The effects of temporary visual deprivation on reaction time to an auditory stimulus

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Abstract

Previous studies have consistently shown that prolonged deprivation of vision results in the enhanced perception to auditory stimuli. The purpose of this study is to examine the relationships between temporary loss of vision (via blindfold) and reaction times to auditory stimuli in addition to heart rate and brain wave activity (EEG). In this study 31 (19 females and 12 males) college student participants were randomly assigned to being blindfolded or not blindfolded and monitored while performing a reaction time test. Heart rate, brain wave activity, and reaction time were recorded throughout the reaction time test. It is hypothesized that blindfolded individuals react more quickly to an auditory stimulus than seeing individuals, that participant heart rate decreases between the start of the auditory task and immediately prior to the first auditory stimulus, and that EEG beta-waves are present in individuals immediately after hearing an auditory stimulus. Our results indicate there was no statistically significant difference in reaction time between the two treatment groups. Additionally, heart rate did not significantly decrease between the start of the auditory task and first auditory stimulus. Beta waves were present in all participants immediately following the auditory stimulus. The results of this study can be used to inform future studies on short-term visual deprivation, to enhance understanding of the effects of temporary blindness on auditory perception, and to possibly inform the effects of temporary visual deprivation as a means to increase reaction time as applicable to everyday life.

Introduction

Prolonged deprivation of vision has been shown to enhance components of auditory perception such as auditory reaction time, sound localization, and verbal memory in subjects with congenital and early-acquired blindness (Starlinger, 1981; Gougoux, 2005). The specific mechanisms behind the neuroplasticity of altered cognitive performance have yet to be fully identified. However, evidence suggests the involvement of the visual cortex in enhancing auditory perception. Additionally, Rauschecker and Korte (1993) found that cats with early-acquired blindness showed an increase in auditory representation in the anterior ectosylvian (AE) cortex, a processing center of polymodal stimuli located at the junction of the parietal, temporal, and frontal lobes. It was hypothesized that this increase in auditory representation in the AE cortex was due to a decrease in the pre-existing competition between auditory and visual inputs (Rauschecker et al. 1993).

In conjunction with reaction time, anticipation of a stimulus leads to a decrease in heart rate (Brunia and Damen, 1987). This study, therefore, will utilize a Pulse Oximeter to determine whether heart rate decreases between the beginning of the auditory task and immediately before the first auditory stimulus. EEG data will act as a positive control to determine whether the participant hears the stimulus, as the presence of β-waves immediately after the presentation of the auditory stimulus can be used to indicate that the participant heard and reacted to the stimulus (Haenschel et al, 2000; Lokuta personal communication).

While the research discussed above has illustrated the correlation between long-term blindness and increased auditory perception, it is unknown whether short-term blindness similarly enhances auditory perception. The aim of this study is to determine whether auditory perception is enhanced in individuals with short-term blindness, as measured by a faster reaction time to an auditory stimulus. This study will measure reaction time, heart rate, and brain wave activity in vision occluded and normal vision participants to assess how physiological functions respond when vision is eliminated. This study will also investigate whether faster auditory reaction time is acquired over time or if there is an immediate change in reaction time upon loss of vision. Although much of the current literature consists of studies examining more long-term sensory deprivation situations, these findings will provide a preliminary understanding of short term sensory deprivation.

Methods and Materials

Participants

The 31 participants (61 percent female) in this study included students enrolled in Physiology 435 at the University of Wisconsin-Madison and acquaintances of Physiology 435 students. Male and female participants ranged in age from 20-25 years old. One male participant had mild hearing loss, but the volume of the auditory stimulus was increased to compensate for hearing loss. All participation was voluntary, and participants signed a consent form prior to study participation.

Materials

A random integer generator on a TI-89 II Graphing Calculator was used to assign participants to each condition. Brain wave activity was measured using an Electroencephalogram (EEG) and electrodes (BIOPAC electro-lead set SS2L with 3 BIOPAC Disposable Electrodes EL503 per participant). EEG assembly was executed by the same researcher each time for consistency. EEG data served as a positive control to determine whether the participant had heard the stimulus as indicated by the presence of β-waves (Figure 1). Heart rate was monitored using a Pulse Oximeter (Nonin, #9843). Reaction time was measured using a BIOPAC hand switch (SS10L) and BIOPAC Headphones (OUT1 or OUT1A). Data for the brain activity and reaction time was collected using BIOPAC software (MP36, BIOPAC Systems, Inc.) on two Dell® Inspiron 530 Desktop Optiplex 7020 Computers. Data for heart rate was recorded using Microsoft Excel.

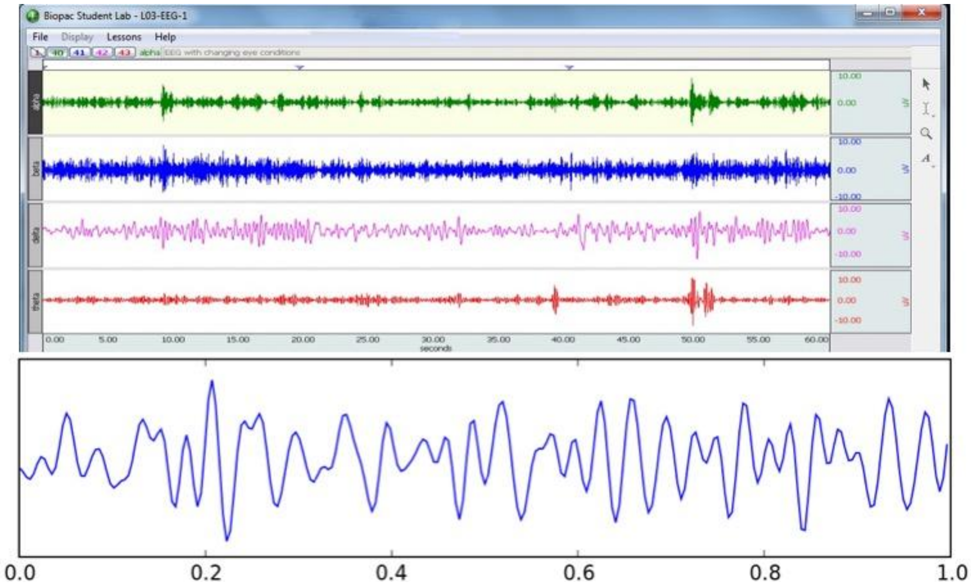


Figure 1. Representative Biopac EEG recording interface, with one-second interval of β-wave readout (second row from top) enlarged for clarity. Presence of β-wave immediately following auditory stimulus presentation used to confirm that participant heard and responded to stimulus.

Experimental Design

Differences in reaction times were compared between participants who were blinded and those who were not. To produce relatively equal numbers of both male and female participants in each condition, male and female participants were "yoked," with male-female pairs randomly assigned to a given condition. For example, if the first three male participants were randomly assigned to the blindfolded condition, the first three female participants would also be assigned to the blindfolded condition. It was not determined whether the participant would be blindfolded until after EEG set up in order to reduce the effects of experimental bias.

Procedure

The question regarding the effects of temporary blindness on reaction time will be investigated by exposing participants to an auditory stimulus and measuring reaction time, either with or without a blindfold. Prior to beginning the experiment, a consent form detailing participation expectations was presented to and signed by each participant before proceeding with the experiment. The participant was then seated facing away from the computer monitors, and the Pulse Oximeter was positioned on the index finger of the participant's non-dominant hand. A baseline heart rate reading was recorded at this time. Surface electrodes were then placed on the participant’s scalp as displayed in Figure 2a, allowing 5 minutes for adhesion.

2a

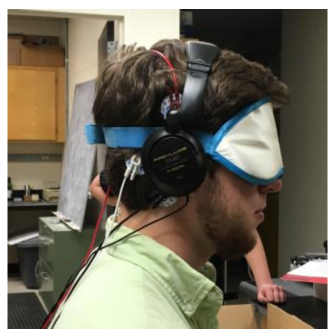

2b


Figure 2**.** Placement of EEG electrodes. Hair was parted to achieve maximum adhesion. Electrodes were allowed to set for 5 minutes before attaching leads (2a, left). Complete equipment set up on a “blind” participant including EEG electrodes and cables, reaction time task headphones, and a blindfold (2b, right).

During the 5 minutes allotted for electrode adhesion, the reaction-time hand switch was placed in the participant’s dominant hand, and calibrated by allowing the participant to hear and react to the auditory stimulus they would be presented with during the experiment. Once EEG electrodes were firmly attached to the participant's scalp, minimal impedance was verified on the “electrode check” channel of the BIOPAC. Next, the participant was assigned to either the “blind” (blindfolded) or “not-blind” (not blindfolded) condition. Figure 2b illustrates the complete equipment set up on “blind” participants.

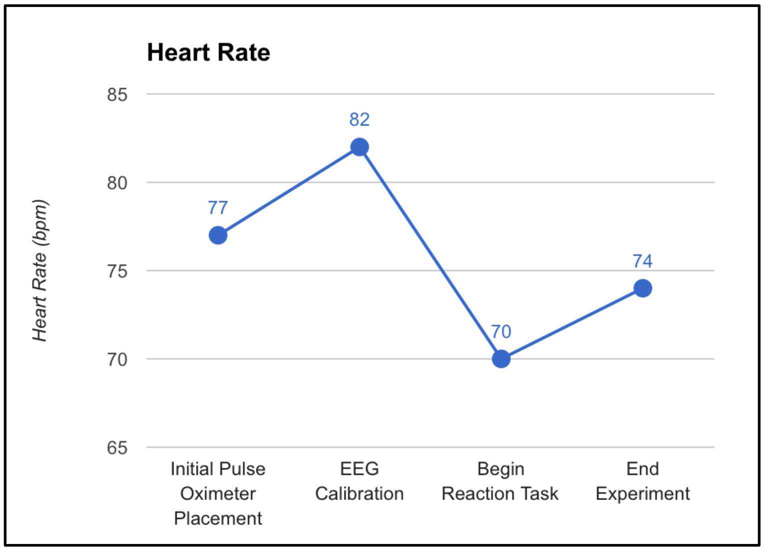


Figure 3. A representative graph of a participant’s heart rate data at various time-points. Heart rates taken during experimental set-up, during EEG calibration (when the participant thought the reaction task had started), immediately before the first reaction task stimulus, and upon completion of the reaction task.

Following EEG set-up and lead adhesion, participants were verbally told the reaction task was going to begin. At this time the EEG was calibrated and a second heart rate measurement was taken. A full profile of a single participant's heart rates can be seen in Figure 3. This heart rate measurement served as an experimental baseline for comparison to heart rates measured immediately before and after the reaction task. The experimental baseline heart rate measurement was taken at this time because the participant was led to believe that the reaction task had started. Participants were instructed to remain silent to minimize EEG impedance. Following EEG calibration, BIOPAC programs were synchronized to simultaneously record brain wave activity and reaction time. Immediately prior to beginning the reaction time task, a third heart rate measurement was taken. The reaction time task consisted of 10 bursts of white noise with random time intervals between each stimulus. The program recorded the time it took the participant to push the button on the hand switch following exposure to each stimulus (Figure 4).

Figure 4. BIOPAC reaction time interface. Reaction time was measured as the time between the presentation of the auditory stimulus and the initial pressing of the hand switch button by the participant.

This portion of the experiment lasted roughly 70 seconds. Upon conclusion of the reaction time task, the participant was notified that the experiment was complete. After experimenters ensured that all data had been recorded from the Pulse Oximeter and BIOPAC, a fourth and final heart rate measurement was taken. This measurement was taken prior to removal of electrodes to prevent influence of any possible discomfort from electrode removal on heart rate. All equipment was disassembled and the participant was excused. A timeline of the experimental procedure can be seen in Figure 5.

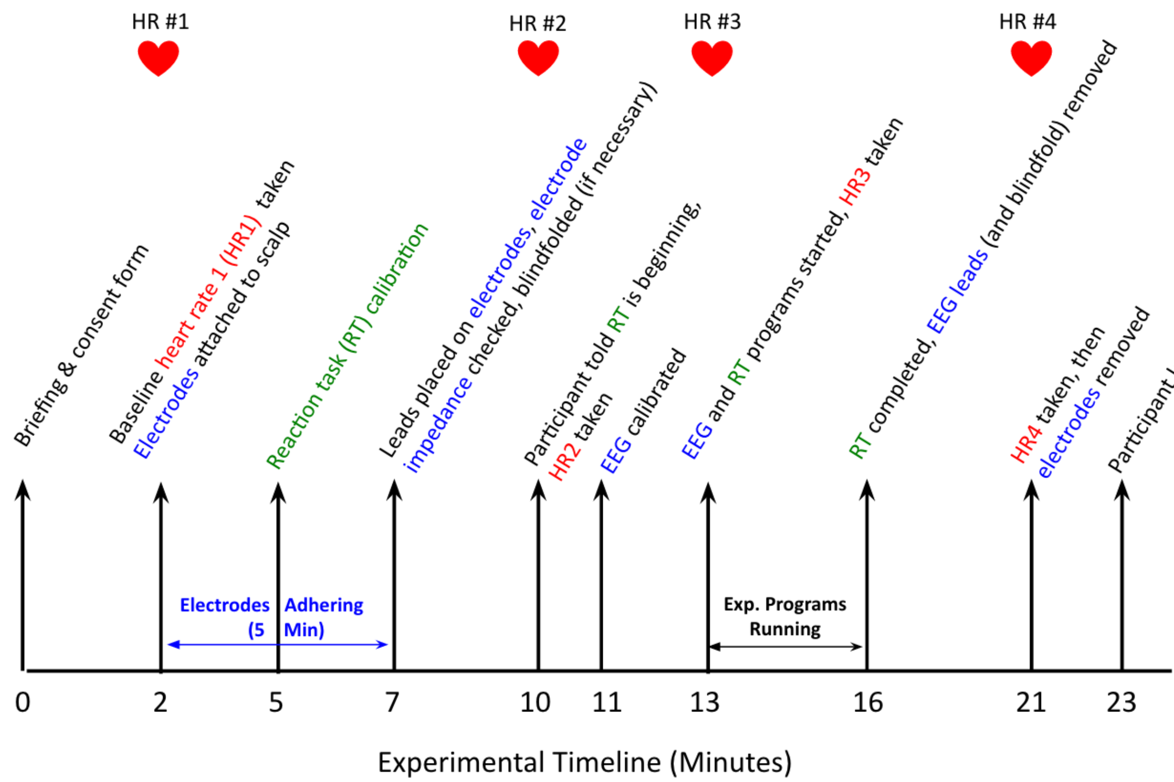


Figure 5. Timeline of the experimental procedure. During the 5 minutes allotted for electrode adhesion, the reaction task was calibrated, allowing the participant to experience the task before the actual task began. The final heart rate was taken prior to removing electrodes to prevent possible discomfort of electrode removal from influencing heart rate.

Data Analysis

Heart rate data collected at each time point was averaged. A one-way ANOVA was used to determine whether there were significant differences in heart rate as a function of when the heart rates were taken during the experiment. EEG data was analyzed categorically to determine whether β-waves were present immediately following presentation of auditory stimuli. Reaction times of participants in each condition were averaged, and a 2-sample t-test was used to determine whether there were significant differences in reaction time based on whether or not participants were blindfolded.

Results

Reaction time

The mean reaction time for all ten auditory stimuli for the visual group was 0.277 seconds (SD=0.0567). The reaction time for the blindfolded group was 0.314 seconds (SD=0.0647) (Figure 6). The mean reaction time for all ten auditory stimuli based on sex was also plotted (Figure 7). Because reaction times over time used a within-subject instead of between-subject design, it is possible that a few participants with very large decreases in reaction times over time influenced the observed trends. Follow-up tests were conducted, in which the pairing effect was removed by randomly assigning a single male and female reaction time to each of the 10 measurement points. For example, a single male and female first reaction time were randomly assigned to the first time point. Only one reaction time per participant was allowed; a randomly-selected participant who had already been selected was dismissed and replaced with a different participant. Blindfolded participants displayed significantly slower reaction times over time compared to visual participants, $t(54) = 2.2$, $p = 0.005$. Reaction times did not significantly differ over time as a function of gender.

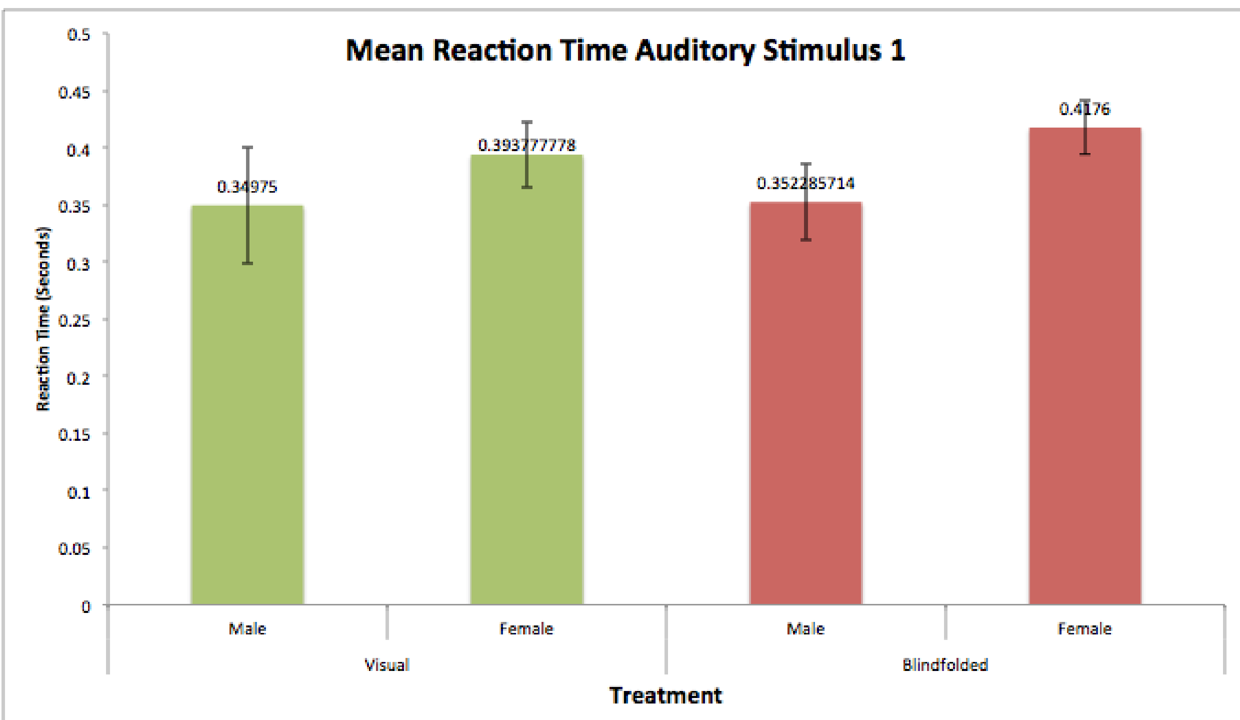


Figure 6. Mean first reaction time for each treatment. Error bars represent one standard error. Independent t-tests revealed that male first reaction times (M = 0.35, SD = 0.088) did not differ significantly from female first reaction time (M = 0.41, SD = 0.08), $t(26) = -1.76$, $p = .09$. First reaction times were also not significantly different between visual (M = 0.38, SD = 0.090) and blindfolded (M = 0.39, SD = 0.084) participants, $t(26) = 1.30$, $p = 0.21$. A multivariate between-subjects ANOVA was performed to analyze whether the first reaction time to an auditory stimulus is influenced by participant gender or visual status. Interaction between sex and visual status did not influence reaction time, $F(2, 26) = 2.12$, $p = 0.14$. First reaction time did not vary as a function of gender, $t(26) = -1.76$, $p = 0.09$, or as a function of treatment, $t(26) = 1.29$, $p = 0.2$.

Figure 7. Mean reaction time for all ten auditory stimuli, divided by sex. Error bars represent standard error. A multivariate ANOVA was performed to determine whether reaction times changes over time. Male participants (M_{1M}=0.351, SD_{1M} = 0.088; M_{10M}=0.256, SD_{10M}= 0.091) were found to have significantly lower reaction times over time compared to female participants (M_{1F}=0.406, SD_{1F}=0.079; M_{10F}=0.294, SD_{10F}=0.066), $t(286) = -5.69$, $p < .001$.

Reaction times were plotted against the two treatment groups, visual and blindfolded (Figure 8). Visual groups, overall, had a faster reaction time as compared to blindfolded groups.

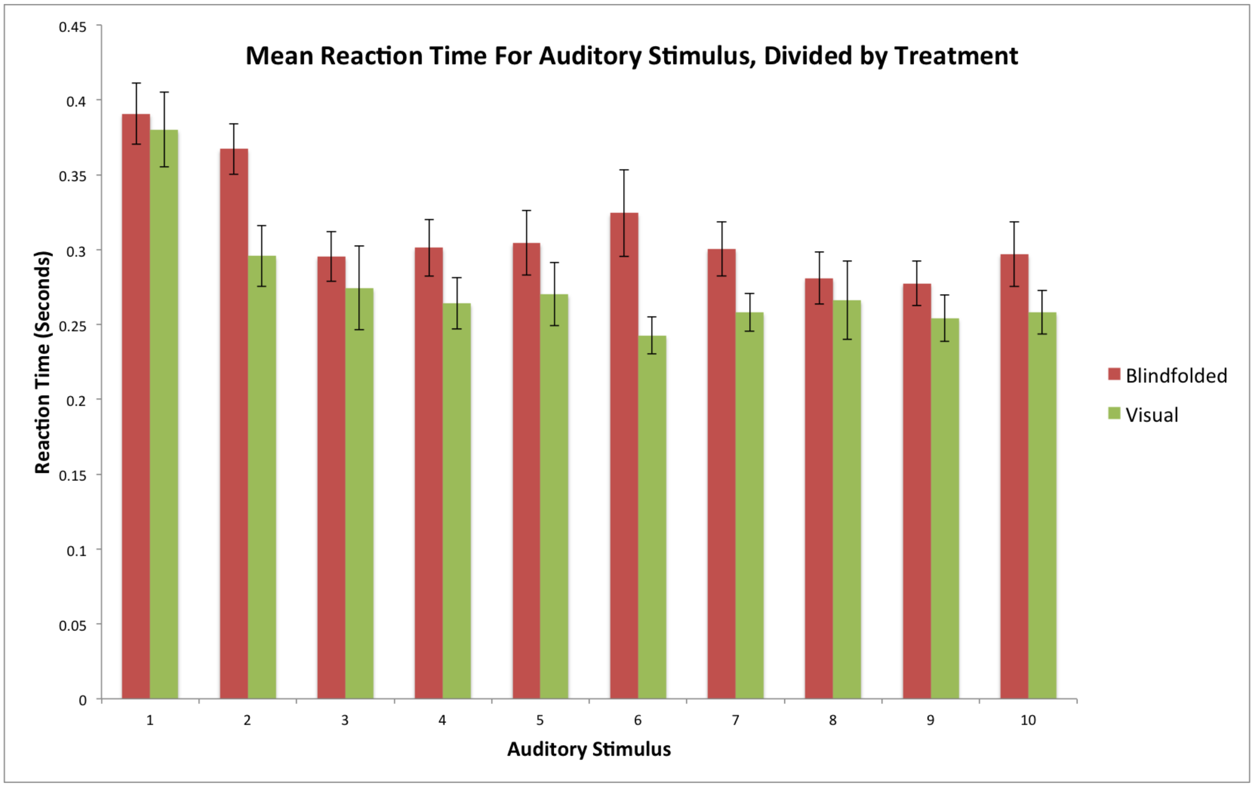


Figure 8. Mean reaction time for auditory stimulus as divided by treatment. Error bars represent standard error. Independent t-tests were performed to determine whether visual status influenced reaction times over time. Visual participants (M_1=0.380, SD_1=0.025; M_{10}=0.258, SD_{10}=0.015) displayed faster reaction times over time compared to blindfolded participants (M_1=0.391, SD_1=0.0203; M_{10}=0.297, SD_{10}=0.0216), $t(286) = 5.63$, $p<.001$.

EEG

EEG data was collected for 16 participants. Beta-waves were identified at time-points immediately following auditory stimulus presentation in EEG readouts of all participants.

Heart rate

The average heart rates for both treatment groups were calculated at four timepoints (Figure 9). The mean heart rate at each time point for the visual treatment group was 81 bpm (SD=14.169), 76.93 bpm (SD=10.381), 76.07 bpm (SD=10.845), and 78.93 bpm (SD=8.535), respectively. The mean heart rate at each time point for the blindfolded treatment group was

73.88 bpm (SD=17.385), 72.41bpm (SD=14.396), 71.82 bpm (SD=15.318), and 75.63 bpm (SD=14.605), respectively.

Male participants (visual and blindfolded) had mean heart rates at each time point of 82.04 bpm (SD=16.81), 76.61 bpm (SD=14.91), 78.1 bpm (SD=16.16), 80.53 bpm (SD=14.55), respectively while female participants (visual and blindfolded) has mean heart rates of 74.06 bpm (SD=15.16), 72.93 bpm (SD=11.20), 70.83 bpm (SD=10.61), 75.22 bpm (SD=10.12), at each time point respectively (Figure 10).

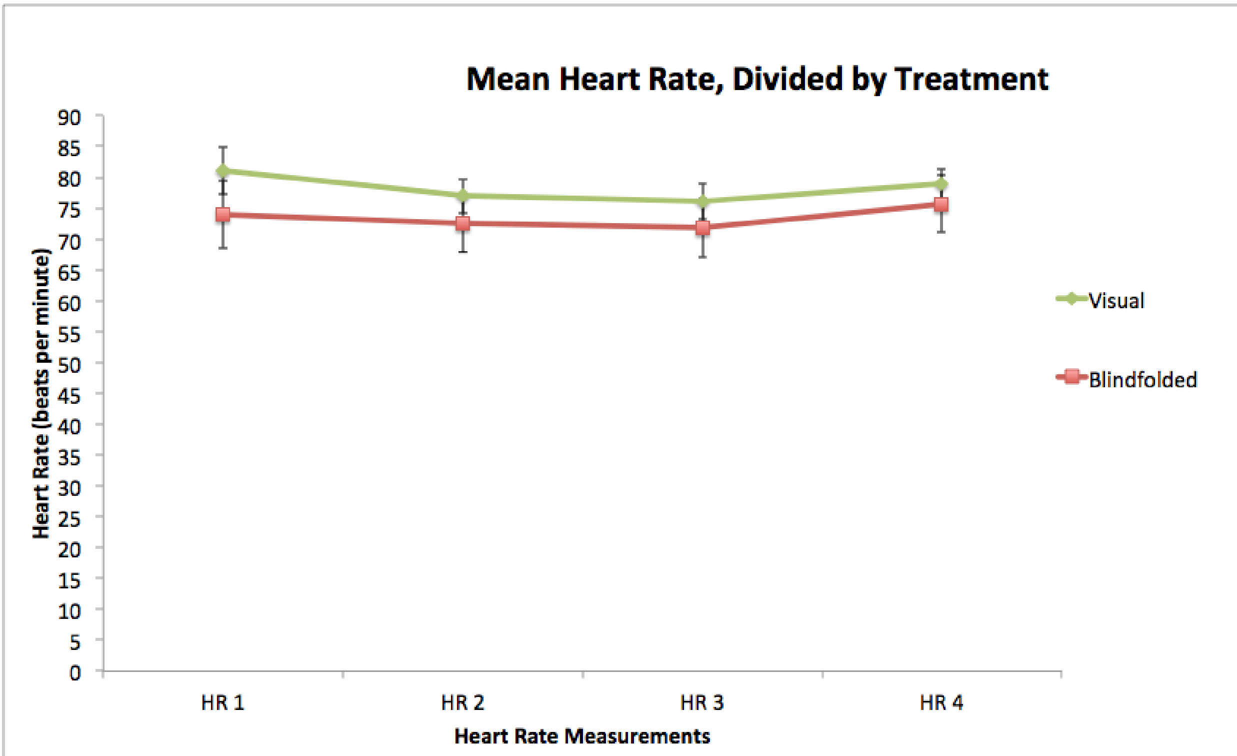


Figure 9. Mean heart rate at each time point for visual and blindfolded participants. Error bars represent one standard error. The mean heart rates at each time point for the visual group were 81 bpm (SD=14.169), 76.93 bpm (SD=10.381), 76.07 bpm (SD=10.845), and 78.93 bpm (SD=8.535). The mean heart rate at each time point for the blindfolded treatment group was 73.88 bpm (SD=17.385), 72.41bpm (SD=14.396), 71.82 bpm (SD=15.318), and 75.63 bpm (SD=14.605). Mean heart rates did not change as a function of treatment, $t(111) = -0.965$, $p = 0.34$. Mean heart rates also did not vary across time, $t(111) = -0.084$, $p = 0.93$.

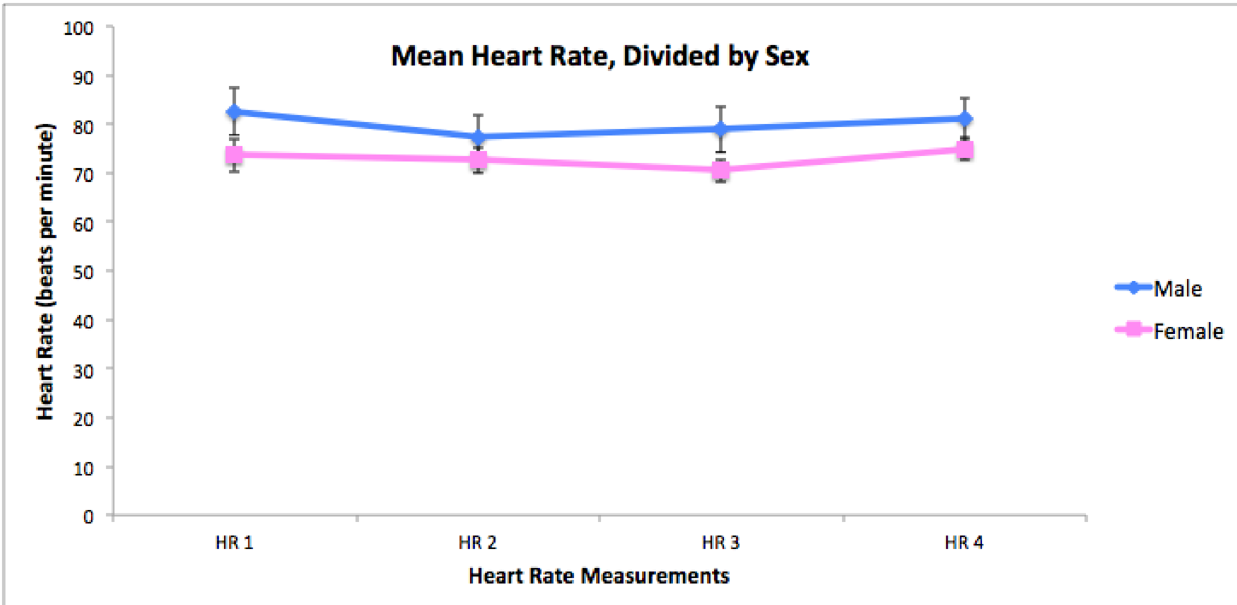


Figure 10. Mean heart rate at each time point for male and female participants. Male participants (visual and blindfolded) had mean heart rates at each time point of 82.04 bpm (SD=16.81), 76.61 bpm (SD=14.91), 78.1 bpm (SD=16.16), and 80.53 bpm, while female participants (visual and blindfolded) has mean heart rates of 74.06 bpm (SD=15.16), 72.93 bpm (SD=11.20), 70.83 bpm (SD=10.61), 75.22 bpm (SD=10.12), at each time point. Error bars represent one standard error. Mean heart rates did change as a function of sex, $t(111) = 3.076$, $p = 0.00264$.

Discussion

We hypothesized that blindfolded individuals would react more quickly to an auditory stimulus than seeing individuals, that participant heart rate would decrease between the start of the auditory task and immediately prior to the first auditory stimulus, and that EEG beta-waves would be present in individuals immediately after hearing an auditory stimulus. Blindfolded participants displayed slightly slower reaction times compared to visual participants, leading to a rejection of the reaction-time hypothesis. Research at Brandeis University found that visual deprivation enhanced inhibitory feedback of basket cells (GABAnergic inhibitory interneurons) on neurons found in the primary auditory cortex (Maffei et al, 2006). Inhibition of auditory cortex neurons may decrease the speed of auditory signal interpretation, thus increasing the delay between hearing the stimulus and reacting to it. Increased inhibitory feedback between these cells may explain slower reaction times found in this study. Also, while not statistically significant, male participants did show a slightly larger decrease in reaction time over time when compared to female participants. This suggests that males and females may have similar initial reaction times (Figure 6), but that males are more likely to improve at the reaction task over time (Figure 7). However, changes in reaction time over time are inconclusive due the presence of a possible pairing effect.

Heart rate did not decrease significantly between the start of the auditory task and the first auditory stimulus, leading to a rejection of the heart rate portion of the hypothesis. However, males displayed significantly higher heart rates than females, regardless of treatment and time-point. EEG data revealed the presence of beta waves immediately after the auditory stimulus in all participants that had β-wave data, which supports the research group's hypothesis that participants would display β-wave activity immediately after hearing the auditory stimulus. Data from previous studies were unavailable for more information regarding the whole body response to reaction time tasks. The current study is the first to focus on these specific variables. While the hypotheses were rejected, the rejection can set a precedent for future research manipulating these variables.

In constructing our study, we made several important assumptions regarding the collection of data and the accuracy of measurements used for our biological variables. We first assumed that reaction time to an auditory stimulus is relatively uniform in our study population, and that any differences in reaction time are more likely due to treatment (blind or seeing) than to individual differences in reaction time.

It was assumed that the Pulse Oximeter consistently and accurately measured heart rate among all participants. In addition, it was assumed all participants were healthy and free of significant cardiovascular symptoms that would result in large, short-term fluctuations in heart rate. Finally, it was assumed that participants had not consumed amounts of caffeine or other sympathomimetic agents in quantities different from their usual consumption immediately prior to participation.

The largest experimental assumption was accurate collection of EEG brainwave data and that beta-waves present immediately after presentation of the auditory stimulus are indicative of the participant hearing and responding to the stimulus was possible. Adhesion of the EEG leads to the head of each participant sometimes was more difficult due to the amount and texture of hair present. The same researcher attached all leads for all participants in order to reduce variation in lead placement and attachment.

In addition to experimental assumptions, an important theoretical assumption was made that measuring reaction time was an accurate operationalization of auditory perception. However, it may be that auditory perception could be better analyzed by a Pure-Tone Test, which assesses the decibel level of a threshold auditory stimulus below which a patient is unable to detect a sound (MacPhee et al, 1988). An advantage of this technique over reaction time may be that the variable of individual reaction speeds are eliminated, thus focusing only on the sensitivity of an individual's auditory perception. It may be valuable to conduct a future study using the Pure-Tone Test on both blindfolded and seeing participants to investigate whether temporary visual deprivation increases auditory perception when this perception is independent of a person's reaction time, which may not be completely dependent on auditory perception.

The presence of a slight practice effect in males suggests that individuals with long-term or congenital blindness may become more sensitive to auditory stimuli over time. Future studies could use multiple sessions of reaction time tasks for blindfolded individuals to investigate whether this practice effect can be enhanced with more practice and identified in female as well as male participants. Though temporary blindness was not found to significantly decrease reaction time to an auditory stimulus, the results of this study can still be used to inform future studies on the effects of short-term visual deprivation. This information can also be used to enhance understanding of the effects of temporary blindness on auditory perception, in hopes that it will used for practical applications in everyday life where reaction time is most important, perhaps most notably in driving or in professional/recreational sports.

Visibility decreases when driving at night, leading to a state similar to temporary blindness. Questions attempting to understand differences in perception of day driving versus night driving may suggest how the auditory reaction changes, such as responding to a horn from a car veering uncontrollably towards your car. Exploring topics such as these have life-saving implications and may be used, for example, to modify headlights in cars in order to allow greater light to see and respond quickly to an impending accident.

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