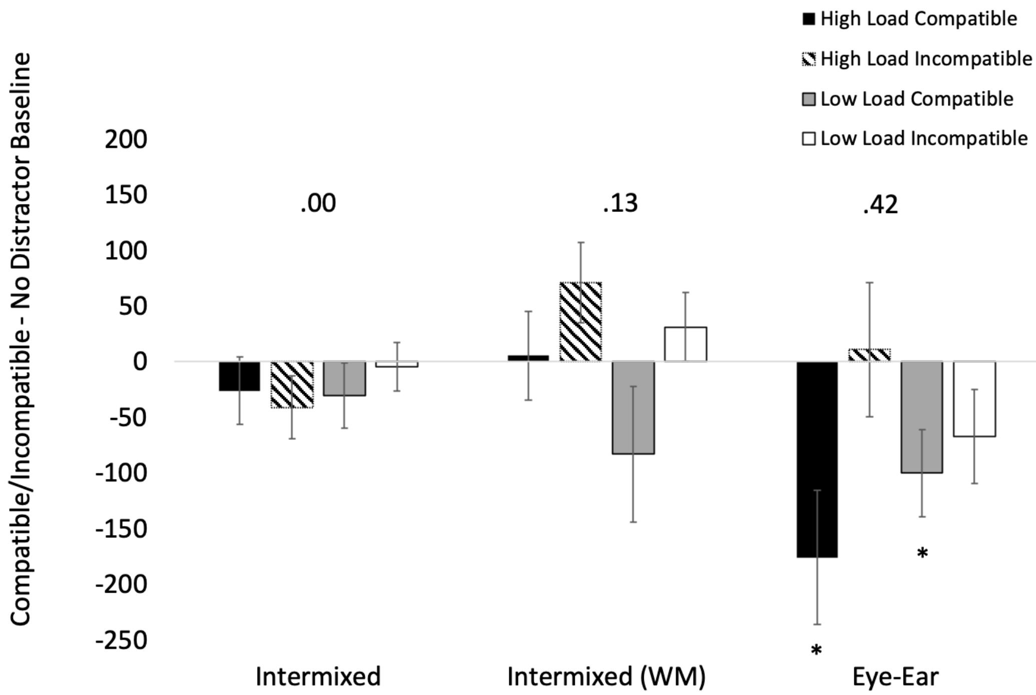

Figure 11: RT difference scores in the auditory distractor conditions in Experiments 2 & 3. Error bars denote Standard Errors. Values denote effect sizes associated with the main effect of compatibility).

General Discussion

Participants in the current study completed variations of a visual selective attention task while being presented with auditory and visual distractions under low and high perceptual loads. Throughout this study, participants were presented with a bird or a dog with compatible or incompatible visual or auditory distractors, and were asked to respond to which target animal they saw in a small target box in high loads or low loads of information. In Experiment 1, participants were asked to complete the selective attention task from Robinson et al (2018) with a shortened stimulus presentation, and I also added a no distractor condition to serve as a baseline control to estimate facilitation and interference effects. Results showed that visual distractors tend to be more distracting than auditory distractors, and compatible distractors were more distracting than incompatible distractors. There was no support for PLH within the visual modality for both auditory and visual distractors. The results seem to show participants were able to ignore all auditory stimuli, and I followed my next experiment with two different tasks that could potentially address the lack of auditory distractibility issue and further explore auditory distractibility.

In Experiment 2, auditory and visual distractor trials were either intermixed (intermixed conditions) or were intermixed with an eye or ear presented before each trial, which indicated which stimuli participants were supposed to report (eye/ear conditions). In the intermixed condition, visual distractors were more distracting than auditory distractors, while incompatible distractors decreased performance more than compatible distractors. As in Experiment 1, data in the intermixed condition provide no support for PLH (Lavie, 1995); however, this likely stemmed from auditory and visual distractors having relatively small effects on the visual responses. Intermixing auditory and visual distractors also appeared to have little or no significant effect on auditory distractibility as the effects of compatible and incompatible auditory distractors never differed from the no distractor baselines.

In Experiment 2, I also increased attention to auditory stimuli in the eye/ear condition by requiring participants to periodically respond to the auditory stimuli, and auditory distractor effects were generally stronger in these conditions. Compatible distractors increased accuracy and incompatible distractors decreased accuracy; however, the same overall pattern was found across low and high load. The response time analyses showed a slightly different pattern with auditory stimuli speeding up responding in three of the four conditions (see Figure 7). Thus, increasing attention to the auditory modality appeared to speed up responding to the visual targets, as opposed to slowing down responses on incompatible trials. A significant load compatibility interaction was found in the eye/ear condition; however, distractor compatibility was more pronounced under high (not low) load.

In Experiment 3, I used the intermixed trials from Experiment 2 with a working memory task to see if increase cognitive load or periodically responding to auditory stimuli was responsible for stronger auditory effects. To do this, I added a six digit number to the beginning of each trial, asking participants to memorize that number before completing the bird/dog task. Once they responded to the bird/dog task, a six digit number reappeared (either matching the previous number or differing by one digit) and the participant was asked if this was their number from earlier. I found that the results from Experiment 3 matched closer to the intermixed condition results from Experiment 2, showing that increased auditory effects in the eye/ear task likely stem from requiring participants to periodically respond to auditory stimuli, not from increased cognitive load.

Research examining the Perceptual Load Hypothesis (PLH) often shows that distractors have a larger effect in low load conditions because of more available resources to detect distracting stimuli (Lavie, 1995; Lavie & Tsal, 1994). While our findings do not support PLH for auditory or visual distractors in the visual modality, the findings are consistent with a growing body of literature showing that compatible and incompatible auditory distractors have a larger effect under high load (Robinson et al., 2018; Tellinghusien & Nowak, 2003). In Tellinghusein and Nowak (2003), researchers hypothesized that increased cognitive load could account for auditory distractibility. In Experiment 3, we found no support for this hypothesis, as increasing cognitive load had no effect on auditory distractibility. While future research is needed, it is possible that this effect stemmed from periodically responding to the auditory stimulus in the eye/ear task. With the eye/ear task having participants pay close attention to auditory stimuli, participants may have struggled to filter out the distractors because the resources needed to focus attention were being separated between two different modalities.

Auditory dominance literature suggests that auditory stimuli should automatically engage attention and disrupt or delay visual processing (see Robinson & Sloutsky, 2010 for a review). This account predicts that auditory stimuli should have a negative effect on visual selective attention tasks and that PLH should not predict performance because auditory distractors should be detected under low and high load. The current findings are interesting for two reasons. First, auditory stimuli only affected visual processing when participants had to periodically respond to auditory stimuli (eye/ear condition). This has important implications for our understanding of potential mechanisms underlying auditory dominance. While most auditory dominance studies require participants to divide attention across sensory modalities and respond to changes in auditory and visual information (Barnhart et al., 2018; Dunifon et al., 2016; Robinson et al., 2016; Sloutsky & Napolitano, 2003), participants in the current study only had to respond to a single modality on each trial. This may suggest that auditory stimuli are disrupting response selection, not the encoding of the visual information.

This study provided evidence of auditory facilitation effects, with accuracy scores that exceeded zero and response time scores below zero in the eye/ear task, but shows little support for auditory dominance/interference. While future research is needed, the facilitation effect likely stems from semantic congruency (Iordanescu, Guzman-Martinez, Grabowecky, & Suzuki, 2008) with participants responding faster when auditory and visual information provide complementary information (dog paired with dog bark). However, this only provides an explanation for facilitation effects and it is unclear why auditory dominance effects were not found with conflicting auditory information slowing down visual responding. One possibility is that auditory interference occurs after stimulus encoding with effects being most pronounced when sensory modalities are competing for a response.

Although the findings do provide some evidence for auditory and visual stimuli distractibility by effecting accuracies and response times and that PLH could not account for these effects, there were some limitations. First, the stimuli were presented extremely fast, giving participants very little time to process the information presented to them. Second, the tests in nature were very repetitive and long, leading to participants potentially having become mentally exhausted by the end, especially in Experiment 3. Limitations aside, the most interesting results from this study are the facilitation effects with auditory stimuli speeding up responses in the eye/ear task of Experiment 2. This could suggest that auditory stimuli are triggering some sort of "arousal" in attention resources, and allowing for quicker responses to be made. This could be preliminary research for studies that look into auditory stimuli's role in learning or performing.

In summary, selective attention is crucial for many tasks, and it is important to understand what factors account for auditory and visual distractibility. My findings show that: (a) visual distractors had a larger effect on visual selective attention than auditory distractors and (b) PLH did not predict auditory distractibility, and in fact, I found the opposite effect with distractor compatibility having a larger effect under high perceptual load. This should be further explored in future research, as the strange facilitation effects during high load could indicate some sort of "arousal" in the mind, creating the ability to better use our attentional resources while completing tasks.

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