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THE EFFECT OF SIMULTANEOUS, IRRELEVANT AUDITORY AND VISUAL STIMULI ON A FORCED-ATTENTION DICHOTIC LISTENING TEST

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The Effect of Simultaneous, Irrelevant Auditory and Visual Stimuli on a Forced-Attention Dichotic Listening Test

A thesis submitted in partial fulfillment of the requirements for the Master of Science at Virginia Commonwealth University.

by

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List of Abbreviations

REA…………………………..Right Ear Advantage

LEA…………………………..Left Ear Advantage

NoEA…………………………No Ear Advantage

CV…………………………….Consonant-Vowel

Abstract

THE EFFECT OF SIMULTANEOUS, IRRELEVANT AUDITORY AND VISUAL STIMULI ON A FORCED-ATTENTION DICHOTIC LISTENING TEST

By Keri Davis, M.S.

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science in Biomedical Engineering at Virginia Commonwealth University.

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Many of the studies examining cognitive control during selective attention across different sensory modalities conflict. This study was designed to study the effect of an irrelevant visual stimulus and an auditory distraction of backward speech on a forced attention dichotic listening test. I predicted that the visual stimulus and backward speech would not have a significant effect on the ear advantage. The results showed that all subjects were able to force their attention to the ear regardless of the visual or auditory distracters. In addition, I found that an irrelevant visual stimulus affects auditory attention more so in the left visual field than the

right visual field. This proves that top-down processing can override bottom-processing and auditory tasks demanding full processing capacity limit the processing of the irrelevant visual stimulus.

Chapter 1

Introduction

A dichotic listening test is the simultaneous presentation of auditory stimuli to the left and right ear. The stimuli can be speech or non-speech sounds; however stimuli must be aligned at the beginning of the acoustic burst to achieve simultaneity. The dichotic listening task can overload the brain with information and subsequently, the stimulus that is selectively heard can be observed. Dichotic listening has been used for decades to study hemisphere lateralization and attention. Dichotic listening tests have been used frequently for analysis of top-down and bottom-up processing. Top down processing refers to instruction given processing and bottom-up processing is stimulus driven. While not completely true, the closer to the periphery in a sensory system the more the system is considered hard wired. Bottom Up represents the neurological pathway coding and symmetry. Cognitive effects of attention are top down. Recent studies have combined dichotic listening tests with visual stimuli to observe attention and cognitive control across sensory modalities. Results have been inconclusive and conflicting regarding visual stimuli on auditory processing.

The present study employed an irrelevant visual stimulus as a distraction, along with backward speech, to observe the effects in a forced dichotic listening test. In the late 1960's, Doreen Kimura found that the processing for backward speech was the same as normal speech; thus it showed a right-ear advantage (REA). Kimura's study focused strictly on processing of backwards speech; whereas this study presented backwards speech as an irrelevant, distracting stimulus. Marcel Kinsbourne (1970) was one of the first to examine the role of attention on the asymmetries of the auditory system. The current study is designed to manipulate attention across different sensory modalities.

Top-down processing will prevail through all variations of this study and the distractions will not significantly affect the forced listening instructions is the hypothesis to be tested. It is believed that cognitive control of the sensory modalities can overcome distractions to perform accurately in a dichotic listening test and that neurological asymmetry will not matter in humans.

Chapter 2

Background

2.1 Dichotic Listening Overview

A dichotic listening test is the presentation of speech (or non-speech) stimuli to each ear simultaneously with a qualitative measurement of understanding. It was originally developed by Donald Broadbent in 1954 to study the attention load of air traffic controllers (Hugdahl 2009). He studied the control systems and discovered that their failure can be caused by too much simultaneous information, causing the controller to react to unimportant signals (Broadbent 1962). He later developed the "filter" theory of selective attention (Hugdahl 2009), namely that simultaneous auditory stimuli would exceed the capacity for information processing. Thus, the information would be divided into two distinct stimuli, allowing processing of one stimulus and rejection of the other. He paved the way for future studies involving perception and attention.

Prior to Broadbent's work, Colin Cherry (1954) had used similar methods to observe the cocktail party effect, the ability of humans to focus on the speech of a single person when surrounded by a noisy environment. Some factors may optimize this effect, such as, the voices coming from different directions, different speaking voices, or the brain compensating with predictions of speech (Cherry 1954).

Doreen Kimura (1961) developed her dichotic listening technique. The test was originally performed with spoken dichotic pairs of digits and was developed in the hopes of a better understanding of the left temporal lobe. A higher percentage of digits heard in the right ear were reported correctly (Kimura 2011). This study highlighted the importance of the crossed pathways of speech perception. Tthe advantages of the crossed pathway had not been detected previously because everyday speech arrives at both ears. The dichotic listening test reveals a competition between the two ears in which the crossed pathways becomes significant in selectively hearing one stimulus.

Kimura (1968) reported the presentation of backward speech dichotically. No matter how unfamiliar or meaningless the verbal stimulus is, as is the case with backward speech, the processing is consistent with that of normal speech and shows a REA (Kimura 1968). Therefore, the left hemisphere is likely activated for more than just processing the meaning of speech.

In the 1970's, Marcel Kinsbourne developed the attentional model of hemispheric asymmetries. It states that asymmetrical perceptions can be attributed to differences in hemisphere activation. He found a right-sided advantage for detecting visual, auditory, and tactual stimuli due to a greater activation of the left hemisphere (Merrill 2011).

Hugdahl suggested using forced-attention to study the effect of attention on speech/language laterality (Hugdahl 2000). The forced-attention paradigm brings into focus the aspect of cognitive control to dichotic listening. The ability of a subject to overcome the REA depends not only on the stimulus, but also, on the subject's ability to control attention as well as the instructions by the examiner.

By instructing a subject to focus attention on the left ear, Bryden (1988) found that the REA is decreased and often times resulted in a left-ear advantage, or LEA. By focusing on the right ear, it is also possible to increase the REA; thus the ear advantage could be manipulated by attention (Hugdahl 2009). This finding suggests that the top down influences mask any advantages neuro asymmetry may provide to the right ear.

The most important variable in building a dichotic listening test is stimulus control. Various sound stimuli have been employed to determine ear advantage. It has been demonstrated that speech sounds are critical in perceiving a REA. Noises, such as, humming, coughing, or laughing, show no REA (Kimura 2011). Melodic, environmental sounds, and emotional tones show a LEA (Kimura 2011). Thus, from a structural perspective, the left hemisphere is specialized for language processing; whereas the right hemisphere is dominant for processing nonverbal sounds (Kimura 2011).

2.2 Auditory Pathways

The hearing process begins when the sound enters the auditory canal and waves set the tympanic membrane into vibration. Tympanic vibration is then transmitted to the three small bones, incus, malleus, and stapes, which connects to the cochlear via the oval window. In the cochlea, the vibration is encoded into neural signals. The basilar membrane is a structure within the cochlea. This structure is narrow and stiff near the oval window and widens and reduces stiffness towards the other end. High frequency vibrations get picked up at the narrow section of the membraneb and low frequency vibrations will travel to the other end of the membrane (Schnupp 2011). Thus, the frequency of a sound is determined by the location of maximal vibration on the basilar membrane.

Auditory nerve fibers arise in the cochlea (spinal ganglion cells) forming the eighth cranial nerve. The nerve enters the cochlear nucleus in the brainstem and bifurcates into two different paths; one path to the anteroventral cochlear nucleus and the other to the dorsal cochlear nucleus. Information from the dorsal cochlear nucleus and some from the anteroventral nucleus travel directly to the inferior colliculus of the midbrain, bypassing the superior olivary complex. Fibers from the anteroventral cochlear nucleus will innervate the superior olivary complex of the brainstem; this will eventually be sent to the inferior colliculus, as well (Schnupp 2011).

The neurons from the superior olivary complex ascend along the lateral lemniscus to the inferior colliculus. Along this path, and within the inferior colliculus, there are many crossings of the neurons; thus this region, the cortex and midbrain, is most excited by sounds presented contralaterally (Schnupp 2011). The olivary complex contributes significantly to spatial localization.

The inferior colliculus integrates frequency and spatial information from the brainstem. From here, axons then project to the medial geniculate body in the thalamus and its output fibers innervate the auditory cortex in the temporal lobes and smaller projections to limbic structures of the brain, such as the amygdala. The auditory cortical fields of each side are connected via the corpus callosum and the anterior commissure. The auditory cortex is connected to other areas of the brain including the prefrontal cortex (Schnupp 2011). A diagram with the projected pathways and crossings are shown in Figure 1.

The Ear

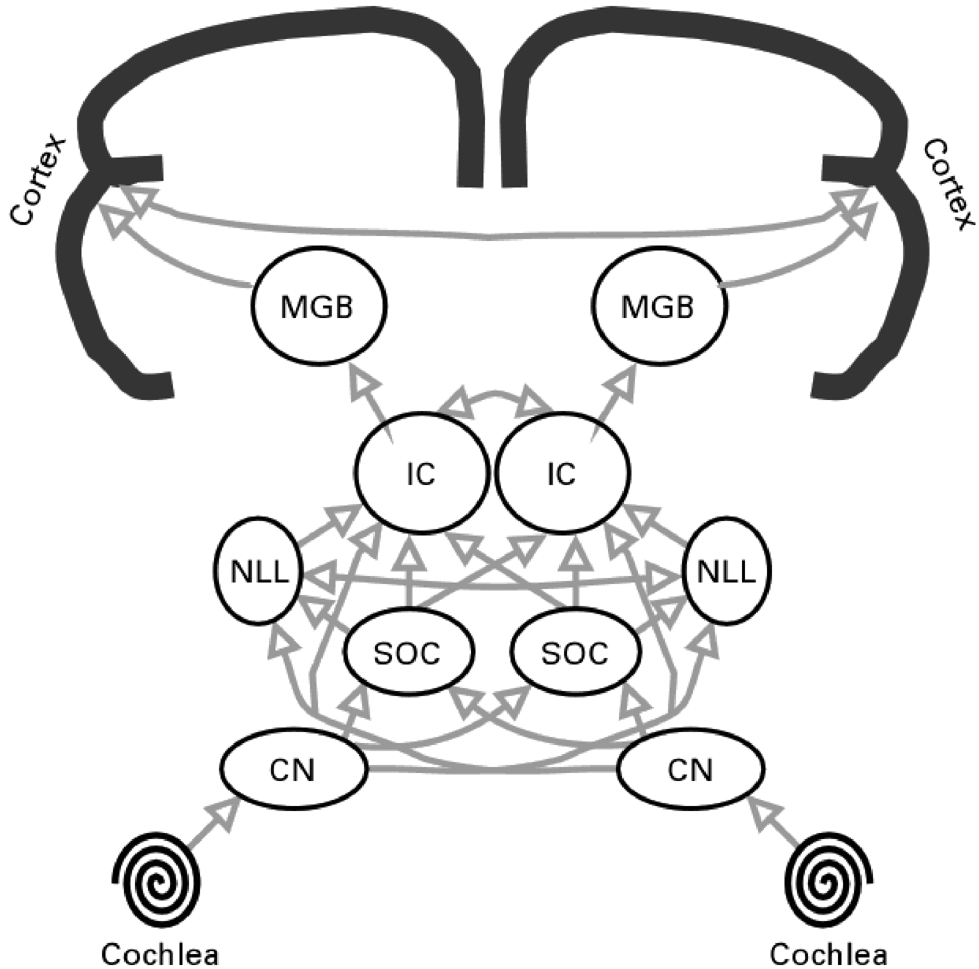

Figure 1. The Hearing Pathway (Schnupp 2011)

The leminiscal pathway was just described. This pathway is tonotopic so that the neurons are arranged anatomically by frequency. Thus the frequency space coding of the basilar membrane is preserved in higher nuclei (Schnupp 2011), high frequencies activate the medial auditory cortex and low frequencies activate more anterolateral regions in the temporal plane (Humphries 2010).

The pathway from the dorsal cochlear nucleus is termed nonleminiscal and lacks tonotopic order. It has a major innervation to the limbic system and the auditory association cortex and likely to coordinate emotional and conditioned reflexes to sound (Schnupp 2011).

Thus there are two major pathways for each ear that code speech stimuli. Time of arrival, while synchronous at the ear, varies at the cortex depending on the path and the number of synapses. Auditory inputs get sent strongly to the contralateral hemisphere, suppressing and delaying auditory information from the ipsilateral pathway. Information that reaches ipsilateral right hemisphere is delayed due to the need to be transferred across the corpus callosum to the left hemisphere before processing (Hugdahl 2003).

2.3 Visual Pathway

Neural networks in the visual system support shape, color, and object discrimination. The visual field of each eye consists of a right and left hemifield, which are further divided into a temporal and nasal hemiretinal. The retina receives visual information from the left and right visual field. Each hemifield projects to the ipsilateral nasal and the contralateral temporal hemiretinal, (Figure 2) (Wright 1998).

The visual information, from the respected visual fields, will travel on the optic nerve and cross at the optic chiasm. Prior to the visual cortex, visual fibers will also project to the superior colliculus, the hypothalamus, lateral geniculate nucleus and the pretectum (Wright 1998).

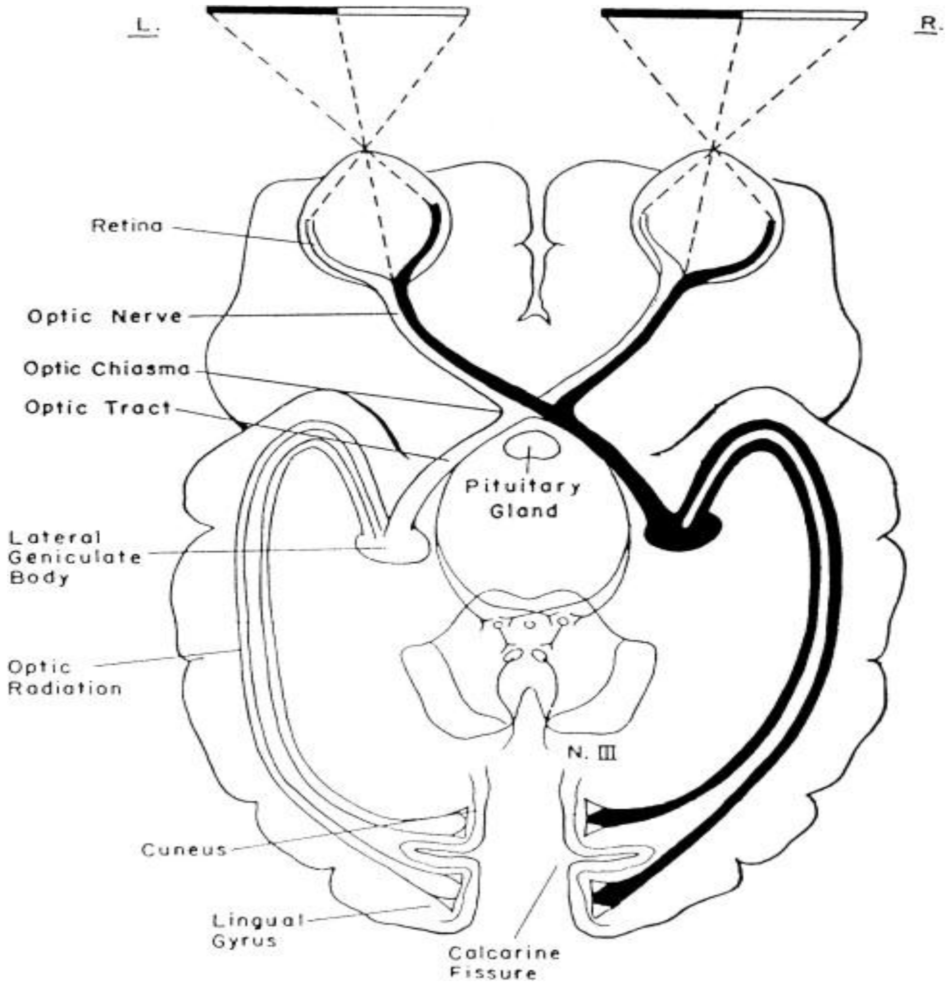

Figure 2. The Visual Pathway

2.4 The Brain and Hemisphere Lateralization

The cerebral cortex is divided into four major lobes; the frontal lobe, the parietal lobe, the temporal lobe, and the occipital lobe. The occipital lobe is mainly involved in visual processing; the parietal lobe is involved in touch and taste sensation and multisensory intregration; the frontal lobe is involved in many functions, such as, decision making, problem solving, motor function, generally termed executive function; and the temporal lobe is involved primarily in hearing. The Heschl's Gyrus region of the temporal lobe is the location of the primary auditory cortex in humans and receives the leminiscal projection (Schnupp 2011). Speech sound analysis is largely carried out in the association area of the auditory cortex; whereas speech motor processing is carried out in the frontal lobe, in a Broca's area. Unlike Heschl's Gyrus, most evidence points to Broca's area being primarily confined to the left hemisphere.

The planum temporale is larger in the left than the right hemisphere in right handed individuals; however, it is significantly smaller in patients with schizophrenia (Yamasue 2004). This asymmetry contributes to the neural basis of left hemisphere dominance for language and speech perception. Much clinical and brain imaging evidence has supported this dominance. Testing has revealed that right hemisphere dominance is seen in less than two percent of the population (Schnupp 2011).

Another way of answering the speech sound pathway question is the use of experiments of disease states. When patients with right or left hemisphere strokes were tested with a binaural and a dichotic complex pitch task (tonal not speech), the group with right hemisphere damage had significant difficulty with the dichotic task; whereas, both groups performed well on the binaural task. The corpus callosum is thought to be the main interhemispheric pathway; although the anterior commissural and smaller subcortical connections exists (Hugdahl 2003).

A study by Pollmann (2002) had patients with lesions in the posterior parts of the corpus callosum perform a dichotic listening test. From this study, it was concluded that auditory stimulus in the left ear has to be transferred over the corpus callosum to be processed in the left hemisphere (Hugdahl 2003).

PET-data indicate an increase in the REA during forced attention to the right ear causes decreased blood flow on the right side, not an increase in blood flow of the left side (Hugdahl, 2000). Therefore, the auditory signal from the nonattended ear appears to be filtered when crossing the corpus callosum (Hugdahl 2003).

Patients with left side frontal lobe lesions lacked the REA during a standard dichotic listening test; however, patients with right side frontal lobe lesions had a REA similar to the control group. The patients with a left frontal lobe lesion lacked attention modulation, as well. These results indicate left hemisphere language dominance, particularly within the frontal lobe area. Therefore, the left frontal lobe appears to be involved in bottom-up and top-down processing of auditory stimuli (Hugdahl 2003).

There is no known asymmetry of visual areas in the occipital cortex that would correspond to functional asymmetries involving the presentation of visual stimuli of any kind because each cerebral hemisphere is equally represented by sensory (hemifields) in each eye (Hugdahl 2003).

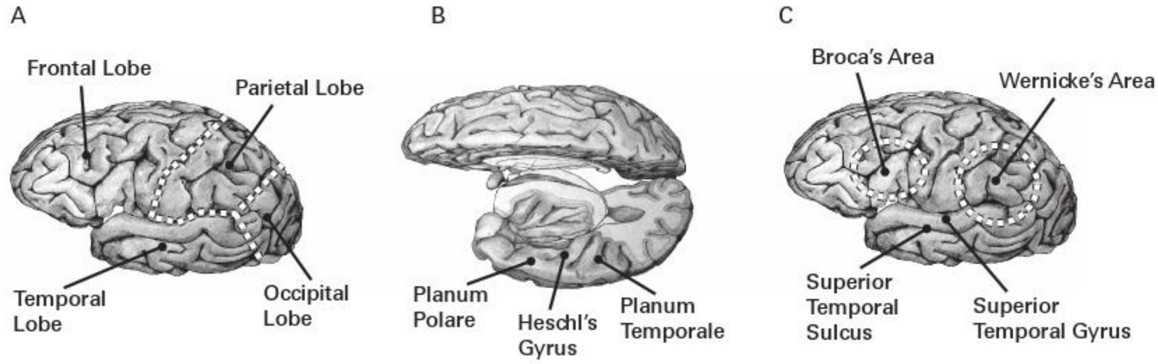

Figure 3. Brain Organization (Schnupp, pg 160)

2.5 Top-Down vs. Bottom-Up Processing

Bottom-up processing is starting with small details and building up to a final product. In auditory processing, it is known as "stimulus driven" or "automatic" processing. Top-down processing is starting with the large picture and breaking it down into smaller details. It is also known as "instruction driven" or "controlled" processing (Hugdahl 2003).

The REA found in dichotic listening studies is a common example of auditory bottom up processing. Attentional modulation of the dichotic listening ear advantage would be an example of auditory top down processing.

The resulting REA is believed to be a combination of language specialization of the left hemisphere, suppression of left ear input to the left hemisphere by the contralateral pathway, and the degradation of signals crossing the corpus callosum (Hugdahl 2003). Under forced-attention conditions, the ear advantage can shift depending on the stimulus and the ability of the subject to cognitively control attention. The suppression of intrusions from the nonattended ear has the greatest effect on directing attention (Asbjornsen 1995).

2.6 Load Theory of Attention

Nilli Lavie (1995) suggested that selective attention was not a result of only identifying irrelevant stimli and actively excluding it from processing. Rather, he proposed that the exclusion was also dependent on the high pereceptual load of the relevant stimuli. The interference from distracting stimuli was found to occur only under low load conditions. Thus, irrelevant stimuli were found to be processed only when there was sufficient capacity for processing, i.e. under low-load conditions. Under the high-load conditions, the selective processing occurs early on through no active inhibition (Lavie 1995).

This theory has been studied within and across sensory modalities. Much conflicting evidence has been found across different sensory modalities. Klemen (2009) studied fMRI data to analyze auditory perceptual load effect on the processing of task-irrelevant visual images. The data supported Lavie's Load Theory of Attention, showing a decrease in recognition of the visual stimulus under high auditory load. This study employed visual images and sine waves of various frequencies (two tones were used for low-load and five for high-load conditions) (Klemen 2009). However, this theory can also be explained by top-down processing. The increased perceptual load could lead to an increased suppression of the irrelevant stimulus (Klemen 2009).

Rees (2001) found a strong activation in the visual cortex to an irrelevant stimulus during high- and low-load auditory tasks. This indicates that the processing of an irrelevant visual stimulus occurs independently of auditory perceptual load. Rees (2001) concluded that attentional load can modulate irrelevant perception within sensory modalities, but not between them.

Chapter 3

Materials

The present study involved the use of an audiometer, headphones, a computer equipped with the editing software, Audacity, and a visual stimulus. The current chapter will provide further detail on these materials.

3.1. Audiometer

An Orbiter 922 Clinical Audiometer was used for the pure-tone audiometric hearing; employing a pair of HDA 200 standard (acoustic dome) audiometric headphones.

Figure 4. Orbiter 922 Clinical Audiometer

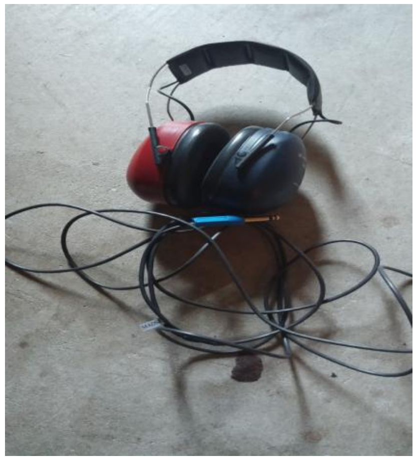

Figure 5. HDA 200 headphones

3.2. Audacity

An Acer Aspire One 722 Netbook was equipped with the free audio editor and recorder, Audacity, was used to record, edit, and playback the dichotic listening tests. A pair of Device Engineered Audio Gear headphones was used for the Audacity playback. They had a frequency range of twenty Hertz to twenty kiloHertz and an impedance of thirty-two ohms. The speech stimuli were played at 60 dB SPL.

Figure 6. Device Engineered Audio Gear Headphones

3.3. Visual Stimulus

A Knog Frog Strobe White LED light was used to manipulate attention with blinking strobe light capability. The light outputs 25 lumens and was clipped to a moveable stand throughout the test.

Figure 7. Knog Frog Strobe White LED Light

Chapter 4

Methods

4.1. Participants

Ten right-handed subjects between the ages of 20 and 25 with normal hearing were recruited from the Virginia Commonwealth University academic community. Participants took a pure-tone audiometric hearing test and a minimum hearing threshold of 25 dB HL was set as a baseline for normal hearing for the study. Subjects who failed this test were excluded from the study. Other inclusion criterion was right-handedness for all subjects.

4.2. Design

The Bergen dichotic listening test was modeled in this study by using the six stop consonants with the /a/ vowel for thirty pairs of consonant-vowel (CV) syllables, with no homologous pairs (same speech sound). The voice of a thirty-four year old male was recorded for the CV syllables and a prerecorded, general mid-western male speaker reading the "Rainbow Passage" was downloaded from the newsgroup alt.usage.english online. The "Rainbow Passage was chosen because it has the same occurrence of speech sounds as standard English. A copy of the Rainbow Passage is presented in Appendix 1-A. The order of the CV pairs was randomly chosen for the study, as shown in Appendix 1-C, and the CV syllables were recorded separately for each ear. The order of pairs remained consistent for the experimental trials.

The CV syllables recorded via Audacity were edited to improve sound quality. Syllables were amplified by 0.3 decibels and gaps between them were silenced to eliminate extraneous noises. Further editing required the left and right ears to be aligned by generating or removing silences at the beginning. Noise between syllables was first removed and then silences were added to ensure consistency between times. For the standard dichotic listening test used to familiarize the subject, one second was designated as the interstimulus interval; with ten sets of pairs. The remaining trials used thirty CV pairs and an interstimulus interval of two seconds. The standard test was fifteen seconds long, and the trials were one minute and fifteen seconds.

The “Rainbow Passage” was used as the backward speech for the study. The prerecorded file was uploaded into Audacity. The passage was reversed with the Audacity effects feature. It was then amplified to match the recorded audio for the CV syllables so that all audio was at the same level of loudness. The passage was properly aligned by adding silences in conjunction with the silences previously added for the CV syllables.

4.3. Trials

The experiments were conducted in a soundproof booth to eliminate excessive exterior noise. Before trials began, a pure-tone audiometric hearing test was completed. The subjects were instructed to raise their hands when they heard a sound. The left and then the right ears were tested with frequencies between 250 Hz and 8 kHz.

The standard dichotic listening test was performed next to familiarize the subjects with hearing the CV syllables since they are not used in everyday language, and to observe any significant right- or left- ear advantage. The subject was given a pen and a sheet of paper with a possibility of choices for each pair of syllables. There were four choices; two of the options were not heard in either ear. The subject was instructed to circle the CV they heard the best. The paper for this test was collected at the conclusion of this test. The subjects were requested for a follow-up with the standard dichotic listening test, as well, to test the reliability of the results for the ear advantage.

The experimental trials were set up after assurance of normal hearing and following any concerns or questions after the standard test. The backward passage was previously muted and the light remained off until the beginning of the experimental trials. New papers were handed out for each trial with six choices for each dichotic pair; they were collected following each trial. The first trial had the backward passage played with the subject instructed to attend to the right ear. The light for this trial was placed on the right. In the second trial subjects attended to the left ear and the backward passage was played in the right ear; with the light in the left of the subject's visual field. The third trial left the light in the left visual field. The backward passage was played through the left headphones and the subject attending to the right ear. The final trial had the subject attending the left ear with the backwards speech played in the right ear. The light was switched to the right side of the subject (Table 1).

Table 1. Attention Manipulations for Each Trial

Trial 1	Forced Right; Left Backward Speech; Light on Right
Trial 2	Forced Left; Right Backward Speech; Light on Left
Trial 3	Forced Right; Left Backward Speech; Light on Left
Trial 4	Forced Left; Right Backward Speech; Light on Right

Chapter 5

Results

All recruited subjects were found to have normal hearing from the pure tone audiometry test. The average hearing thresholds can be found in Table 2 below.

Table 2. Average Hearing Threshold for Each Subject

Subject	Hearing Threshold (dB HL)
#1	10
#2	15
#3	25
#4	10
#5	20
#6	20
#7	10
#8	10
#9	10
#10	25

A laterality Index (Hugdahl 2003) was calculated to analyze ear advantage for each subject with the formula [(Right Ear Correct – Left Ear Correct)/(Right Ear Correct + Left Ear Correct)]*100. A positive value indicates a REA and a negative value would indicate a LEA. A value of zero would indicate NoEA. The closer the absolute values of the laterality index to one-hundred, the greater the ear advantage.

The sum of the standard dichotic listening tests showed all but one of the subjects had a REA.

The results of the first and third trial revealed that all subjects had a REA with the given attention manipulations previously described. The second trial had four subjects having a LEA and six having a REA. The fourth trial had an even split of five subjects having a REA and five having a LEA.

When a subject chose an answer that was not heard in either ear, it was noted to be NoEA and was not taken into account for determining ear advantage for the trials.

Table 3. Laterality Index for Each Trial and for Each Subject

Subject	Standard Test	Trial 1	Trial 2	Trial 3	Trial 4
#1	0	92.86	-36	92.86	-50
#2	46.67	11.11	20	9.09	7.69
#3	52.94	20	21.43	7.69	7.69
#4	47.37	57.14	-18.18	40.74	7.69
#5	88.89	50	4	23.08	31.03
#6	89.47	76.92	30.43	51.72	-53.85
#7	55.56	84.62	-40.74	14.29	-11.11
#8	15.79	44.83	-25.93	54.55	28
#9	78.95	25.93	4	78.57	-51.72
#10	55.56	40.74	13.04	23.08	-52

For all subjects, trial one had thirty-eight choices that had NoEA, trial two had fifty, trial three had thirty-eight, and trial four had thirty-three. Out of a total of 300 possible, for all subjects, 199 CV syllables from the right ear and 65 from the left ear were heard for trial one.

For trial 2, 121 were reported from the right ear and 121 from the left ear; for trial 3, 184 from the right ear and 78 from the left ear; and for trial 4, 115 from the right ear and 152 from the left ear. All values are defined in Table 4.

Table 4. Cumulative NoEA, REA, and LEA for Each Trial for All Subjects

Total/Trial	Trial 1	Trial 2	Trial 3	Trial 4
NoEA	38	50	38	33
REA	199	121	184	115
LEA	65	121	78	152

Table 5. Total NoEA, REA, LEA, and Laterality Index for Each Subject

Subject	Total NoEA for all Trials	Total REA for All Trials	Total LEA for all Trials	Laterality Index
1	11	69	40	26.61
2	29	51	40	12.09
3	15	60	45	14.29
4	17	64	39	24.27
5	12	69	39	27.78
6	16	66	38	26.92
7	12	60	48	11.11
8	17	64	39	24.27
9	11	62	47	13.76
10	19	54	47	6.93
	Average=15.9	Average=61.9	Average=42.2	

Chi-square statistical analysis of the data with the forced-right attention and left backward speech revealed that the ear advantage is independent of the light position (P=0.371). In the forced-left attention condition, with backward speech presented to the right ear, the ear advantage was found to be dependent on the light position. Chi-square analysis also showed that the ear advantage was dependent on the direction of forced-attention when the visual stimulus was presented in the left visual field and in the right visual field.

Table 6. Chi-Square Analysis

Condition	X2	P-Value
Forced-Right Attention/Left Backward Speech (light position as independent variable)	1.98	0.371
Forced-Left Attention/Right Backward Speech (light position as independent variable)	10.54	0.0051
Right Visual Stimulus (forced-attention/backward speech as indpendent variable)	58.56	0
Left Visual Stimulus (forced-attention/backward speech as indpendent variable)	26.45	0

Chapter 6

Discussion

In a standard dichotic test a REA is expected due to the crossing of a significant amount of auditory signals (~60%) to the contralateral side early on in auditory processing; left ear signals will activate the right hemisphere and right ear signals will activate the left hemisphere because the ipsilateral pathways are inhibited with dichotic stimulation (Schnupp 2011). Since the planum temporale is larger in the left hemisphere for most right handed people, and Broca's area is primarily found in the left hemisphere, the left hemisphere is typically considered to be the major proponent in speech and language processing; thus leading to the REA.

6.1. Comparison Between Trials

For comparison, trial one and three were analyzed and contrasted against one another and trial two and four were also contrasted in a similar fashion. The independent variable for this comparison was the visual stimuli. Trial one was compared with trial four in the next analysis; thus keeping the visual stimuli constant.

The variables of trial one resulted in the largest cumulative REA among all subjects. Trial three resulted in the second largest REA. The only difference among these two trials was placement of the light stimulus; attention was focused on the right ear and backward speech was played in the left ear. Therefore the visual stimulus appearing in the opposite visual field from the attended ear decreased the REA that would be expected.

When the attention is forced to the left ear, with backward speech in the right ear, as for trial two and four, there was a lessened REA. Trial two and four did show a smaller REA than either the first or third trial. The visual stimulus was the independent variable among these two trials. Trial four was the only trial that resulted in a cumulative LEA among the participants; trial two was an even split for LEA and REA. This is in agreement with the previous conclusion of the visual stimulus hindering the REA when it is presented in the opposite visual field of the attended ear.

Trial one and four kept the visual stimulus as a constant; the light was placed in the right visual field. These two trials also had the largest REA and LEA, respectively. The difference between the two trials was the ear that was attended to and the backward speech. Thus, having the attention forced to the left ear, despite the backward speech in the right ear, lead to a significant LEA among participants. It could also be concluded that the subject was able to attend to the instructed ear when the visual stimulus was placed on the right, rather than the left.

6.2. Interpretations

In all trials, when a subject was instructed to attend to one ear over the other, a focus on that ear ultimately led to an increased ear advantage for the ear. Therefore, top-down processing of the auditory stimuli was occurring throughout the trials. This is somewhat surprising with attention forced to left and the added backward speech in the right ear. Backward speech has been found to show a REA (Kimura 1968). The assumption would be that the backward speech and the CV syllable in the right ear would reach the left hemisphere for processing more so than the CV syllable heard in the left ear that would have to cross pathways at the corpus callosum in order to be processed; the right hemisphere is not significantly involved in processing the left ear stimulus (Hugdahl 2003). This indicates that the top-down processing was able to override the expected bottom-up processing that would be expected.

From this study, one could postulate that light in the right visual field did not affect attention as much as light in left visual field. The visual stimulus placed in the right temporal hemiretinal would project to the occipital lobe in the ipsilateral hemisphere; the left hemisphere. The posterior parietal cortex is involved with the visual "disengagement of attention" and the superior colliculus with the "control of visual attention" (Wright 1998). It has been postulated that the front cortical areas can influence visual attention shifts, such that, top-down processing could direct attention away from the visual stimulus (Wright 1998). Thus, there seems to be greater cognitive control over attention when the irrelevant visual stimulus was placed in the right visual field.

Some studies have suggested that distractions create less interference under high-load conditions (Lavie 2004). Applying this to the present study, the left hemisphere is under a greater load when the visual stimulus is coming from the right visual field. Thus, there would be less interference from the irrelevant task.

According to Lavie (2004), the ability to perform tasks involving irrelevant, competing distracters depends on cognitive control availability. Other studies have concluded that "distractor-related activity was independent of attentional load" (Lavie 2004). Thus, irrelevant tasks are detected and processed, regardless of where attention is focused if there is adequate capacity for their perception (Rees 2011).

6.3. Future work

Despite the intriguing results that have been found in the present study, there are further elements that could be added to provide more evidence for the conclusions that have been made. For the present study, backward speech and the visual stimulus was presented simultaneously, however, testing of these independently could provide more information regarding the cognitive control of selective attention across different sensory modalities. Future studies would benefit from brain imaging throughout the trials to provide information concerning the areas of activation in the brain.

Numerous other variables could be used to assess top-down processing further. With regards to the present study, extended trials could be utilized to observe the extent of the effect of the visual stimulus over time. The times between CV syllables could affect the processing of the stimulus, as well.

Chapter 7

Conclusion

The present study has confirmed the superiority of cognitive controlled top-down processing over bottom-up processing in a dichotic listening environment with irrelevant visual and auditory stimuli. The results of the present study further indicate that visual stimulus in the right visual field has a lessened effect on the forced attention processing than the visual stimulus in the left visual field. Perhaps the overload in the left hemisphere results in an exclusion of processing of the irrelevant stimulus. Future work with brain imaging on forced attention studies with irrelevant stimuli is recommended to highlight the areas in which activation is observed to better understand the cognitive control of attention.

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Appendix 1-A

The Rainbow Passage

The Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long, round arch, with its path high above and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Throughout the centuries men have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation. Th the Hebrews it was a token that there would be no more universal floods. The Greeks used to imagine that it was a sign from the gods to foretell war or heavy rain. The Norsemen considered the rainbow as a bridge over which the gods passed from earth to their home in the sky. Other men have tried to explain the phenomenon physically. Aristotle thought that the rainbow was caused by reflection of the sun's rays by the rain. Since then, physicists have found that it is not reflection, but refraction by the raindrops, which causes the rainbow. Many complicated ideas about the rainbow have been formed. The difference in the rainbow depends considerably upon the size of the water drops, where the width of the colored band increases as the size of the drops increase. The actual primary rainbow observed is said to the effect of superposition of a number of bows. If the red of the second bow falls upon the green of the first, the results is to give a bow with abnormally wide yellow band, since red and green lights when mixes form yellow. This is a very common type of bow, one showing mainly red and yellow, with little or no green or blue

Appendix 1-B

CV Syllables for Standard Dichotic Test

Standard Dichotic Listening CV Syllables	
1	KA-PA
2	BA-TA
3	DA-KA
4	BA-PA
5	PA-TA
6	GA-DA
7	KA-BA
8	TA-GA
9	PA-KA
10	DA-BA

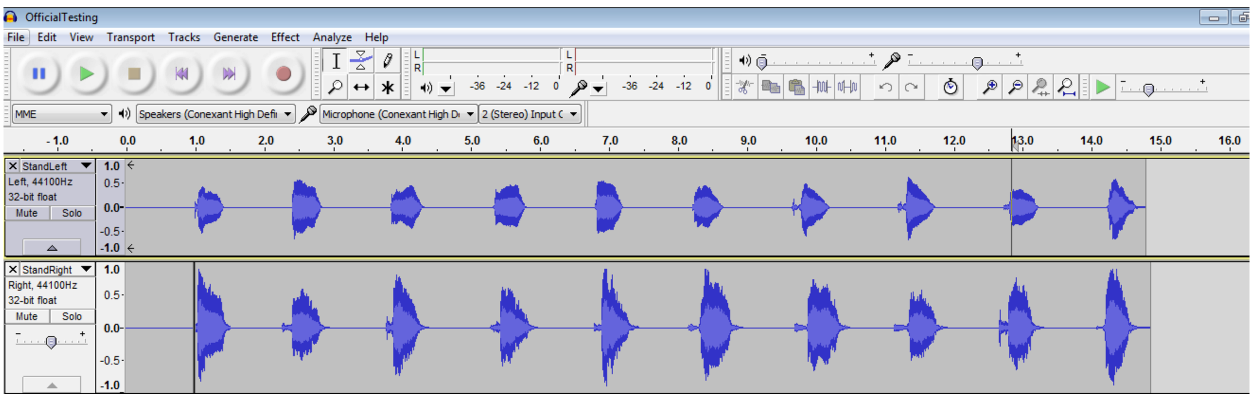
Appendix 1-C

CV Syllables for Trial Tests

CV Syllables for All Trials			
1	KA-PA	**16**	GA-DA
2	KA-DA	**17**	PA-KA
3	TA-KA	**18**	TA-PA
4	BA-PA	**19**	TA-DA
5	DA-KA	**20**	PA-BA
6	KA-GA	**21**	GA-BA
7	KA-TA	**22**	BA-DA
8	GA-TA	**23**	DA-GA
9	DA-BA	**24**	DA-TA
10	TA-GA	**25**	GA-KA
11	BA-TA	**26**	TA-BA
12	BA-KA	**27**	GA-PA
13	PA-GA	**28**	DA-PA
14	BA-GA	**29**	KA-BA
15	PA-DA	**30**	PA-TA

Appendix 1-D

Audacity Recording for Standard Dichotic Test



Appendix 1-E

Audacity Recording for Trial Tests