Listening is Seeing: Effects of Auditory Load on Inattentional Blindness

Timothy J. Lano1, Liwei Sun2, Bridget H. McGuinness3, Mehran Motevaze4, and Jessica H. Nguyen5
Department of Psychology, University of Minnesota, Minneapolis, Minnesota

Inattentional blindness (IB) is the failure to notice an unexpected, yet obvious, visual stimulus due to focused attention on another task. This study sought to examine the effects of auditory load on IB and if IB increases in concordance with cognitive load between medium and high auditory load conditions. Participants were asked to view an IB video showing cards being dealt that had been paired with either music or music with embedded tones. They were asked to count the number of cards and report if they saw anything unusual in the video. The results indicate that as auditory load increases, IB increases. These results seem to indicate that there is a limit to attentional abilities, at which point unexpected events go unnoticed and that a trend of increasing IB can be seen in conformity with increasing cognitive load.

In modern society, it seems as though people’s attention is constantly divided amongst multiple tasks simultaneously, commonly referred to as multitasking. Such tasks may include checking e-mail and talking on the phone, reading an article and listening to the television, or even the highly debated issue of driving while talking on a cell phone. Although it may seem as though humans were designed to multitask, there appears to be a limited capacity for the human nervous system to process information. This capacity was theorized by Broadbent (1958) and evidenced by decrements in performance while performing multiple cognitive tasks. It could be hypothesized that practice in multitasking might increase the ability to perform certain cognitive tasks concurrently. However, researchers have actually found that those that multitasked more often were worse at it than those that did not multitask as often (Ophir, Nass, & Wagner, 2009).

It soon becomes apparent that there are limitations to how much a person is able to effectively process and respond to cognitive tasks, but the mechanisms underlying this principle seem rather mysterious. Salvucci and Taatgen (2008) recently developed the theory of threaded cognition as a mathematical model for calculating the extent to which individuals are able to multitask in terms of both concurrent multitasking and sequential multitasking. As an analogy to their theory, Salvucci and Taatgen describe the idea of a chef preparing multiple meals at once. They draw upon the idea that the chef has an oven, a stove, and mixers at his disposal. This is analogous (though very simplified) to different regions in the brain such as the somatosensory system, visual system, and auditory system. The chef also has orders (tasks) that he is to fill. These orders sometimes need the use of the same apparatus to be completed. Based on this analogy, the concept of multitasking may be considered serial events rather than simply parallel events because each task may require the same resources. This introduces the concept of cognitive bottlenecking, which is the idea that when two tasks attempt to access the same cognitive resource, only one will be able to effectively make use of the resource at one time. Cognitive bottlenecking still makes use of Broadbent’s (1958) ideas on distinct resources in that other

1 Timothy Lano (lanox014@umn.edu) is a junior graduating December 2013 with a B.S. in Psychology and a minor in Neuroscience. He plans to pursue postgraduate studies in clinical psychology with a focus on either schizophrenia or anxiety disorders.

2 Liwei Sun (sunxx706@umn.edu) is a senior graduating in December 2012 with a B.A. in Psychology. He plans to go to graduate school with a focus on cognitive neuroscience.

3 Bridget McGuinness (mcgin097@umn.edu) is a junior in the College of Liberal Arts. She will receive her B.A. in Psychology in December 2013 with plans to attend graduate school for the Master of Professional Studies in Integrated Behavioral Health program.

4 Mehran Motevaze (motev003@umn.edu) is a junior in the College of Liberal Arts. In May of 2014 he will receive his B.A. in Psychology. He plans to pursue postgraduate studies to become a Physician’s Assistant.

5 Jessica Nguyen is a senior in the College of Liberal Arts. She will be graduating in May 2013 with a B.S. in Psychology and a minor in Biology.
tasks may be affected negatively in order to complete all tasks presented. By utilizing these theories, it may be deduced that the addition of unexpected stimuli may produce hindrances to the performance of an individual if they allocate limited attentional resources to the unexpected stimuli.

One consequence of an organism having limited attentional resources is the phenomenon known as inattentional blindness (IB). IB is the failure to notice an unexpected, yet obvious, stimulus because attention is focused on another task (Mack, 2003). There are differing degrees to which this may present danger. It could be as harmless as overlooking a vehicle while changing lanes. Understanding the mechanics behind this phenomenon may help reduce number of tragic accidents and save the lives of many. On a more fundamental level, it can provide insight into the limits of human cognition.

Relating multitasking and inattentional blindness is a matter of observing the concept of cognitive bottlenecks. This was demonstrated in a study conducted by Macdonald and Lavie (2008) in which the researchers observed the effects of low perceptual load versus high perceptual load on inattentional blindness. First, they had the participants use a computer and

\[ \text{perceptual load} \]

\[ \text{inattentional blindness} \]

This was demonstrated in a study conducted by Macdonald and Lavie (2008). There are differing degrees to which this may present danger. It could be as harmless as overlooking a vehicle while changing lanes. Understanding the mechanics behind this phenomenon may help reduce number of tragic accidents and save the lives of many. On a more fundamental level, it can provide insight into the limits of human cognition.

Relating multitasking and inattentional blindness is a matter of observing the concept of cognitive bottlenecks. This was demonstrated in a study conducted by Macdonald and Lavie (2008) in which the researchers observed the effects of low perceptual load versus high perceptual load on inattentional blindness. First, they had the participants use a computer and correctly identify the letter X or N that flashed briefly on a grey screen. The researchers then created high perceptual load by introducing additional letters that are similar in form to the target letter (i.e., H, K, M, W, and Z). Low perceptual load was produced by the use of O instead of similar letters. The participants were then asked to press the appropriate button to indicate seeing X, N, or the “critical” stimulus (CS), which was a small, grey meaningless figure. Macdonald and Lavie (2008) found that the ability to detect the CS at baseline was not significantly different from detecting the CS during low perceptual load. However, during high perceptual load, there was a significant reduction in the detection of the CS relative to baseline. It may be concluded that higher cognitive loads increase inattentional blindness. This supports the idea that greater amounts of resources used in one cognitive area will lead to an increase in inattentional blindness as it follows the cognitive bottlenecking paradigm.

However, a recent study conducted by Beanland, Allen, and Pammer (2011) sheds new light on how cognitive load influences inattentional blindness. The researchers wanted to investigate the effects of attending to music on inattentional blindness. In their study, they had participants observe black and white L’s and T’s on a computer screen. They were then instructed to count the number of times the white letters “bounced” off the sides of the screen. They did this while listening to ABBA’s “Mamma Mia”. In one condition, the participants were instructed to simply listen to the music. In another condition, the participants were to listen for an embedded tone and make the appropriate response when they heard a tone. Near the end of each trial, a gray letter A would travel horizontally across the middle of the screen. The results of this experiment were somewhat counterintuitive. Attending to music with embedded tones actually decreased inattentional blindness. Thus, although inducing an overload of stimuli to one cognitive area within the brain (e.g., visual or auditory) appears to cause a decrement in certain abilities, it would appear that lesser amounts of stimulation to multiple modalities are not detrimental to a person’s ability to multitask.

Previous studies restricted stimulus overload to one modality without observing the effects over multiple modalities. The conflicting results of these studies present a new opportunity for research. Beanland et al.’s (2011) study indicated that attending to music decreases inattentional blindness. They concluded that this may have been due to the predicted U-shaped curve of load on IB. That is to say that low load and high load see higher rates of IB than moderate load because participants get distracted easily or the task is so difficult that it requires cognitive resources that are not available, thus inducing IB. In the case of moderate load with the accompaniment of a simple auditory task, IB occurs at a lower frequency because it maintains the individual’s attention at the point where distractibility is less of an issue, but does not take up enough cognitive resources to induce IB. However, the auditory task must be simple enough to avoid increasing cognitive load. In contrast, the increase in cognitive load based on MacDonald and Lavie’s (2008) research might suggest that the increased cognitive load should increase inattentional blindness monotonically. This study aims to further extend the research of Beanland et al. (2011) and investigate if there could be some ‘optimal point’ at which cognitive load is relatively high, and yet, inattentional blindness is low. More specifically, this study seeks to observe whether inattentional blindness might increase with increased auditory load as consistent with the theory of limited resources in cognition, when the complexity of the cognitive (auditory) task is increased. Additionally, the goal of this study is to replicate Beanland et al.’s findings that IB decreases while attending to music.

In this experiment, different levels of inattentional blindness across three groups represented by three levels of auditory load were observed. Low load consisted of just listening to a song. Medium load consisted of listening to the same song, but with embedded tones (similar to Beanland et al. study). High load required the participant to listen for the key word “one” within the song lyrics. Thus, the high load condition resembled the higher cognitive function of speech comprehension. The visual part of the task included watching a video of cards being turned over. The participant was to count the number of black cards (i.e., spades and clubs) turned over, amidst a total of 42 cards. In a survey, at the end of the task, the participants were asked if they saw anything unusual in the video. If so, they were asked to identify what it was that was unusual. The correct identification of the unexpected stimulus (a blue-backed card in a red-backed deck) was counted as noticing (e.g., “I saw a blue card in a red deck”). Any “no” responses or incorrect attempts at identifying the unexpected stimulus was counted as not noticing. Based on the past theories incorporating limited cognitive resources and threaded cognition, it is hypothesized that there will be an increase of inattentional blindness in the group required to perform the high load (increased complexity) auditory task compared to the
medium load. It is also expected that results from this study will be similar to the Beanland et al’s finding of decreased IB while attending to music (i.e., medium load will see a decrease in IB relative to low load).

METHOD

Participants

Forty-five subjects were selected via convenience sampling from three different sections of a psychological research methods class and from the acquaintances of the researchers at the University of Minnesota. The age range was 18 to 32 with a mean age of 21.78 (SD = 3.11). The sample included 19 females and 26 males. Individuals indicated race as follows: 73.33% Caucasian, 24.44% Asian/Pacific Islander, and 2.22% African American. All individuals had normal or corrected-to-normal visual acuity and no hearing deficits were reported. All individuals participated either as a course requirement or freely without compensation. Finally, subjects were distributed across each level of auditory load, low (n = 16), medium (n = 15), and high (n = 14).

Materials

An inattentional blindness video was created using an HTC Hero phone’s video application/camera and two different colored decks of Bicycle playing cards. There were 42 total cards used: 19 black (club or spade) cards with red backs, 22 red cards (diamond or heart) with red backs, and 1 black card with a blue back. The cards were filmed being turned over from face down to face up. The face down side was visible until the card was turned over and stacked in a pile. This video was presented using the website YouTube.com (respectively, videos for the low, medium, and high auditory loads are as follows: watch?v=FYoSNT0rRzg, watch?v=N8KPSbdjxng, and watch?v=Sd8AI4DT0kw). They were played on a laptop computer (Gateway MX6927).

The song used for the auditory task was called Be the One performed by The Fray, off of the CD The Fray [Bonus Disc]. The segment of the song used was from 1:47-2:37. In low auditory load and high auditory load conditions, only the song was paired with the video. In the medium auditory load condition, the music was paired the same way, but the addition of a tone was introduced at varied intervals of the track (i.e., 11, 15, 20, 30, and 41 second marks in the video). The music was paired with the video using Picasa, a program affiliated with Google, Inc. The five tones were generated using the website soundjay.com/censor-beep-sound-effect.html. They are 500 ms in duration and 900 Hz in frequency. They were embedded in the video using Goldwave software (Goldwave, Inc.). The target word in the high load condition, “one”, appeared five times in the audio clip. A pair of Bose earphones was used to present auditory stimuli.

In all three conditions, the participant was asked to count the number of black cards (i.e., club or spade). Participants were presented with a paper survey at the end of the task to record the measure of inattentional blindness through the use of two questions. The first question asked, “Did you notice anything unusual in the video,” and required the participant to circle yes or no. The second question pertained only to those that answered “yes” and requested a description of the unusual event that they noticed (e.g., I saw a blue card within the red deck). The latter portion of the survey gathered demographic information.

Procedure

The researchers first obtained informed consent. Then the participants were randomly assigned to one of three groups that represented different levels of the independent variable: low auditory load, medium auditory load, and high auditory load. Before beginning the task, the participant adjusted the volume of the audio clip while listening to another segment of the song to achieve a comfortable listening level that also permitted the participant to perceive the lyrics. Each participant was told that they were to watch a video of cards being flipped and they were instructed to count the number of black cards (club or spade). Also, all participants were informed that there would be music playing in the background.

Additionally, each group was given information in regards to their assigned auditory task. The low auditory load group was told to simply listen to the song, but was given no specific task regarding audition. The medium auditory load group was told to verbally respond “Yes” each time that they heard a single tone. Finally, the high auditory load group was instructed to respond, “Yes” each time that they heard the word “one” in the song. The researcher recorded the number of “Yes” responses for each participant. There were a total of 5 occurrences of either the tone or the word “one”.

At the end of the video, the participant was asked to fill out the survey described above. At the end of the experiment, each participant was debriefed on the true intentions of the experiment.

RESULTS

The dependent variable was measured using two questions asked on the survey following the task. Based on the answers given (e.g., I saw a blue card in a deck of red cards), the participants were categorized as either seeing the unexpected stimulus or not seeing it. A chi-square test of independence was performed to compare rates of noticing the stimulus between the three groups of low auditory load, medium auditory load, and high auditory load.

Analyses showed that the proportion of participants who noticed the unexpected stimulus significantly differed between the low auditory load group, medium auditory load group, and the high auditory load group, $\chi^2(2) = 7.90, p = 0.019$. The data illustrate that those in the low auditory load group (68.75%) noticed the unexpected stimulus more than those in the medium auditory load group (20.00%) and the high auditory load group (35.71%). The pie charts in Figure 1 display this pattern. Pair-wise comparisons between conditions were then used to test differences between each group. A pair-
significant difference, load group and the high auditory load group did not indicate a 0.34. Lastly, a pair-wise comparison between the low auditory group and the high auditory load group, found to significantly differ between the medium auditory load of participants who noticed the unexpected stimulus was not noticed the unexpected stimulus in the low auditory load, medium auditory load, and high auditory load conditions.

A pair-wise comparison between the low auditory load group and the high auditory load group indicated that there was a significant difference between the low auditory load group and the high auditory load group. Also, the high auditory load group displayed a slightly better score in noticing the unexpected stimulus than the medium auditory load group. Nonetheless, a pair-wise comparison between the low auditory load group and the high auditory load group did not indicate a significant difference, \( \chi^2 (1) = 3.27, p = 0.07 \).

**DISCUSSION**

It was originally hypothesized that there would be an increase of inattentional blindness in the high auditory load group as compared to the medium auditory load group. While there was a significant difference when comparing the low, medium, and high auditory groups, pair-wise comparisons did not support the research hypothesis. This was evident from the lack of a significant difference between the medium auditory load group and the high auditory load group. Also, the high auditory load group displayed a slightly better score in noticing the unexpected stimulus than the medium auditory load group.

Another surprising result was the fact that the results found in the research conducted Beanland et al. (2011), in which a decrease of inattentional blindness while attending to tones in music, were not replicated. The results from this study seem to contradict their findings in that low auditory load group scored significantly better than the medium auditory load group. However, there are some differences between their experiment and ours that may account for differences observed.

Although an attempt at using similar methodologies to the Beanland et al. (2011) study were made, we were unable to set up a program similar to theirs and so resorted to using the video recording with the song and tones embedded. Also, the unexpected stimulus in the current experiment differed from the unexpected stimulus in the Beanland et al. (2011) study. Their unexpected stimulus may have been more overt in the sense that it did not conform to the same pattern as the other letter (i.e., bouncing vs. sliding across the screen) as compared to the same repetitive motion of flipping cards. This might be enough to produce a difference between the two studies and these differences may account for the low number of individuals within this study that noticed the unexpected stimulus in the medium auditory load group. Finally, a major source of difference resides in the fact that in the Beanland et al. (2011) study, participants pressed a button each time a letter bounced off the side of a computer screen, while the current study had them count the number of black cards and report their counts at the end. In having the participants count the cards, the researchers inadvertently included memory in addition to the auditory and visual tasks. The addition of another area of cognition hinders performance overall, consistent with MacDonald and Lavie’s (2008) cognitive load theory. If there is a delicate balance between number of cognitive areas tested and cognitive load that does exist, the addition of memory to the task may be sufficient to tip the proverbial scales enough to see a decrement in attentional abilities with increasing cognitive load.

The trend across conditions showed increasing inattentional blindness with increasing cognitive load (although the difference between the low and high load conditions was not significant due to the small sample size). The researchers’ findings in this study are consistent with the threaded cognition theory proposed by Salvucci and Taatgen (2008). From this theory, the researchers postulate that as cognitive load increases, inattentional blindness also increases. The significant difference between the low auditory load group as compared to the medium and high auditory load groups seems to support this concept. Based on this study’s significant results, we conclude that auditory load does appear to play a role in increasing inattentional blindness. As cognitive demands increase, increases of inattentional blindness are expected. The involvement of memory may have increased cognitive load and may be the reason as to why the researchers were unable to replicate the Beanland et al. (2011) study.

With these conclusions in mind, limitations of results need to be discussed. Two major limitations to the results of this study stem from the unintended use of memory in the task and the construct validity of the video created as there are not many videos similar to the one used. Future research should address the differences between this experiment and previous studies that may have produced inconsistent results. For example, the fact that this experiment utilized a task that depended upon memory may have placed additional demands on attentional resources. One option may be to replicate this study, but completely avoid the memory task altogether.
However, another option for research may purposefully involve memory and move toward concepts involving multi-tasking.

After conducting this research, it seems evident that people may be more prone to missing unexpected occurrences in their environment due to multiple senses registering stimuli. This can result in rather harmless mishaps or in devastating accidents. Understanding the boundaries of cognition is an important goal if we hope to reduce these possible accidents in our lives. In furthering our understanding of our boundaries in cognition, we can hopefully gain greater insight to our human limits in multitasking and potentially increase stretch the limits we have to greater extremes.

REFERENCES


