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The Lynks Reader

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THE LYNKS READER

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

by

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Table of Contents

List of Tables

List of Figures

Abstract

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Many adults and children have problems reading and comprehending books, signs, written directions, etc. These same individuals have difficulty processing written materials as a result of right hemisphere interference. The Lynks Reader (DLR Co., Richmond, VA) is a commercially developed device which has been used to help individuals move from their right to their left hemisphere and to increase reading fluency and comprehension. The objective of this project was to evaluate the best way to use the various forms of the Lynks Reader. Using the device demonstrated an increase in reading fluency and comprehension by increasing the left hemisphere dominance. In addition, different types of headphones

with microphones, and music devices (MP3 or CD player), were studied to determine which performs best in formulating a more effective device. Furthermore, the voice and music sound level and frequency output of the device was calibrated to insure the efficacy.

CHAPTER 1
INTRODUCTION

Over ten million children are plagued with a reading disability. The drop out percentage for children with readings difficulties in high school is about ten to fifteen percent. Only two percent continue to finish a four year college education. These are astounding numbers becoming even more profound when additional data suggested half the adolescents and young adults with criminal records have a learning disability. (WETA, 2006) Many adults and children have been tested for reading disabilities which include dyslexia, spelling, phonic reading, illiteracy and neurological processing of sound reading. Extensive imaging and neurological research has been preformed studying dyslexia and brain processing involved in reading.

Dyslexics have difficulty within two common parameters found in language which are visual and auditory perception. (The National Center for Learning Disabilities, 2003) According to auditory linguistics, students learn through vocal communications (lectures or discussions) by listening and interpreting tone of voice, pitch, speed and other nuances. (Learning styles Explained, 2007) This is a left hemispheric strategy where dyslexics have a deficiency spelling and decoding words. The visual-spatial method specializes in the students learning words and numbers by pictures, illustrations, diagrams, and flip charts.

For instance, sight reading is a visual-spatial method which uses the right hemisphere to recall and visually decode words.(Dinsmore and Isaacson 1986)

The right hemisphere is limited to visually decoding, or recognizing, words when learning to read by using short term memory. Short term memory is active memory storing a limited amount of information at a time.(Farlex, 2007) This short term memory limits adult individuals with a major hearing problem, or being deaf, to approximately a fourth grade reading comprehension level. The inability to hear prevents these individuals from developing auditory linguistics. Numerous adults and children without hearing difficulties have reading and spelling problems, reading below their expected grade level.(Swanson,1982)

To achieve a reading level above fourth grade, left and right hemisphere neural pathway development is crucial. Therefore, an auditory linguistics reading strategy should be used. The Lynks Reader (Digital Lateral Reader Corporation of America, Richmond, VA) was developed to assist children with difficulty shifting strategies from right to left hemisphere and thus increasing reading fluency and comprehension. Left hemisphere dominate people are problem solvers, analytical and verbal. Right brain dominant individuals are more artsy, mathematical and visual in nature. Left hemisphere dominance is an increase in activation of analytical traits verse visual or right hemisphere. The Lynks Reader was designed to aid individuals with English as a second language improving reading fluency, comprehension, and to move dominance from the right to the left hemispheres.

The two sets of data referenced below have been compiled using the Lateral Reader (Digital Lateral Reader of America, Richmond, VA) which is an earlier model of the Lynks Reader. The Lateral Reader was a LP turn table, or stereo cassette, playing music continually in the left ear. Headphones were plugged into the left side component and a microphone was plugged in the right side of the component. Hence, when the teacher or students spoke into the microphone their voice was directed into the right ear. Data collected from this earlier prototype was analyzed without digital or analog switching algorithms. The first study was carried out during an eight week period using eighty Army recruits with English as a Second language. This study was split into a control of forty recruits, and forty experiment recruits who used the Lateral Reader device while being taught or tutored. The experiment army recruits used the device five days a week for two hours per day executing a four and one-half average reading level increase over the control group. They revealed increases in reading fluency and in REA (right ear advantage, left hemisphere dominance) with an almost statistical significance of a *p-value*=0.06. The second trial was a consecutive five week study conducted with fifteen learning disabled high school students without a control group. They demonstrated a two level reading grade increase (5th to 7th) during the five week period using the Lateral Reader.(Lenhardt,1999)

With the No Child Left Behind government agenda in effect, it is very important to determine if this device will help to improve reading proficiency. The Lynks Reader is a commercial device, developed over twenty years ago, with very little information about how to use it effectively. The Lynks Readers are devices which present music in a

calibrated fashion in both ears. As the person reads out loud, music silences in the right earphone. The voice of the reader then enters the right ear activating the left hemisphere. The wrist vibrotactile device, placed on the right wrist, is attached to the Lynks Reader and activates once the individual starts reading into the microphone. The wrist vibrotactile device was designed to notify the left hemisphere that reading is occurring.

This thesis identifies processing and use parameters for the four different types of Lynks Readers using college student volunteers. Lynks Readers will increase left hemisphere dominance and reading fluency. This will be verified by using a dichotic listening test, three nonsense syllable tests and a college level reading comprehension fluency test. These are educational tests focused on giving achievement scores of reading and academic levels on each individual that volunteer.

Students examined different headsets and music players while using the Lynks device over a four week period of eight fifteen minute sessions. Prior to testing each, volunteers were administered a survey to determine their background reading, education, and musical training. Subjects' gender was documented. After each session, students were required to answer a questionnaire establishing operational parameters and best performing devices compatible with the Lynks Reader, i.e. type of headphones with microphone, MP3 players, CD players, etc. Sound level was measured for music and voice into the devices using LabVIEW 8.0 and a SA-77 FFT. Two of the Lynks Readers, with the wrist vibrotactile watch attached, was measured for acceleration using a portable handheld device called the SA-77 FFT.

CHAPTER 2

BACKGROUND

2.1 Dichotic Listening

Dichotic listening is presenting different stimuli to each ear simultaneously. Most people exhibit left hemisphere dominance (right ear advantage) or right hemisphere dominance (left ear advantage) when administered a dichotic listening test. Bryden (1963) demonstrated right handed children, with a right ear advantage (REA), exemplify increased attention with verbal stimulus. Kimura (1964) established by using nonverbal stimuli, for example music, a left ear advantage (LEA) is revealed. Bakker (1970) illustrated ear asymmetry with lateral awareness using children, which have normally developed laterality, having REA for verbal material and LEA for non-verbal material. In addition, he established children, with confused laterality awareness for non-verbal material, exhibit no ear dominance and LEA for verbal material. Hugdahl (1999) clarified an ear advantage effect with dichotic listening when he researched a relationship with brain asymmetry enhancing the ears contralateral pathway to the primary auditory cortex and suppressing the ipsilateral auditory pathways. Therefore, normal lateralized individuals have left hemisphere dominance for language and speech with a REA for verbal stimulus.

Research suggests some factors effect dichotic listening results and can be seen in trained musicians, men versus women, and left versus right handed people. For instance, research by Sanders and Wenmoth (1998) advocated women, during menstruation, display varied results in dichotic listening for both music and speech. During the midluteal phase, women exhibited more of a REA for verbal task and less during menses. Furthermore, during menses more of a LEA was demonstrated for music task than during the midluteal phases. Voyer and Flight (2001) confirmed men were more lateralized at spatial task than women and women revealed bilaterally with verbal and spatial function. Boucher and Bryden (1997) proved women possessed stronger lateralization for musical task where men displayed stronger lateralization for verbal stimuli. Bever and Chiarello (1974) disclosed musicians had REA for melody recognition task and non-musicians had LEA. Therefore, musicians use an analytical strategy to identify music where non musicians use holistic strategy. Bakker (1970) revealed lateral differences can vary with an individual’s age as well as with left or right handedness. Right handed individuals have REA for verbal material and older people display a greater REA, while left handed people do not demonstrate ear dominance.

2.2 The Brain

The cerebral cortex of the brain is separated into right and left hemispheres, connected by the corpus collosum. The left hemisphere controls the right side of the body and the right hemisphere controls the left side of the body. The hemispheres have two separate functions in controlling the body such as processing the art, literature, time etc.

The left hemisphere processes language, logic, speech, analysis, time sequence and recognizes letters, numbers and words. The right hemisphere controls mainly visual, creativity, patterns, spatial awareness, music processing (non-musicians) and recognizes faces, places, and objects. Most people have a dominant side of the brain. People which are more left hemisphere dominate are problem solvers, analytical and verbal. Right brain individuals are more artistic, mathematical and visual in nature. Therefore, each side of the brain learns differently.

Each hemisphere consists of four main lobes called frontal, parietal, occipital, and temporal lobes. With in these lobes are the Wernicke's area, the Broca area, the parietotemporal system and the occipitotemporal area, exhibited in Figure 1. The focus of this thesis will be on the Lynks Reader and reading strategies using the left side of the brain since this is where language processing occurs. The left frontal lobe controls speech, reasoning, consciousness, planning, regulating emotions and is important for silent reading ability. This frontal lobe contains the Broca's area which is used for processing language and speech manipulations.(Hudson, 2007) The left parietal lobe controls sensory perception and links spoken and written words, or language, which gives us comprehension of reading and hearing words. The left occipital lobe helps in identification of letters by receiving sensory information from the eye sent to the visual cortex. Subsequently, the left temporal lobe controls verbal memory and contains the Wernicke's area for processing language. There is evidence confirming lobes communicate with each other. This is important for reading and can be confirmed by focusing on the left parietotemporal area and the left occipitotemporal area. The occipitotemporal area is

important for fluent reading and rapid automatic access to whole words. The left parietotemporal area is important for reading, comprehending the written and spoken word. This is accomplished by decoding words, mapping letters and words into the spoken word.(Hudson, 2007)

The Wernicke's and Broca's areas are connected by a language loop of nerves located in the left hemisphere called arcuate fasciculus. This is an asymmetrical language function which occurs in ninety percent right handed of people and seventy percent of left handers. In addition, Deaf individuals who use sign language have this loop. This demonstrates that the arcuate fasciculus loop is not specific for the heard or spoken language but is more associated with the person's primary language modality.(Dubuc, 2002) For instance, the left hemisphere Wernicke's receives language information and sends a signal to the left hemisphere Broca's area via the language loop. The Broca's area interprets this language information transmitting it to brain areas related to speech function. (Language Processing, 2007)

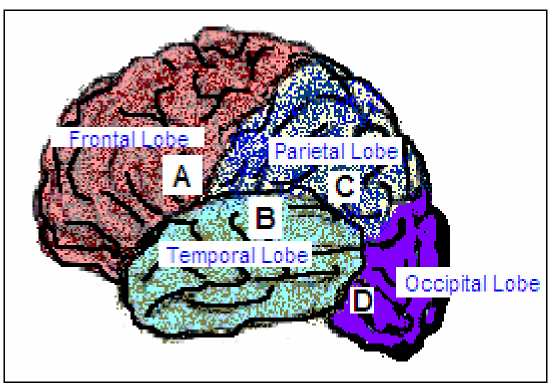


Figure 1: Left hemisphere lobes: (A) Broca area, B: Wernicke's area, (C) left Parietotemporal system, (D) Left Occipitotemporal area

Brain lobes and areas are made up of gray and white matter. White matter is mainly myelin covered connective fibers deeper within the brain. On the other hand, myelin is used to transfer information throughout the brain. Gray matter processes information and is mainly nerve cells. (Hudson, 2007)

2.2 Reading Disabilities

According to the National Institutes of Health, one in seven people have a learning disability and about 80% have reading problems. In general, these could be people with spelling, reading, writing, reasoning, math, sensory, recalling or organizing information difficulties. However, learning disable children must have normal IQ.(LD Basics, 2007) Considered a neurological disorder, learning disabilities, in children and in adults, are attributable to the brain being wired differently. The most common of these learning disabilities are Dyslexia, Dyscalculia, Dysgraphia, Auditory and Visual Processing Disorder, and Nonverbal Learning Disabilities, explained in Table 1. Learning problems, a life long battle, arise in all ages and genders. (LD Basics, 2007)

Dyslexia affects over 2.8 million school aged children. This learning disability is considered a reading disability. Dyslexia is defined as “a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in

relation to other cognitive abilities and the provision of effective classroom instruction."(Hudson, 2007, p2)

Table 1: Learning Disabilities (LD Basics, 2007)

Disability	Description
Dyslexia (reading disability)	difficulty understanding the written word, problems with spelling, Language based
Dyscalculia	Trouble with math concepts and solving math problems, Mathematically based
Dysgraphia	Difficult to form and shape letters and write in a discrete space, Writing based
Auditory and Visual Processing Disorder	With normal hearing and vision have problems understanding language, Sensory problem
Nonverbal Learning Disabilities	Problem with functions related to visual-spatial, intuitive, organizational, and holistic processing, A right brain Neurological problem

Many children growing up with dyslexia portray problems reading at their expected grade level. They fumble over words, trying to sound out words they do not know, obtaining poor results, therefore, not employing auditory linguistic strategies. They do not know as many lexicons as average readers in their grade level. These are considered vocabulary recognition and letter-sound relationship problems.   In the end, a reading comprehension difficulty is a consequence of the complexity in identifying words read and accessing information in the brain.(Hudson, 2007)

The population affect by dyslexia is around five to ten percent.   Disruption of developmental reading is a disorder called dyslexia which does not depict any type of

impairment in motivation, learning ability, intelligence and sensory acuity.(Habib, 2000) Dyslexia does not impair reading ability, however, there are forms of associated reading problems. There are two main types of dyslexia: developmental phonological dyslexia (normal word recognition) and developmental surface dyslexia (impaired word recognition).(Snowling, 1991) The processes required to learn to read, related to dyslexia, are phonological processing theory (underperformance in manipulating phoneme constituent of speech), visual processing theory (shortfall in the visual pathway subsystem), and temporal processing theory (deficit in processing brief stimuli in rapid temporal succession when performing a task).(Blachman, 2004) Neuron-imaging and neuropsychological studies have been completed for these three theories. Children having difficulty starting phonic reading (Bishop, 1992) demonstrated consistency with imaging (Fiez, 1996) and magnetoencephalographic techniques (Nagarajan, 1999) used to determine cortical auditory processing weakness. Reading processing may occur in both hemispheres for dyslexic individuals. This may be on account of less lateralization and hemispheric competition possibly leading to poor reading. In this case, they would have a reduction in right ear advantage in dichotic listening tests.

Imaging research has been accomplished on individuals with learning disabilities compared to those individuals with out learning disabilities to determine any differences between the amount of gray versus white matter in various areas of the brain. It has been proven dyslexics have less gray and white matter in the left parietotemporal area than normal individuals. By having less gray matter, dyslexics can have difficulty with phonological awareness.(Booth, 2001) By having less white matter, they can have a

smaller increase in reading skills than normal individuals.(Voyer, 2001) This decrease in white matter could inhibit processing since the left parietotemporal area does not have as many myelinated fibers for communication with other areas of the brain.(Hudson, 2007)

Functional magnetic resonance imaging (fMRI) research was preformed to determine brain functional blood flow activity. Individuals (with and without dyslexia) preformed tasks under the fMRI. Dyslexics exhibited a decrease in blood flow in areas of weakness and over-activation in other areas of the brain revealing compensation for weakness. (Hudson, 2007) A study by Shaywitz et al. (2002) was conducted with 144 right handed children (with and without dyslexia). These children preformed a number of tasks, in and out of the fMRI, comparing reading brain activity. These children sounded out actual and nonsense words, compared meanings of these words, as well as, identified sounds of letters. Children with dyslexia exhibited less activation in areas of importance in the brain than children without a reading impairment. This research revealed that children, with a reading disability, demonstrated less activity in the left occipitotemporal area and more activation in the right Parietotemporal area, which is a less functional part of the brain for fluent reading. Children with dyslexia can become accurate readers, although they read with decreased fluency which is attributable to this compensation. This research found a decreased amount of function in the lower back parts of the brain and increased amount of function in the frontal area of the left hemisphere of the brain that specialize in reading. Since there are areas of the brain those focuses on different parts of reading, speaking, learning, writing, processing words and sounds, etc, it is problematical to tell if this could be a valid identifier determining Dyslexia children. (Hudson, 2007)

Another study was accomplished by Aylward et al,(2003) using twenty-one children. Ten had dyslexia with intervention and eleven were normal average readers with no intervention. Each set of children, a control group of average readers and dyslexic readers, were placed two times in the fMRI with in twenty-eight hours. There were no differences in the two fMRI with the control children. On the other hand, dyslexic readers with prior treatment demonstrated an under activation before the intervention. After the intervention they displayed increase brain activity in important areas associated with reading. These results closely resembled the control group's fMRI results. The type of intervention provided in this study is unknown. However, these results reveal that if we provide correct stimuli at the correct time in the child's life, they can produce the correct brain function for reading and comprehending material and languages similar to average children without reading difficulties.

Blachman et al. (2004) conducted research using second and third graders with reading disabilities divided into three groups: control, intervention, and school remedial program. The intervention group had 9 months of 50 minute tutoring sessions including an overview of previous lessons and instruction on new material, word practice with letter cards, fluency building, oral reading, and writing words. The MRI looked similar for the whole group at the start of the study. Once the research commenced, an increase in activation in reading areas of the left hemisphere was demonstrated in both the intervention group and the control group. At the end of the study, an increase in left hemisphere Occipitotemporal area was depicted whereas right hemispheres demonstrated a decrease in activation in the same area.

As shown above, individuals with dyslexia exhibit different brain processing than individuals without reading disabilities. These dyslexic people are not unintelligent; they just need different tools and interventions to help them achieve reading comprehension and fluency at their desired level. If these individuals receive help and intervention at an early age they can avoid reading problems in the future. These interventions at earlier ages, as explained, can help increase the brain processing centers.

2.4 The Ear and Auditory Nerve

The ear consists of the outer, middle and inner ear. The outer ear is the ear lobe called the pinna and the auditory canal. As sound enters the auditory canal it passes to the tympanic membrane and moves the ossicles in the middle ear. The ossicles are three bones (malleus, incus, and stapes) that move the oval window in the inner ear. The oval window vibrates the fluid filled camber called the cochlea. The cochlea has three fluid filled chambers called the scala tympani, scala vestibule and scala media. These vibrations activate the Organ of Corti and the basilar membrane, therefore, initiating the auditory process. The sensitivity of the organ of Corti starts the process of discrimination of sound frequencies. These, in turn, activate the auditory nerve (8^{th} cranial nerve) that includes the acoustic nerve and the vestibular nerve.

Sound travels via the auditory pathway contralateral and ispilateral to the auditory cortex in the brain ending at the brain stem. A synapse is made with the cochlear nuclei and most of the fibers connecting to it crossing over to the opposite side of the brain. The contralateral pathway of the right ear travels to the left side of the brain. Reversely, this is

true for the left ear. However, some fibers do stay on the same side of the brain (ispilateral). As these fibers travel through the brain they ascend into the pons superior olive, which specializes in localization of sound. As this sound ascends, it progresses into the lateral lemniscus then innervating the midbrain inferior colliculus. Subsequently, this sounds travels to the thalamus's medial geniculate nucleus sending the auditory signals to the auditory cortex. (Bear, 2007) The auditory cortex is located in front of the Wernicke's area shown in Figure 1.

2.5 Mechanoreceptors and Somatosensory Cortex

The skin has mechanoreceptors which are sensory receptors that are apart of the somatic sensory system. These receptors are sensitive to physical distortion, for example, pressure, bending, moving, vibration, pricking, touching etc. The receptors in the skin are as follows: Merkel, Meissner corpuscle, hair follicle, Pacinian corpuscle and Ruffini. Each of the mechanoreceptors helps distinguish differences between each type of physical distortion. Mechanoreceptors are slowly and rapidly adapting. The rapidly adapting mechanoreceptors respond quickly to stimulus by stopping firing even when stimulus is still present. The Meissner and Pacinian corpuscles both are rapidly adapting. The Pacinian corpuscle, in the epidermis layer of the skin, can be found in both glabrous and hairy skin. It has a diameter of approximately one mm and can be up to two mm in length. Furthermore, the Pacinian corpuscle has a large receptor field, and when stimulated, the vibration travels via the median nerve. This nerve innervates the forearm, wrist and hand.

The slowly adapting mechanoreceptors are Merkel and Ruffini corpuscles firing while a stimulus is present.(Bear, 2007)

Vibrations of the skin can activate different mechanoreceptors. Vibrations around 200-300 Hz activates the Pacinian corpuscle, while 50 Hz is a sensitive rang for the Meissner corpuscle. The Pacinian corpuscle, when compressed during each vibration, activates the nerve, opening the channels as a result of its deformation. The receptor potential is then generated. When the depolarization increases enough, an action potential will be produced. This action potential will dissipate despite continuous vibrations caused by the corpuscle loosing its deformation. The refractory period is the time when another action potential can be fired once the Pacinian corpuscle becomes deformed once more. (Bear, 2007)

The median nerve enters and leaves the vertebral column the C6-C8 and T1. Fibers from C6 innervate the inside near the top inside thumb around to the other side of the thumb up through the arm. Fibers from C7 innervate in-between C6-C8 on the top of the arm and hand. Fibers from C8 innervate from the ring finger around to the back to the ring finger and up the arm. Fibers from T1 innervate a narrow portion under the forearm and up the arm. The cervical vertebrae are C6-C8 and thoracic is the T1 vertebra. (Bear, 2007)

The Somatosensory Cortex specializes in sensations from the body, for instance, pain, touch, temperature, pressure, joint and muscle location. These areas are separated into modalities because of the different targets and pathways to the brain. They are touch, pain, temperature and proprioception. Touch pertains to contact, vibration and pressure. The touch helps determine texture and shape by touch without seeing the object. Pain and

temperature focuses on the extreme high and low temperatures as well as with itch and tickle sensations. Proprioception is the relation of the locations of the joints, limbs, tendons, etc. within the body. (Bear, 2007)

The touch system process progresses from vibrations on the wrist to the brain with the sensation traveling ispilaterally to the spinal cord. The signal arrives at the dorsal root ganglion unit, traveling up to the medulla where it crosses over to the contralateral position. The sensory information travels to the thalamus and finally arrives at the cerebral (primary somatosensory) cortex. The primary somatosensory cortex is located at the front part of the parietal lobe illustrated in Figure 1. (Bear, 2007)

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Lynks Readers

Lynks Readers (digital and analog boards) were used while attached to headphones with microphones and/or a wrist vibrotactile watch created by the Digital Lateral Reader Corporation of America, Richmond, VA). The Lynks Reader was initiated with music playing in both ears. The test subjects commenced reading out loud into the microphone, causing their voice to enter the right ear instead of the playing music. Furthermore, if the wrist vibrotactile watch was attached, it would initiate vibration when speech was spoken in the microphone. The vibrations and voice into the right ear informed the left hemisphere that reading was occurring.

The Digital Signal Processing (DSP) Lynks Reader device used the DSP board with a Motorola DSP56309EVM chip. This chip included a one hundred and ninety-two MB memory, amplifiers and a microphone input with a preamplifier as depicted in Figure 2(Digital Lateral Reader) and Figure 3(Chip and Diagram). Using Kyma 5.1 software, the processing of algorithms was developed on a Capybara 320 Sound Engine. The Capybara

320 was a multiprocessor computer with RAM that runs with a main computer. The Kyma software (Symbolic Sound, Champaign, IL), used on this board, has specialization for speech processing, real-time spectral analysis, re-synthesis with the ability to filter and adjust time, frequency, amplitude, compression or expansion.(Lenhardt, 1999) Headphones with microphone and CD/MP3 players were attached via stereo plugs on the Digital Lateral Reader exhibited in Figure 2(a).

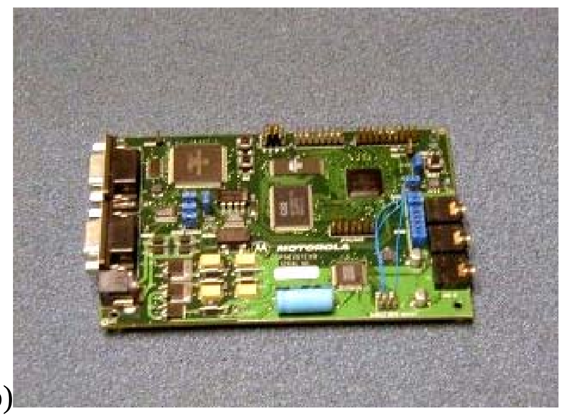
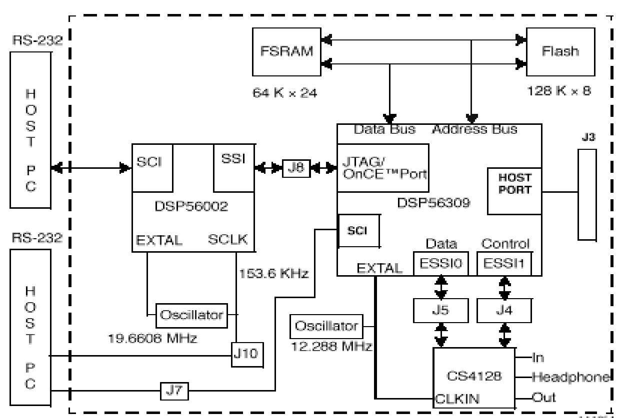
(a)  (b) 

Figure 2: Digital Lynks Reader (DLR Co., Richmond, VA)
(a) Device with MP3 player and Optimus PRO-50MX headphones and microphone
(b) DLR board (Lenhardt, 1999)

a



b

Figure 3: Chip and Diagram (Freescale Semiconductor, 2007)
a) DSP56309EVM and b) Block diagram of DSP56309EVM

The analog board, Figure 4(a), was designed using a PC board layout program and sent to the PC board company. This company produced the board and the parts were attached manually. This board contained amplifiers and level detectors to derive control signals for switching. The switching was executed with solid state integrated circuits using field effective transistors (FET) which acted as closed or open circuits controlling the signal flow. The wrist vibrotactile was attached via a cable along with stereo headphones/microphone combinations and the music source (CD or MP3 player).


(a) (b) (c)

Figure 4: Analog components and vibrotactile watch
(a) Analog Board components (b) wrist vibrotactile device (c) Analog Board with attachments

The wrist vibrotactile device, Figure 4(b), is a small DC motor that has been used in pagers and cell phones. It uses 1.3V and runs at 70mA. The counter weighted motor is 6mm in diameter and 17 mm long and weights 0.005g. Both the DSP and Analog boards were designed to stop music playing in the right ear of the headset. The voice goes into the right ear once a voice was initiated into the microphone. In addition, the analog board has

a wrist vibrotacile device attached and starts vibrating when a voice commences into the microphone.

3.1.2 Devices to use with Lynks Reader

The Lynks Readers were evaluated with four different types of headphones with microphones. The microphones' has a high quality voice reproduction and response range. In testing headphones, a variety of headphones with microphones were evaluated. For example, Altec Lansing with a microphone having a soft earphone covers instead of ear cups was tested to see if ear cups are necessary for noisy environments. Furthermore, a set of headphones with ear cups, displayed in Figure 5 (d), was also evaluated to determine if they would provide good isolation from noises in the room. These headphones are described in Table 2 and exhibited in Figure 5(a-d).

Table 2: Headsets and microphone (all headphones are shown in Figure 5)

Headphones with Microphone	Description	Estimated Price
Optimus PRO-50MX with boom mic	Stereo output, frequency response is 10-22,000 Hz for the headphones and for the microphone has an operation of 100-20,000 Hz, ear cups that fit over the ears.	$25.00
CS-100 KOSS with KOSS mic	Stereo output, Frequency response for the headphones are 30-16,000Hz and for the microphone 100-16,000Hz. They have soft earphones covers.[25] Left and Right headset have to be flipped when speaking into the microphone for the right ear to hear your voice	$19.99
Cyber Acoustics AC-401 with Boom mic	Frequency response for the headphones are 20-20,000Hz and for the microphone 100-16,000Hz. Ear cups fit on the ear, volume control[11]	$19.99
Altec Lansing AHS322 with Boom mic	Frequency response 20-20,000Hz for headphones and microphone 100-10,000 Hz, noise canceling technology[38]	$19.99

Two CD and two MP3 players were evaluated to observe their compatibility with the use of the Lynks Readers for music channel input and output. These are displayed in Figure 5(e-h). The CD players were the Trutech model T100-CD and the Classic model CL160. The MP3 players were the Ultra Hydra 1GB model CE FC and the Philips 512MB model SA1100.

Figure 5: Headphones, MP3 players and CD players
(a)Altec Lansing, (b)Cyber Acoustics, (c)CS-100 KOSS, (d)Optimus PRO-50MX

(e) MP3 Ultra Hydra 1GB, (f)MP3 Philips 512MB, (g)Trutech, (h) Classic

3.1.3 Software and Instrumentation

The sound levels (decibels), frequency and intensity of music and voice outputs of the Lynks Reader headphones, along with the dichotic listening consonant vowels, were measured. LabVIEW 8.0 signal processing software, Signal FFT Analyzer, SA-77, (Figure 7) and the microphone SHURE SM48 (Figure 6) were utilized to make these measurements. LabVIEW 8.0 is a software program that acquires and analyzes sounds, voices, and/or signals applied to the program. This signal processing software was set up to input data in graphical format. The SHURE SM48 is a vocal microphone designed for sound reinforcement and studio recording with a frequency response of 50-15,000 Hz(Zzsound,2002).

The handheld Signal Analyzer, SA-77, made by RION CO., LTD, produced a Fast Fourier Transform (FFT) for sounds as well as acceleration. Fast Fourier Transforms (FFT) is an algorithm for computing a set of discrete data values to produce a graph. The SA-77 FFT measured acceleration of the wrist vibrotactile device and music emitting from the headset of the Lynks Reader. The SA-77 FFT Signal Analyzer has a direct input for the accelerometer with a preamplifier having a frequency range of DC to 50000 Hz and a dynamic range display of 80 dB. This device was designed for analysis of vibration and sound out in the field. It was hand-held and battery operated with an option to plug into an outlet. The display on the SA-77 FFT displays time waveforms, spectrums, or PFD

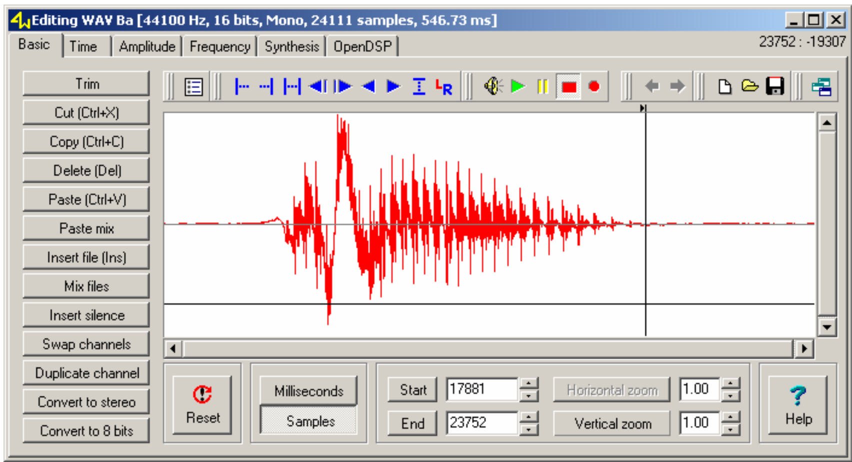
(amplitude probability density function) and the information can be saved within the instrument. (Manual, RION)

Figure 6: Microphone: SHURE SM48

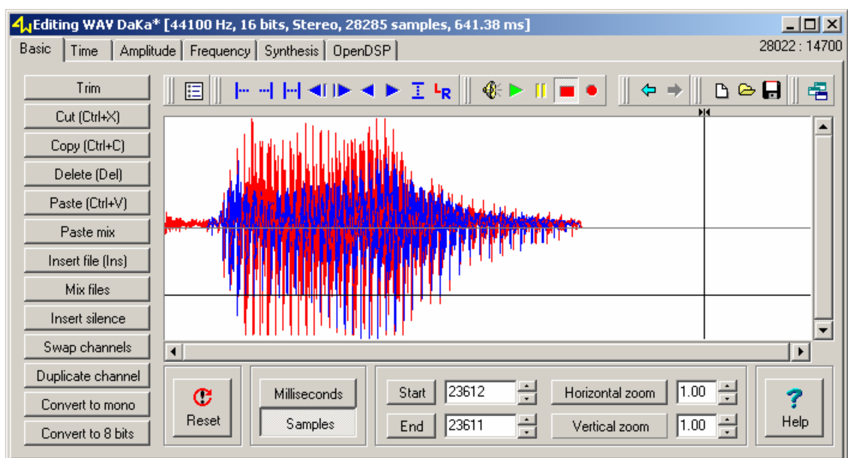
Figure 7: Signal Analyzer FFT: SA-77

Ace of WAV version 2.7 and Cool Edit96 were sound editing software use to record and combine the consonant/vowel sounds employed in developing a dichotic listening test. Ace of WAV 2.7 was a sound editing software and synthesizer, previously known as Acid WAV™ © 1998-2006. It gives the ability to swap channels and to change channels from stereo to mono or mono to stereo, and to copy/paste. Ace of WAV, depicted, in Figure 8, demonstrated the software capabilities for this process. Cool Edit96 was a digital sound editing software program that edits, records and plays and was similar to a recording studio. This Cool Edit96 software was utilized with an IAC sound proof

chamber and an Electrovoice 664 microphone as well as with an RCA sound board. The Electrovoice 664 microphone was designed for public address applications and was a cardioid microphone ideal for semi-professional recordings.



a)



b)

Figure 8: Basic Ace of WAV screen: a) /ba/ sound in mono, b) /da//ka/ sound in stereo

3.2 Methods

3.2.1 Design of Investigation

With a total of ten volunteers, eight subjects were assigned one of the four Lynks Readers for a four week period of eight fifteen minute sessions. Two subjects were controls that will not use the Lynks Readers in their session. The Lynks Readers used were the analog board, the digital signal processing board, the wrist vibrotactile device and a combination of the analog board and the wrist vibrotactile watch, all with headphones. The basic set up, in Figure 9, depicts the block diagram of the Lynks Reader with the wrist vibrotactile device.

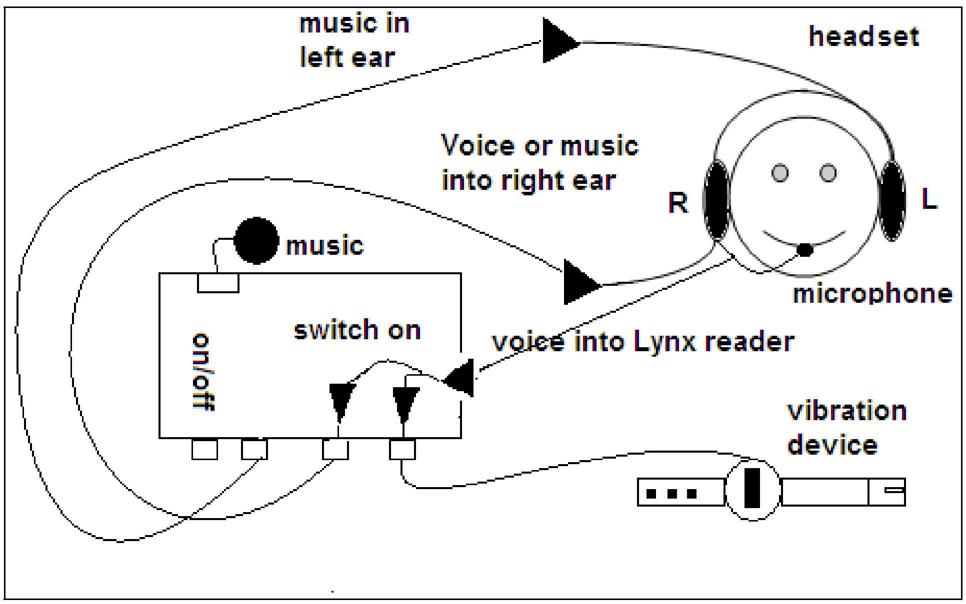


Figure 9: Block diagram of the Lynks Reader with vibration device

Eight subjects participated in eight sessions wearing a stereo headset with microphone attached with music playing in both ears. When the individual started reading aloud, the right headphone went silent. The individual’s voice was heard in the right ear,

activating the left hemisphere. The left ear/right hemisphere was distracted by the music being played in the left ear.

Two of these eight individuals were using the wrist vibrotactile watch and were not using music. The wrist vibrator was placed on the right wrist and connected to the analog board with no music in either ear. They had a set of headphones with microphone connected to the analog board (only using the microphone). When the subject spoke out loud into the microphone the vibration manifested itself on the right wrist. This was to activate the left hemisphere without distracting the right hemisphere.

The final two individuals were controls. The control group had only one session and this session was without a Lynks Reader. Music played in both ears while the controls read aloud for fifteen minutes. This control was to determine if there confounding effects from reading out loud for fifteen minutes, or having music playing in their ears, causing an increase in the administered pre and post test.

At the launch of the study, each individual completed a language acquisition survey. A questionnaire was filled out about the instruments, equipment used and how the devices worked. The headphones and CD/MP3 players varied from session to session to check the compatibility with the instrumentation.

Each individual was administered a pre and post test evaluation for left and right hemisphere dominance (Dichotic Listening Test) and fluency ability (three nonsense syllable fluency test and one college level fluency reading test). The dichotic listening test was developed and assessments run against a commercial version. The FFT with frequency vs. magnitude and sound waveforms were acquired with LabVIEW. The Lynks

Reader device was tested with music and voice coming through the headphones. This produced the FFT of the frequency input production, sound waveform and decibel level at the highest sound which would come out of the device. These were determined with LabVIEW and SA-77. The vibrotactile wrist device was tested for the vibration level using the SA-77 with accelerometer. This produced an FFT graph.

3.2.1 Survey and Questionnaire

1) Language Acquisition Survey

A language acquisition survey was developed to determine if the candidates were musically trained, had any hearing difficulties, or had a learning disability. Furthermore, reading habits, English as a first or second language, gender, and left or right handed were recorded. As previously discussed, these were all questions that could play a role in the results of the dichotic listening test and reading fluency results. An example of this test is in Appendix A (A) Language Acquisition Survey.

2) Questionnaire

The questionnaire was developed to determine the operational parameters, instrumentation, and how the devices operated. This divulges how the subjects were adapting to the Lynks Readers and accessories. This evaluation of audio input/output devices and the wrist vibrator were conducted to determine which headphones/microphone combination works the best with each Lynks Reader. This questionnaire was administered to all individuals following each session.

3.2.3 Academic Test

1) Dichotic Listening

To test the hemisphere dominance, a dichotic listening test was used. The dichotic Consonant-Vowel listening test was obtained from AUDiTEC of St. Louis™. It included quality recordings of auditory tests with 30 pairs of consonant/vowels (/da/, /ka/, /ba/, /ta/, /pa/, /ga/).

The test was administered each time with one replication for a total of 60 consonant/vowels (CVs) pairs. In the middle of the testing, the headsets were reversed to prevent any bias from occurring as a result of the headsets. The individuals were given at least sixteen pairs of trial runs before the test was initiated. They were required to get 14 out of the 16 correct before the dichotic listening test could be administered. The subjects were asked to repeat exactly what they hear for each pair of sounds. If they only heard one CV sound, they reported that sound. However, if they heard two sounds, they reported two sounds.

The dichotic listening test scoring procedures were demonstrated by Daniel S Beasley in "Audition in Childhood: Methods of Study". Reporting procedures he explained included: Right ear Correct (REC), Left ear Correct(LEC), Right-Left (R-L) =REC-LEC, Total Items Correct (TC)=REC+LEC, Double Correct(DC), Neither correct(NC), Percent of Correct(POC)=REC/TC, and Percent of Error(POE)=LEC/Total Error. All data was displayed using the above nomenclature and formulas. The Right Ear Advantage was calculated. The REA was determined by taking the percent of right ear correct minus the percent of left ear correct.

2) Nonsense fluency Test

The three nonsense syllable fluency test were developed by taking nonsense three letter words and placing them randomly on a list to create a one syllable, a two syllable, and a three syllable word test. The nonsense word test was used to take away the ability of individuals to use sight vocabulary, i.e. cat or dog. These sight words were memorized and recited by the use of the right hemisphere. When nonsense words were read, i.e. sev, vek, nimger, sevnemtok, the left hemisphere was used to pronounce the words. These test are demonstrated in Appendix A (b, c, and d).

All the individuals read each of the three tests aloud for one minute. The amount of nonsense syllable achieved on each list within that minute determined the individual's reading fluency. An average of all three nonsense fluency tests was used to compare the pre and post test of each person in determining the amount of increase.

3) College level reading fluency test

A reading fluency test was created using a college level book "Basic transport phenomena in Biomedical Engineering" 2nd edition, Ronald L. Fournier, 2006, pages 388-389. Several passages from this book were used for the test. This provided a basic idea of reading comprehension and fluency of reading material at the test subjects' expected college grade level. The Fry Readability Formula determined the grade level of this book's passages. The average grade level of this book was college level (average number

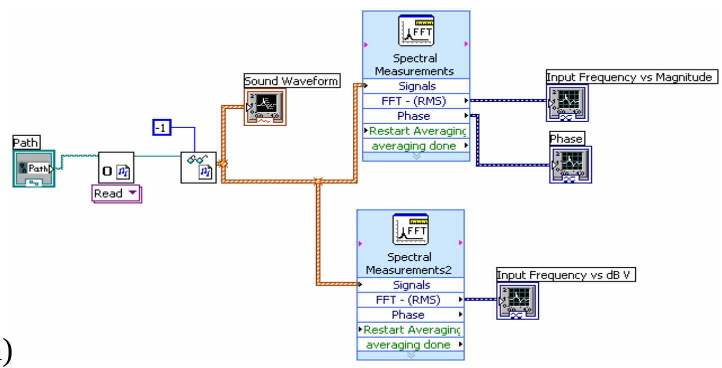
of sentences per 100 words was approximately four and average number of syllables per 100 words was approximately 163).

Each individual read out loud for one minute to determine achievement within the college level text. Furthermore, general verbal comprehension questions were asked. Examples were “what did you read?”, “did you understand what you were reading?” and “explain what you read.” This determined if the individual was fluent at the college level.

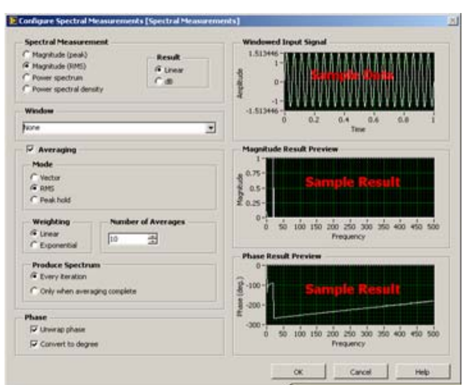
3.2.4 Creating a Dichotic Listening Test

A dichotic listening test was developed with a total of 36 consonant/vowel (CV) pairs of /da/, /ka/, /ba/, /ta/, /pa/, /ga/ at 3sec intervals using a shareware program called Ace of WAV version 2.7. Each sound used was recorded with Cool Edit96 in an IAC sound proof chamber with an Electrovoice 664 microphone and an RCA sound board by Frank Gentges. A pair of CV sounds were opened in AceWAV and combined using the mix button with the original sounds in stereo. The second CV sound was added under the mix button to the current CV sound at 16 bit monoaural with different sounds going into each ear. This is demonstrated in Figure 8 (a and b). Subsequently, the channels were swapped giving another set of pairs, identical to the set just created, into the opposite ear. To prevent any bias from occurring caused by slight variation in the sounds, the "swap channel" function was used to echo each Left-Right pair to give an identical Right-Left pair. This created a total of 36 CV pairs which were combined in random order to create one dichotic listening test with an example test shown in Appendix B.

The two dichotic listening tests were compared using LabVIEW 8.0. The sounds the CVs produce through the headset were recorded using the SHURE SM48 microphone and analyzed by LabVIEW using the block diagram illustrated in Figure 10. An evaluation of the dichotic listing test was preformed to determine any bias between the CV sounds of /da/, /ka/, /ba/, /ta/, /pa/, and /ga/. This was accomplished by looking at the FFT of each sound and comparing them to each other. The spectrum configuration for the graph of frequency and magnitude is displayed in Figure 10 (b) and for frequency and dB V is exhibited in Figure 10 (c).



(a)



(b)

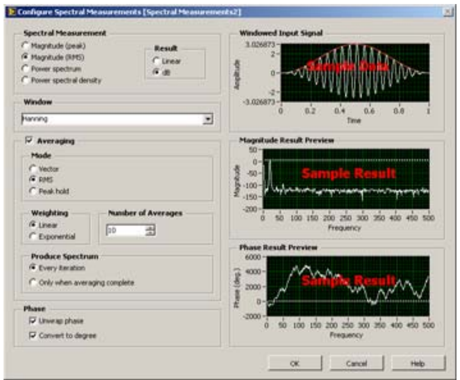
(c) 

Figure 10: LabVIEW (a) Block Diagram, (b) Spectrum configuration (Frequency vs Magnitude), (c) Spectrum configuration (Frequency vs dB V)

3.2.5 Lynks Reader with Music and Voice

This test determined the amount of music and/or voice emanating out of the headphones from the Lynks Reader. The SA-77 FFT was used in comparison with the LabVIEW 8.0 software using random choices of music on the MP3 players. The same settings are described in Figure 10 (a, b and c) for LabVIEW. The settings for SA-77 FFT used are illustrated in Figure 11 (a-d).

The SA-77 was used to collect musical data only. To collect the data on the graph, the cursor was adjusted and the data transposed to excel for graphing. LabVIEW 8.0 was used to analyze both music and voice. Each sound was recorded through the SHURE SM48 microphone and played through LabVIEW. The same LabVIEW diagram was used, as depicted in Figure 10 (a, b and c), to analyze the data and create the graphs.

3.2.6 Vibrotactile wrist device and vibration

A hand held FFT Signal Analyzer SA-77, with the menu settings, was used to determine the amount of acceleration the wrist vibrotactile device produced when speech

had started through the Lynks Reader. This is illustrated in the pictures in Figure 11(a-d). Since the hand held device does not have a print out, an excel graph produced using a total of n=6 runs. The top of each peak was determined by using the scroll button on the SA-77 and logging them into a spreadsheet.

(a) 

(b) 

(c) 

(d) 

Figure 11: SA-77 FFT analyzer
(a) menu page 1, (b) menu page 2,(c) menu page 3,(d) menu page 4

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Academic testing Results

All ten of the individuals participated in a pre and post three nonsense fluency test plus a reading comprehension fluency test, whose results are displayed in Table 3 (a, b and c). Results, from the average of the three nonsense syllable tests, demonstrated a *p-value* below 0.05 for the data between the pre and post tests and between the subjects. An overall increase of 21percent in fluency was revealed for all eight volunteers where the two controls increase fifteen percent. These results are portrayed in Table 3 (a).

Results from the college level fluency comprehension test demonstrated a *p-value* below 0.05 between the pre and post test. We see that the *p-value* was above 0.05 between the subjects. An overall all increase of 29 percent was exhibited for all eight volunteers using the Lynks Readers where the controls related a three percent increase in the college level reading fluency. The results are shown in Table 3 (b).

Results of the college level and nonsense fluency test were compared by establishing the percent increase over the control group for each Lynks Reader. The

analog Lynks Reader demonstrated an increase of 11 percent for the nonsense fluency test and a 21 percent increase for the college level fluency test. The analog plus the wrist vibrotactile device demonstrated an increase of three percent for the nonsense fluency test and an increase of 34 percent with the college level fluency test. The wrist vibrotactile Lynks Reader results increased seven percent for the nonsense fluency test and 40 percent for the college level fluency test. The digital sound processing Lynks Reader fluency test produced an increase of less than one percent for the nonsense test and an increase of 15 percent for the college level fluency test. These results are shown in Table 3 (c).

The results for the dichotic Listening test gave a *p-value* below 0.05 for the data between the subjects. While a *p-value* above 0.05 was demonstrated for the data between the pre and post test. There was an overall decrease of 1.6% from the Right to Left Hemisphere. These results are tabulated in Table 4. Figure 12 (a) demonstrates the REA for all ten individuals during their pre and post test. Figure 12(b) illustrates the difference between the pre and post test as well as a reasonably horizontal trend line.

Table 3: Fluency and College level Fluency Results
a) Average of three nonsense Syllable test, a) College level Fluency test and c) Compare Nonsense Syllable and Comprehension/fluency Fluency Test

a) Average three nonsense Syllable test

Subjects	Start	End	% increase
DSP-1	63.7	74.7	17.3
DSP-2	68.3	77.7	13.7
Analog-3	70.0	92.3	31.9
Analog-4	75.0	91.3	21.8
Wrist+Analog-5	58.3	64.3	10.3
Wrist+Analog-6	73.3	93.7	27.7
Wrist-7	44.0	53.3	21.2
Wrist-8	51.0	63.3	24.2
9(Control)	48.3	54.7	13.1
10(Control)	78.3	92.0	17.4
Average results from 1-8(no control)	63.0	76.3	21.2
Average results from 9-10(control)	63.3	73.3	15.8
ANOVA p-values Between Subjects	3.81E-05		
ANOVA p-values Between Pre and Post	6.4E-05		

b) College level fluency test

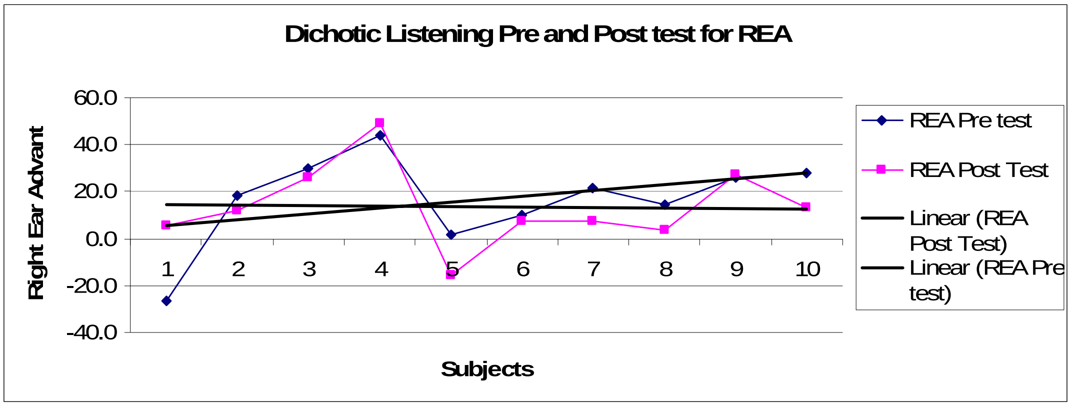
Subjects	Start	End	% increase
DSP-1	177	214	20.9
DSP-2	170	198	16.5
Analog-3	172	193	12.2
Analog-4	166	226	36.1
Wrist+Analog-5	134	164	22.4
Wrist+Analog-6	134	206	53.7
Wrist-7	134	187	39.6
Wrist-8	125	185	48.0
9(Control)	158	154	-2.5
10(Control)	179	195	8.9
Average results from 1-8(no control)	151.5	196.6	29.8
Average results from 9-10(control)	168.5	174.5	3.6
ANOVA p-values Between Subjects	0.356		
ANOVA p-values Between Pre and Post	5.44E-13		

c) Compare Nonsense Syllable and College level fluency Test

Lynks Devices	Nonsense Fluency test (% over control group)	College level Fluency test (% over control group)
Analog	11.6	21.0
Analog+Wrist	3.7	34.9
Wrist only	7.4	40.6
DSP	0.2	15.5

Table 4: Dichotic Listening test Results

Subjects	Pre test: left hemisphere percentage (POC)	Post Test: Left hemisphere percentage (POC)	Difference between Pre and Post test
DSP-1	36.7%	52.7%	16.1%
DSP-2	64.9%	62.9%	-3.2%
Analog-3	59.1%	55.9%	-2.0%
Analog-4	72.1%	74.6%	2.4%
Wrist+Analog-5	50.9%	42.1%	-8.8%
Wrist+Analog-6	60.7%	53.7%	-1.3%
Wrist-7	54.9%	53.6%	-7.0%
Wrist-8	57.4%	51.7%	-5.7%
9(Control)	62.9%	63.6%	0.7%
10(Control)	64.1%	56.6%	-7.5%
Average	58.4%	56.7%	-1.6%
ANOVA p-values Between Subjects	0.00945		
ANOVA p-values Between Pre and Post	0.49397		

(a)


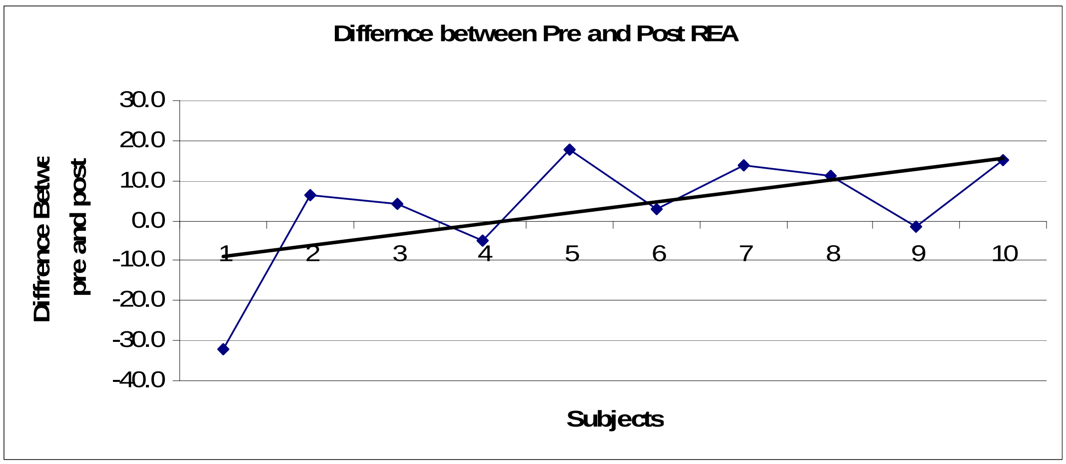
(b)


Figure 12: Dichotic Listening results
(a)REA for pre and post test, (b) difference between REA for pre and post test

4.1.2 Survey and Questionnaire Results

Each individual filled out a language acquisition survey. These results were tabulated into the table displayed in Table 5. Out of the ten Engineering Students, four were men and six were women and all were right handed and native English speakers. Most family members were right handed, except for one subject whose father, brother and sister were all left handed. That test subject has ADHD. Eight of the volunteers studied a second language in high school or college and half found it easy while the other half found it somewhat difficult. Most of these individuals read an average of about six books within

the last year. However, seven of these individuals have had some type of musical training in their background, be it in elementary, middle or high school. This would have been a problem for the dichotic listening test but none of them are considered accomplished trained musicians.

Subsequently, at the end of each session, a questionnaire was completed by each of the eight individuals who had used the Lynks Readers. They answered questions about the instruments, equipment used, and how the device worked. The results were tabulated into two tables which are described in Table 6 (A and B). These eight engineering students started working with the devices reading material from a novel, a college level text book, and journal articles. Within the first week of sessions the students started to notice kinks with the devices. In the first session, the analog Lynks Reader users found the voice sound adjustments to the headset were problematic due to connections. Plug redesign corrected these issues. The sound adjustment at normal comfortable levels for hearing was performed for each individual. This modification insured ease of operation for all subsequent trials.

Table 5: Language acquisition survey results: General Overview

QUESTIONS	TOTAL RESULTS	
	Yes	No
1. Is English your First Language?	10	
2. Have you learned a foreign language(s)?	8	2
a. When did you learn the language(s)?	High School or College	
b. What was the language(s)?	Latin, French, Spanish, Hebrew , Russian	
i. Was it very difficult for you?		
ii. Somewhat difficult?	4	
iii. Not much of a problem?	4	
iv. Very easy?		

3. Are you Right handed?	10	
4. Do you have siblings that are left handed?	1	9
Brother(s)	1	9
Sister(s)	1	9
5. Do you have parents that are left handed?	1	9
Mother		10
Father	1	9
6. Did your parents ever refer to you as:		
a. As late talker as an infant		10
b. As a late walker as an infant		10
7. In Elementary school did you enjoy reading for pleasure?	3-RARELY	
	2-SOME	
	5-MOST OF TIME	
8. Currently how many books have you read in the past year?	5.89-Average number	
9. When you were in elementary and middle school, where you ever tutored in reading?		
a. Elementary	1-tutor in speech	9
b. Middle school	0	9
10. Do you have a diagnosed learning disability?	1-Mild,-ADHD	9
11. Do you recall learning to read? If so was it:		
a. Very easy for you:	5-Easy	4-Don't remember
b. Somewhat difficult	1- Somewhat difficult	
c. Difficult	0	
d. Very difficult	0	
12. Do you play a Musical instrument?	7 Early years, High school	3
a. What instrument?	guitar, piano, drums, flute, violin	
13. As a child, when learning to skip, was it:	9-Very easy for you	1-Don't remember
14. What school grade would you give yourself for the following:	Average Scores	
A+ A A-		
a. Reading	A-	
b. Spelling	B+	
c. Handwriting	B	
d. Drawing	B-	
e. English Grammar	A-	
f. Writing essays	B	
g. Motor skills (running, skipping, marching, doing exercises to music)	A	
h. Posture	B-	
i. Vision	C+	
j. Paying attention to things/not forgetting	C+	
k. Use of Oral Language	B	
l. General Intelligence	A	
m. Math Problems(numbers only)	A	
n. Math word Problems	A	
o. Memorizing telephone numbers	A	

Table 6: Questionnaire Results: General Overview (A and B)

A) Individuals that used the analog board and DSP board

Questions	1	2	3	4
1. Which device are you using?	Analog board	Analog board	DSP board	DSP board
2. How many times have you used the device?	TOTAL 8	TOTAL 8	TOTAL 8	TOTAL 8
3. How did the device work for you (was it easy to operate or were their problems)?	Problems to start with but fixed by second Session. Easy to operate from then on. With one problem with the headset was not working properly	Headphones were clicking in and out on the 1st day, then worked well with no problems after that	easy to operate	easy, no problems
4. When did you stop hearing the music in the right ear?	Went from Never stop hearing to when I talked	when spoke/talked out loud	when talked	intermittent at 1st then not so noticeable, then only 2-3 min into session, then w/in 5 min, to w/in2-3 min to almost immediately
5. Did stop noticing the music in your Left ear? If yes, how long?	no	varied from notice all the time to only noticed when not talking out loud	no, tuned it out to whenever I was talking to only when concentrating	Yes, not focused on sound in left ear, sound was constant but zeroed in on voice, then when music changed noticed the music again, it was distracting.
6. Did the music in the right ear distract you from reading out loud or hearing what you were reading? Explain.	To start hard time reading out loud and found myself mumbling. Then no problems but once with the music cutting in and out	no most of the time to only when music was playing	only when stopped reading for a few sec	No distractions, really didn't notice music in right ear but clicking was noticeable at 1st but then not so much.
7. What type of reading material are you using?	school books, magazines	Novel	newspaper, journal articles	textbook, research papers
8. Which headphones did you use?	Koss(worked great), Altec(problems, very annoying to use), cyber(little problems)	Koss(worked great), Altec(okay), Cyber(problems)	Pro 50-mx. No other headsets worked properly	Pro 50-mx. No other headsets worked properly
9. Did the headphones fit?	yes	yes	yes	yes
10. How was the sound level?	good, fine, or adequate	bit to loud to adjusted perfectly	comfortable/fine	excellent, fine
11. What did you think of the device?	To start would not work properly then no problems from then on. Thought the device worked fine and did not have any major thought about it.	Problems at first with headphones clicking in and out it was not too bad, clicking was distracting, like the device, very nice.	at first it was distracting and confusing, hard to read while listening to music and myself, Always had music in left ear but not on Right to easier with lighter reading and easier each time device was used	Great that it drowns out background noise to focus on content/subject, I read and comprehended without sidetracking, sometimes when song changed it was distracting.

B) Individuals that Used the Analog board w/wrist vibrator and Wrist vibrator only

Questions	5	6	7	8
1. Which device are you using?	Analog board + wrist vibrotactile	Analog board + wrist vibrotactile	Wrist vibrotactile device only	Wrist vibrotactile device only
2. How many times have you used the device?	TOTAL 8	TOTAL 8	TOTAL 8	TOTAL 8
3. How did the device work for you (was it easy to operate or were their problems)?	easy with only two switches	easy, no problems	worked well, no problems	easy to operate
4. When did you stop hearing the music in the right ear?	when I read out loud or spoke, or did not hear it at all	anytime I talked	n/a	n/a
5. Did stop noticing the music in your Left ear? If yes, how long?	Yes, I stopped noticing as I became to hearing myself read, it drowned out the excess noise. Had a problem stumbling over a few words during a few sessions	not really, didn't notice it much	n/a	n/a
6. Did the music in the right ear distract you from reading out loud or hearing what you were reading? Explain.	allowed me to read faster as I became used to the system but I could not retain much information, but the more the device was used the easier to retain information	no, not distracting, it didn't bother me	n/a	n/a
7. What type of reading material are you using?	journal articles, novel	novel	text book	novel
8. Which headphones did you use?	Koss(had problem with the microphone being to sensitive because while breathing it stopped the music, otherwise very good)	Koss(worked great), Altec(okay), Cyber(problems)	Koss	Koss
9. Did the headphones fit?	yes	yes	n/a	n/a
10. How was the sound level?	good, had to adjust a few times	good	n/a	n/a
11. What did you think of the device?	helped me read faster but made it harder to retain all material but other times it was easy to retain material, more the device was used the more I retained, to easier to use and I like it.	worked well, easy to operated	nice and simple, familiar platform(wrist watch), ambivalent, liked it, love the watch	easy to ignore after a few moments, fine, easy to used
12. If using the vibrotactical wrist device.				
a. How was the vibration level?	good	fine	fine	fine
b. Did you stop noticing the vibrations on the wrist?	yes	no	no	yes
c. Was it distracting?	not really	no	no	no

4.1.3 Compare Dichotic Listening Test

The AUDiTEC of St. Louis^{TM} has 30 consonant/vowel pairs of /da/, /ka/, /ba/, /ta/, /ga/, and /pa/. These were compared with the same consonant/vowel sounds created as illustrated in Figure 12-23. The differences, between the sound wave forms for the commercial vs. the made test of each sound, are typified in the Figures 13-18. The FFT of

frequency response vs. magnitude voice sounds for /da/, /ka/, /ba/, /ta/, /ga/, and /pa/ exemplify differences between the commercial AUDiTEC test and the created dichotic listening test in Figures 19-24.

In Figures 25 and 26, an example the sound waveform of /ba//pa/ is demonstrated. Figure 25 represent that the pair combination is aligned at the voice onset time. Figure 26 depicts that the pair combination was aligned up at the burst of the sounds.

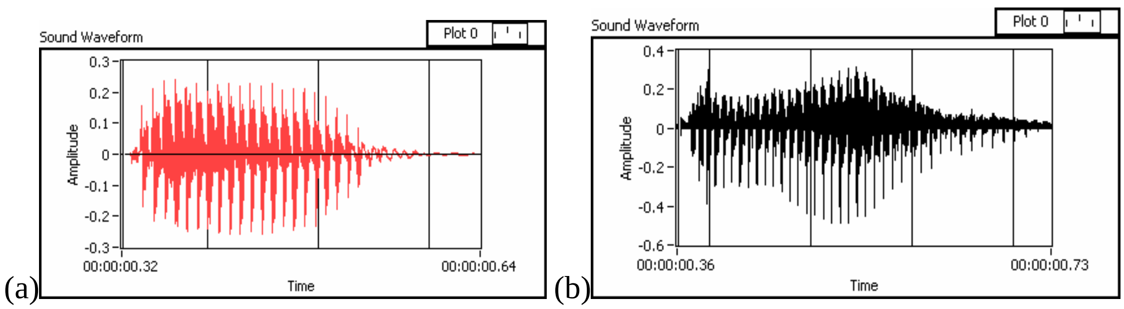


Figure 13: Wave Forms /da/ (a) Commercial (b) Developed

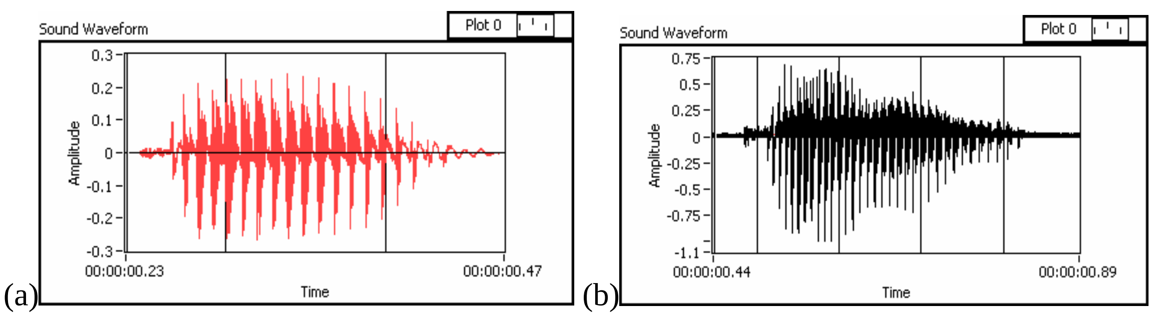


Figure 14: Wave Forms /ta/ (a) Commercial (b) Developed

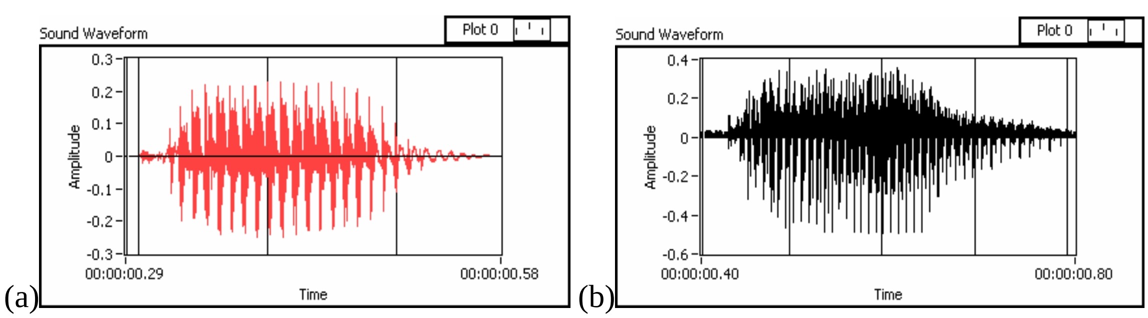


Figure 15: Wave Forms /ga/ (a) Commercial (b) Developed

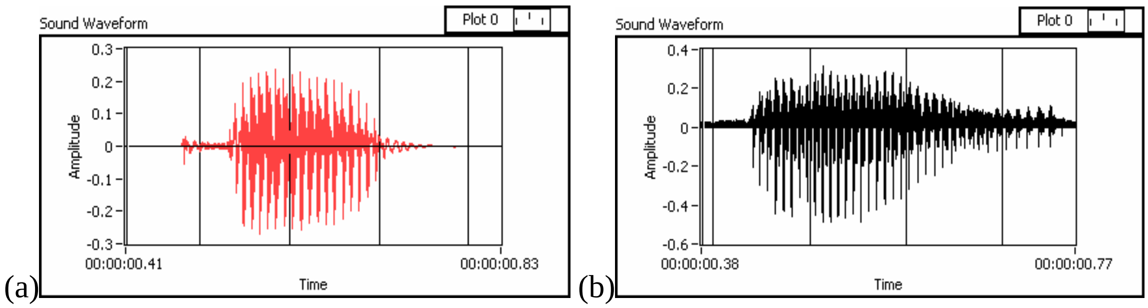


Figure 16: Wave Forms /pa/ (a) Commercial (b) Developed

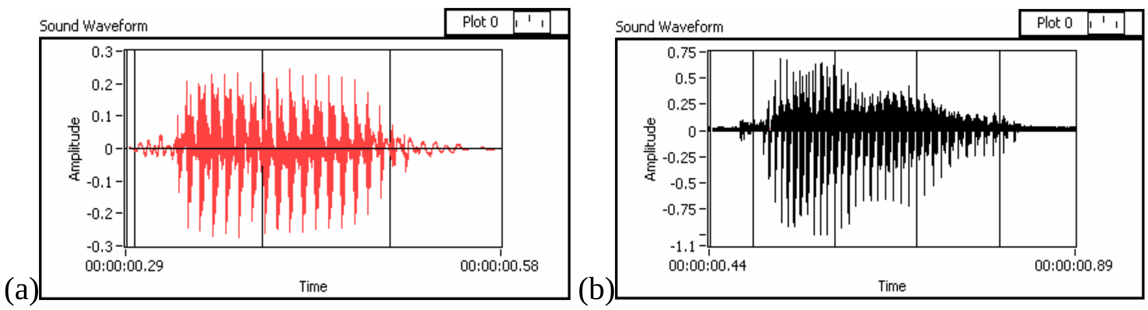


Figure 17: Wave Forms /ba/ (a) Commercial (b) Developed

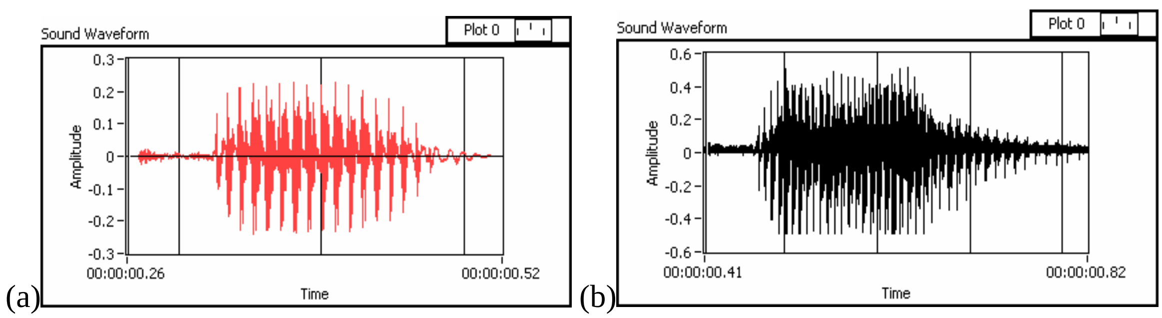


Figure 18: Wave Forms /ka/ (a) Commercial (b) Developed

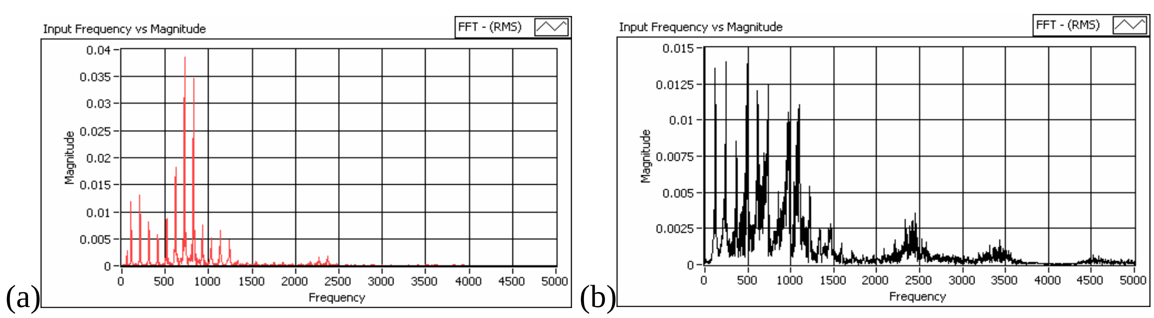


Figure 19: FFT Frequency response /da/ (a) Commercial (b) Developed

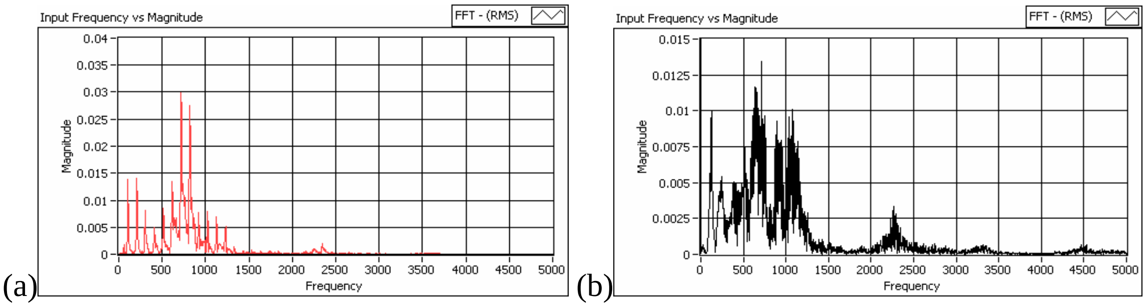


Figure 20: FFT Frequency response /ta/ (a) Commercial (b) Developed

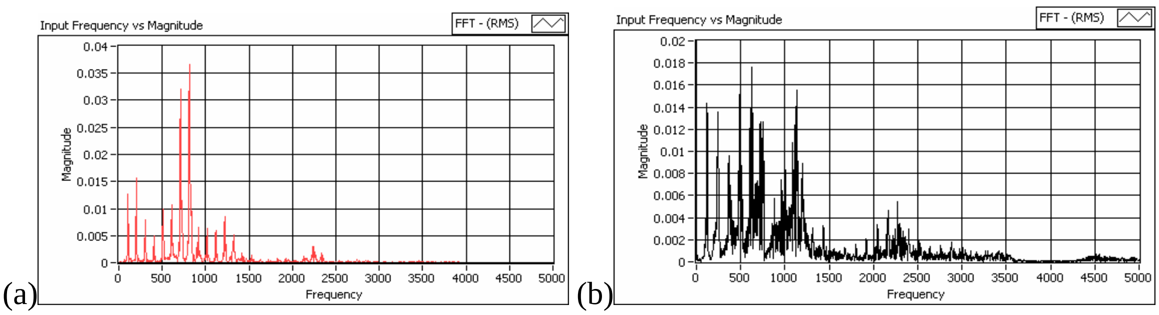


Figure 21: FFT Frequency response /ga/ (a) Commercial (b) Developed

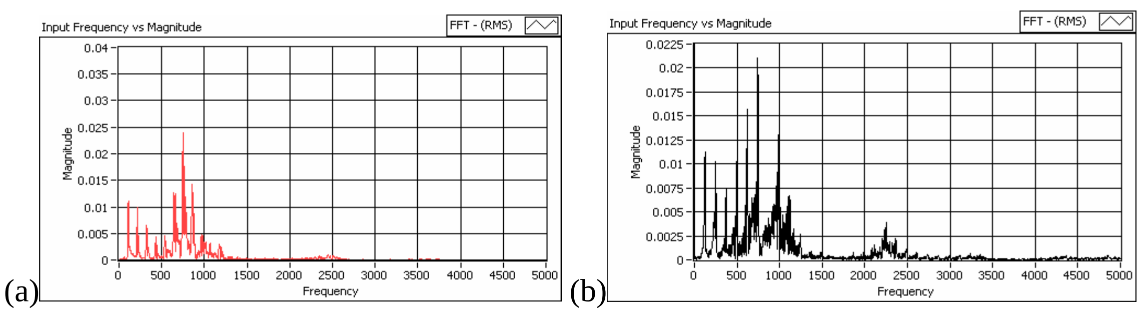


Figure 22: FFT Frequency response /pa/ (a) Commercial (b) Developed

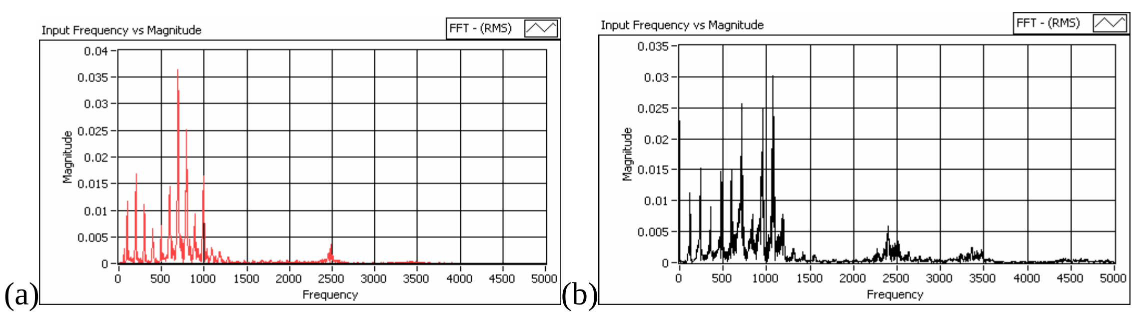


Figure 23: FFT Frequency response /ba/ (a) Commercial (b) Developed

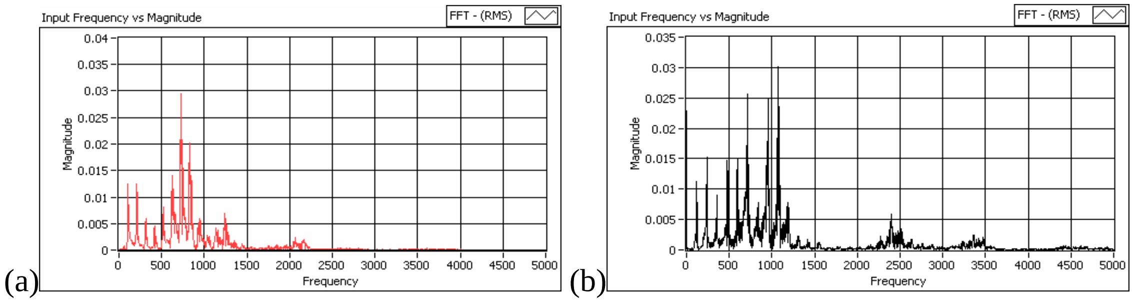


Figure 24: FFT Frequency response /ka/ (a) Commercial (b) Developed

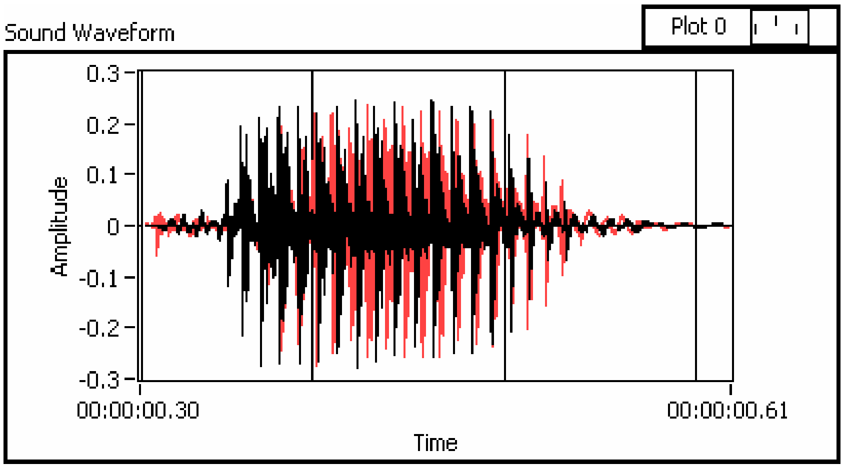


Figure 25: Overlay of sound waveform of /ba//pa/ for Commercial Dichotic listening test

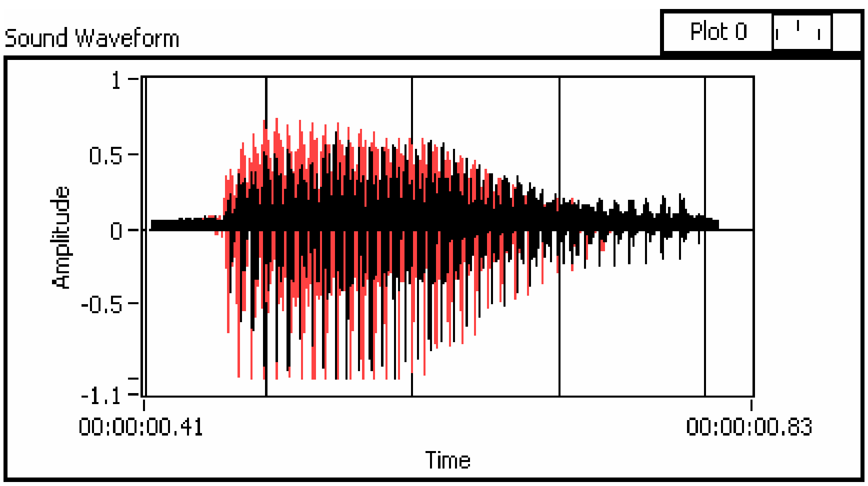
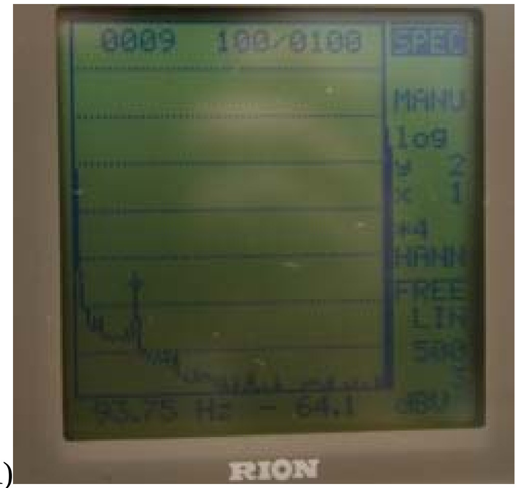


Figure 26: Overlay of sound waveform /ba//pa/ for Developed Dichotic listening test

4.1.4 Music and Voice from the Lynks Device headset

Two instruments were used for determining the amount sound leaving the headset from the Lynks Reader. The FFT SA-77 and LabVIEW were utilized with random choices of music voice fed to the headphone and the Lynks Reader device. Figure 27 (A-B) exhibits examples of the FFT SA-77 screen for the music coming out of the Lynks device into the headphones at n=6. The excel graph of n=6 random music choices, shown in Figure 28, demonstrates the music mainly varies in a range between 70-80dBV with a few music choices that had some range above and below. Subsequently, in Figure 29, a combination of n=6 music peaks reveals the majority of the music is under 80dB V.

LabVIEW results, presented in Figure 30, illustrate all six random music choices and one combination of music. Two types of graphs were produced: the frequency and magnitude (relative value) and the frequency and intensity (dBV). The frequency and magnitude graphs exhibit variations that can occur from music choice to music choice. The frequency and intensity in dBV graphs depicts the most comfortable sound level was at -100dB V as well as the average dBV ranges of 40 dBV; which serve as calibration. These graphs asetope at the higher frequency attributable to a Hanning filter being applied to the analysis of the music. Figure 31 shows LabVIEW results for a voice produced from the Lynks device, which includes the fundamental frequency for a women’s voice at about 120 Hz with harmonics and a dBV range of approximately 40.

(A)

(B)

Figure 27: SA-77 FFT: (A&B random music choices)

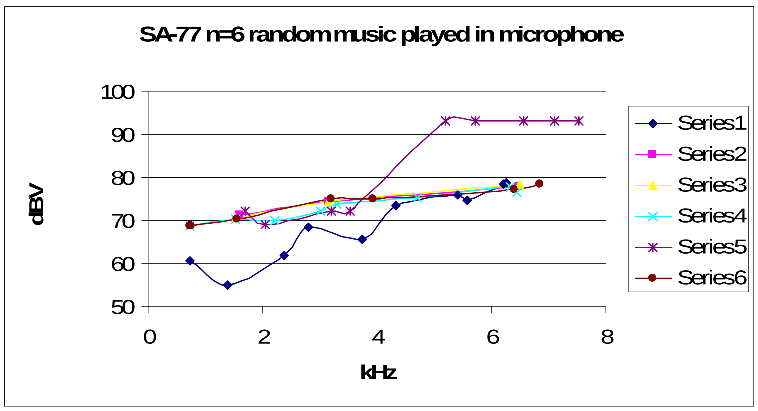


Figure 28: SA-77 FFT random music played in headphones n=6

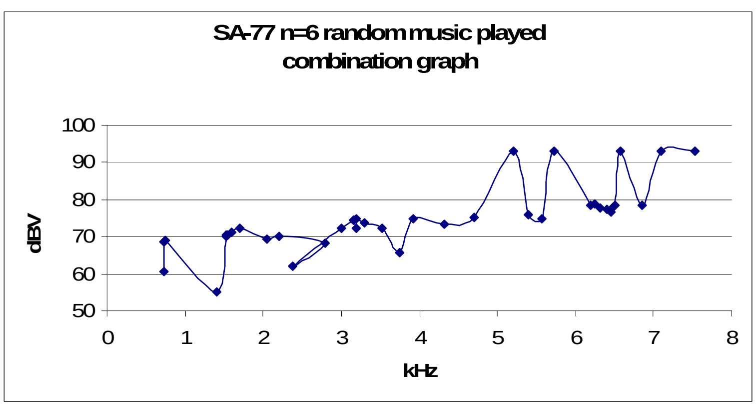
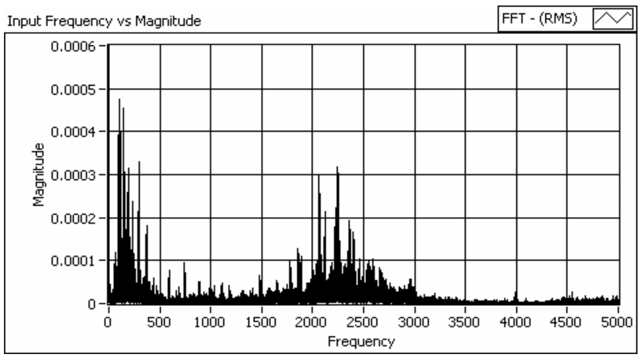
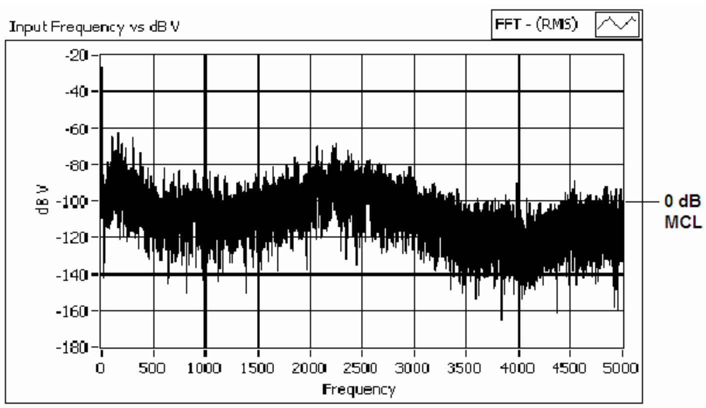


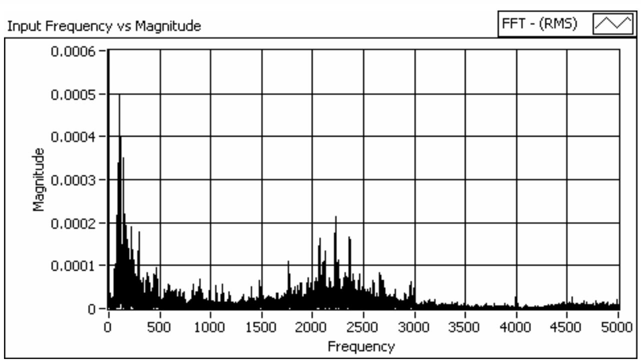
Figure 29: SA-77 FFT random music played –combination of results n=6


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
Frequency

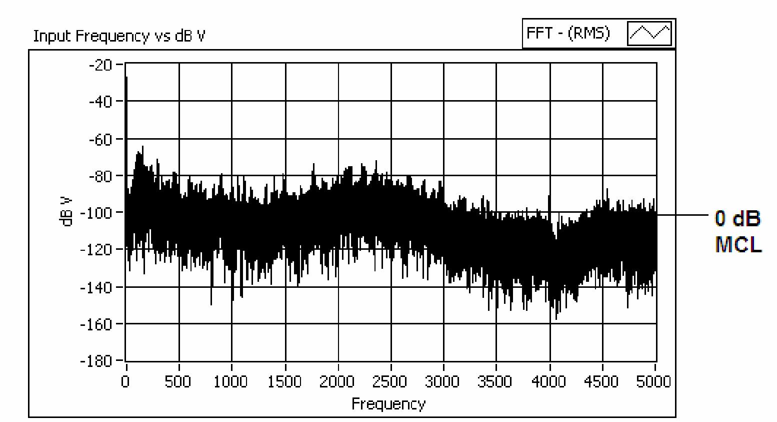
(a)


Input Frequency vs dB V
FFT - (RMS)
dB V
Frequency
0 dB
MCL

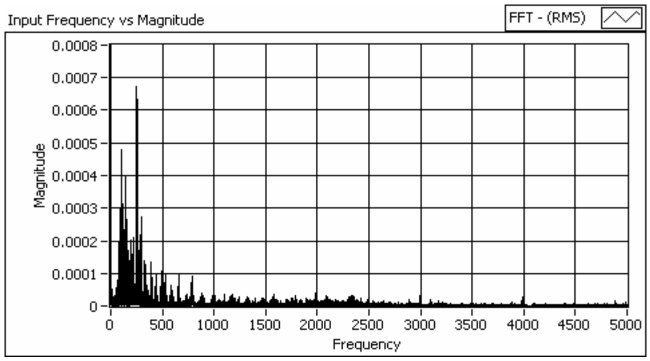
(b)


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
Frequency

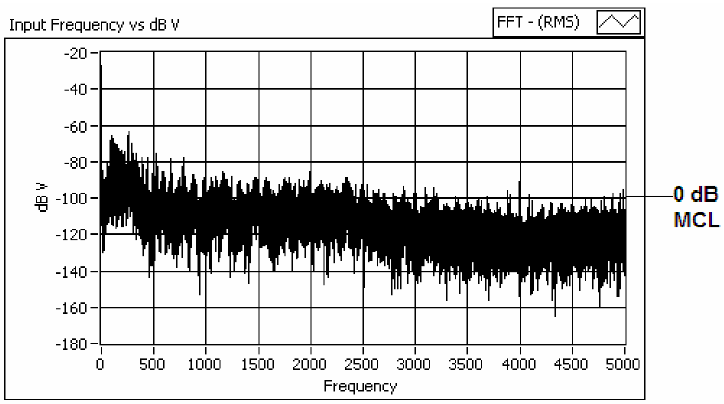
(c)


Input Frequency vs dB V
FFT - (RMS)
dB V
Frequency
0 dB
MCL

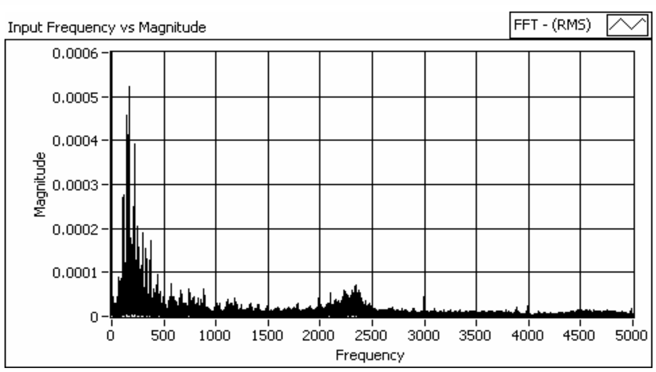
(d)


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency

(e)


Input Frequency vs dB V
FFT - (RMS)
dB V
-20
-40
-60
-80
-100
-120
-140
-160
-180
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency
0 dB
MCL

(f)


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
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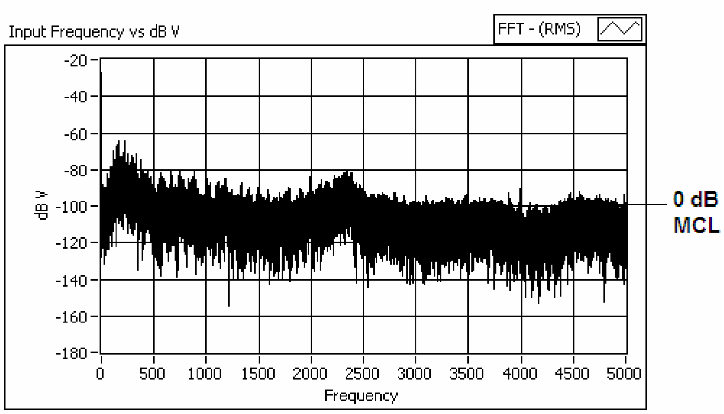
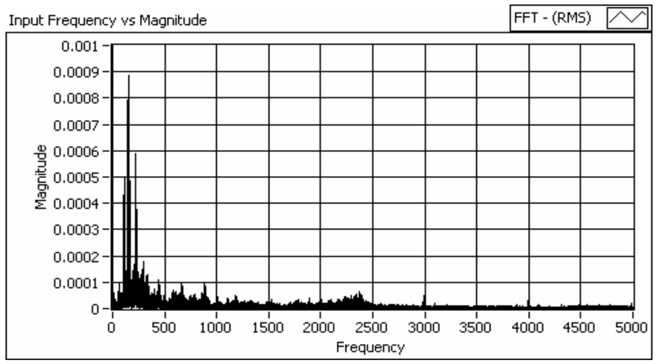
0.0005
0.0004
0.0003
0.0002
0.0001
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency

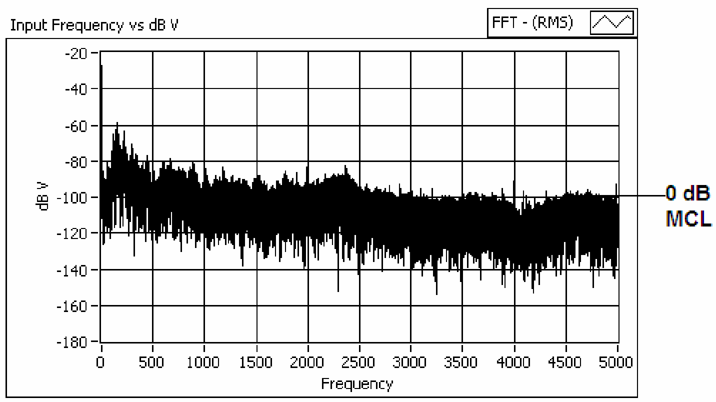
(g)


Input Frequency vs dB V
FFT - (RMS)
dB V
-20
-40
-60
-80
-100
-120
-140
-160
-180
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency
0 dB
MCL

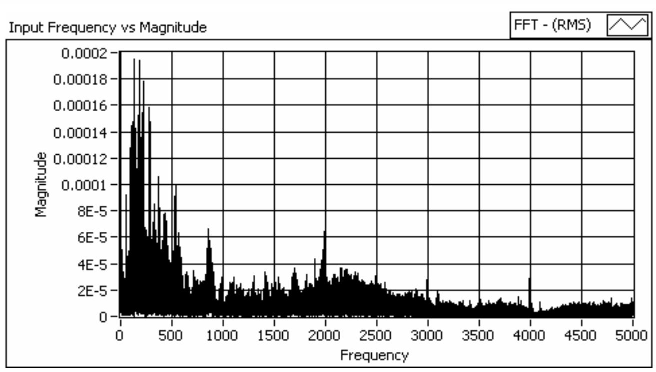
(h)


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency

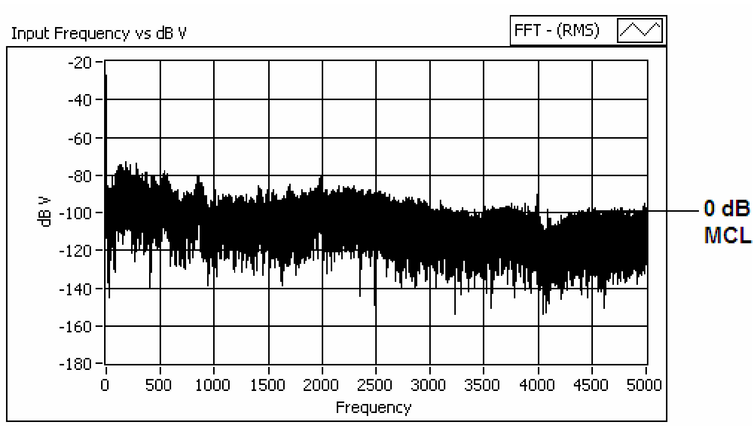
(i)


Input Frequency vs dB V
FFT - (RMS)
dB V
-20
-40
-60
-80
-100
-120
-140
-160
-180
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency
0 dB
MCL

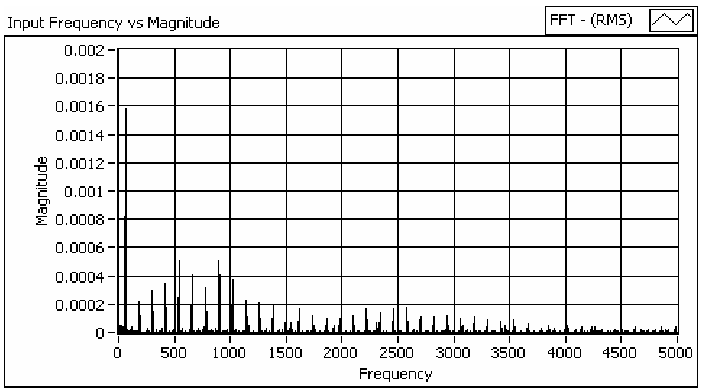
(j)


Input Frequency vs Magnitude
FFT - (RMS)
Magnitude
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
8E-5
6E-5
4E-5
2E-5
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency

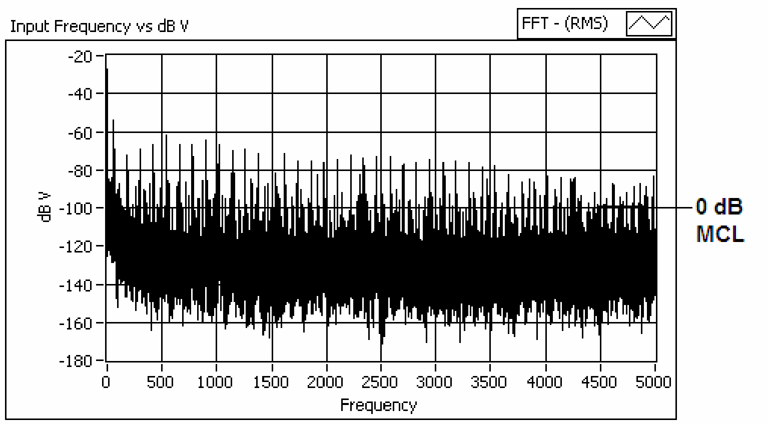
(k)


Input Frequency vs dB V
FFT - (RMS)
dB V
-20
-40
-60
-80
-100
-120
-140
-160
-180
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Frequency
0 dB
MCL

(l)

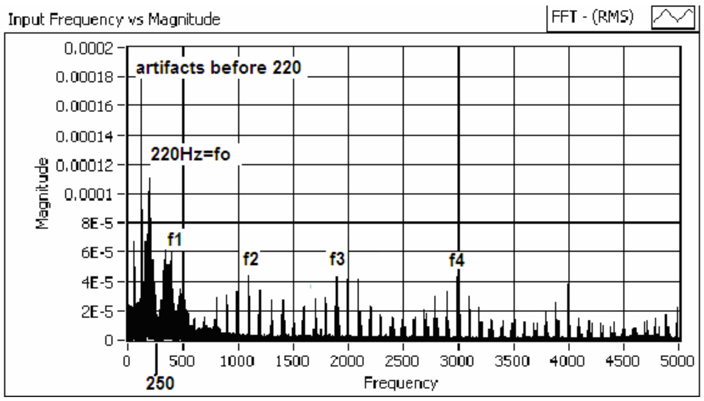


(m)



(n)

Figure 30: LabVIEW results show 6 random music choices and 1 combination of music (a)n=1 FFT magnitude vs Frequency, (b)n=1 dB V vs Frequency, (c)n=2 FFT magnitude vs Frequency, (d) n=2 dB V vs Frequency, (e) n=3 FFT magnitude vs Frequency, (f)n=3 dB V vs Frequency, (g) n=4 FFT magnitude vs Frequency, (h) n=4 dB V vs Frequency, (i) n=5 FFT magnitude vs Frequency, (j) n=5 dB V vs Frequency (k) n=6 FFT magnitude vs Frequency, (l)n=6 FFT dB V vs Frequency, (m)combination FFT magnitude vs Frequency, (n) combination FFT dB V magnitude vs Frequency

(a)


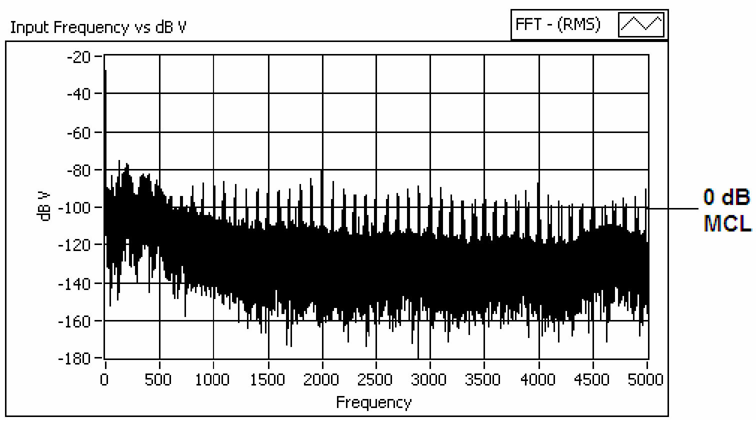
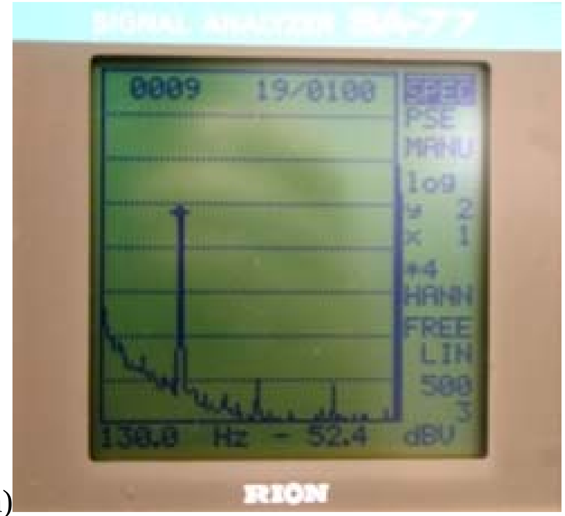
(b)


Figure 31: LabVIEW results for voice out of the Lynk device (a) FFT magnitude vs Frequency and shows fundamental and harmonic frequency's (b) FFT dB V magnitude vs Frequency and shows the most comfortable level of listening (MCL)

4.1.5 Vibrotactile Wrist Lynks Reader

An accelerometer, coupled to the FFT Signal Analyzer SA-77, was used to determine the amount of acceleration produced by the wrist vibrotactile device after speech has imitated from the Lynks Reader. Testing was preformed on the table at n=1 and on the wrist at n=6. An example of the results, found in Figure 32, demonstrated the SA-77 FFT screen with peak results. Fundamental frequency peaks were collected from these graphs, reflected in Table 7, as 130Hz for the table vibration and an average of 116 Hz for mass load on the wrist.

(a) 

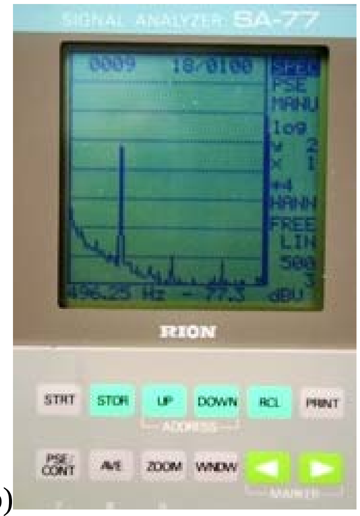
(b) 

Figure 32: SA-77 FFT Wrist Vibrotactile device (a) on the table, (b) on the wrist

Table 7: SA-77 FFT Wrist Vibrotactile device results

	Hz	dB V
Vibrotactile device on table		
n=1	130	52.4
Vibrotactile device on wrist		
n=1	116.25	57.8
n=2	112.5	64.5
n=3	110	73.3
n=4	116.25	69
n=5	112.5	64.5
n=6	130	68.8
Average	116.25	66.3

4.2 Discussion

4.2.1 Academic Testing

The average of the three nonsense Syllable Fluency tests produced statistical results in a Two Way ANOVA. The Two Way ANOVA reveals the results are statically significant between each individual and between the pre and post test since the *p-values* are below 0.05. These results demonstrated a considerable increase of 21 percent for the eight individuals that used the device for four weeks and an increase of approximately 16 percent for the control group that listened to music while reading aloud. This is a difference of a four percent increase in reading fluency for the eight individuals that used the device over the four weeks. In determining the most efficient Lynks Reader for nonsense syllable reading fluency, a comparison between each of the four devices suggested an average increase over the control group for the analog Lynks Reader was approximately 12 percent and for the wrist vibrotactile Lynks Readers was seven percent. The wrist vibrotactile, with the analog Lynks Reader, found an approximate four percent increase while the DSP board exhibited less than a one percent increase. These results demonstrated the most proficient Lynks Readers were the analog device and the wrist vibrotactile device; confirming increased reading fluency.

The college level Fluency and Comprehension test provided adequate self reported comprehension as a result of confirmation using interviewing and informal testing for story details. These individuals revealed a high level of comprehension for the college level text book material. Results for the college level fluency test demonstrated a statically significant *p-value* below 0.05 between the pre and post test, but not between the subjects.

These subjects increased an average of 29.8% over the four week period where the control group had an average of 3.6% increase from the pre to the post fluency test. These results proved Lynks Readers helped the individuals increase in college level reading fluency by 26%. Comparison between each of the four Lynks Readers found an overall increase in college level fluency per device over the control group. This is reflected in the following results: 40.6% for the wrist vibrotactile device, 34.9% for the analog wrist vibrotactile combination device, 21 percent for the analog device and approximately 16 percent for the DSP device. This established the most efficient Lynks Reader for this test is the wrist vibrotactile and combination Lynks Reader. This verified an increase in reading fluency.

The dichotic listening results demonstrated an overall average of REA, or left hemisphere dominance, of 17 percent at the pre test and decreased to approximately fourteen percent for the post test. This is not statically significant and is demonstrated by a Two Way ANOVA with *p-value* above 0.05. These results found no evidence of a change in hemisphere dominance. However, the differences between each individual and the two controls produced statically significant results with a *p-value* below 0.05. This was expected because all people have a different level of REA, however, an increase in REA was expected.

The likely reason no significant change occurred in REA can be attributed to many factors. The right hemisphere was activated by music being played in the left ear. Six of the individuals were women. It has been demonstrated that, depending on when females were administered the test within the month, results will vary as to left or right hemisphere dominance because of hormonal variations. These variations could have been controlled

by having the women tested a week after their menses stage for each of the assessments. The midluteal phase demonstrates more of a REA than the menses stage affecting the results of dichotic listening. Furthermore, the number of pairs of CVs given may have affected testing results. A total of 60 pairs for the dichotic listening tests given to all individuals were sufficient and commonly practiced. Nevertheless, more pairs might have been helpful obtaining more accurate readings. There are still other factors which could have affected the test. For instance, the length of the dichotic listening test will increase in the amount of time the test takes. Consequently, the subjects will have a decreased attention, thus, decreasing the accuracy of the results.

4.2.2 Survey and Questionnaire

By being able to focus on the material, most subjects thought the Lynks Readers helped them concentrate and read faster, where others thought it was distracting right from the beginning. The following are factors which can influence the main results of the academic testing. One issue is the time it takes for most people to get used to reading out loud. Additionally, another concern was speaking into a microphone while listening to their voice coming into the right ear via the headsets. In addition, disruptions occurred caused by voice levels being higher than music levels. Even though the subjects always heard their own voice, sometimes the device would click in and out causing an interruption in reading. Additionally, when the music changed from one song to another, a pause occurred, distracting some of the subjects. Furthermore, the test subjects' comfort level in using the devices surfaced as a result factor. All these factors that can influence the

outcome of the results by causing the individuals to be less focused on reading and comprehending the material.

Choosing headphones with greater sound quality and music playing devices in combination with the Lynks Reader does help with comfort level, concentration and comprehension. All of the eight individuals tested experienced the different types of headphones, MP3 players, and CD players while using the Lynks Reader over the four week period. During this time, the individuals using the Lynks Readers migrated towards Optimus Pro-50MX and KOSS headphones attributable to better sound and less static. The Optimus Pro-50MX and KOSS headphones along with their microphone attachment produced a better voice reproduction playing through the headphones to the ear. All subjects, as a result of the ease of operation and their familiarity with, tended to use one of the two MP3 players on hand instead of the CD players. Owing to their increased comfort level, an increase in comprehension and concentration can occur.

4.2.3 Compare Dichotic Listening Test

The dichotic listening test commercial version aligned the CV sounds, or the Voice Onset Time (VOT), at the start of the sounds. The developed dichotic listening test aligned the CV sounds at the burst of the sounds. This was achieved due to the ease of alignment CV sounds and to avoid infringements on the commercial versions. Figure 24 demonstrates the /ba//pa/ alignment of the VOT of the sound is at the origination of the sound where Figure 25 illustrates the /ba//pa/ alignment of the VOT at the burst of the sounds. Where the /ba/ sound burst, or vibration, starts at the /b/ and the /pa/ sound burst

starts at the /a/ sound when they are pronounced. All dichotic listening test were aligned at the VOT in one of these two ways. There was no documentation to state which is the better or correct way to make the test.

The waveforms and frequency graphs in Figures 13-24 were different in the commercial verses the developed dichotic test because the different voice and equipment used to make each version cause a change in waveform and frequency production. The developed test displayed more of a controlled duration from about 73 seconds to 89 seconds. The commercial version had a wider duration from 47 seconds to 83 seconds.

4.2.4 Music and Voice from the Lynks Device headset

The SA-77 FFT music data graphed in Figure 26, depicts a flat line expect for one peak on series 5. This could be caused by recording some of the random music choices at a higher level intensity because of the amount of sampling taking place. Since the FFT was only doing 100 samples, the graph might have needed more than 1000 to get an overall result to be equivalent to the others. In Figure 27, the excel graph produces about a 40 dBV difference in the music level between the random song choices.

Subsequently, the LabVIEW results in Figure 28 Frequency verse Magnitude graphs, revealed an artifact below 100 Hz. The headphones used have an operation level beginning at 30-20,000Hz and the microphone operational level is at 100-16,000 Hz. These artifacts can be accounted for by instrument or computer noise acquired by LabVIEW. The frequency response given by these graphs is between 100-16,000Hz.

These graphs flatten out after 3500Hz owing to the music being more intense at lower frequencies and flatter at higher frequencies.

The frequency verse dBV results LabVIEW generated in Figure 28 are only good between 100-16,000 Hz. These graphs flatten out to about -100 dBV (dB per one volt) which is the physical result. The physiological result is zero dB which is the most comfortable level of listening. This is how the ear integrates the music. The Hanning filter results in a relatively flat spectrum and is similar to how the ear filters out the sound. Hanning filters are designed to be used with FFT analysis which attenuates the beginning and end of a signal (rise and fall) to reduce the effect of discontinuities at the commencement and conclusion of sampling. The ear takes extremes and flattens them down making the sound clearer, hearing more low frequencies. The frequency vs. dBV graph represents how the ear would perceive the sound. Differences, between the high and low peaks across the graph, give a relative difference of about 60 dBV.

The combination of n=6 music choices is portrayed in Figure 28 m (frequency and magnitude) and Figure 28 n (frequency and intensity in dBV). The frequency and magnitude graph reveals an artifact about 100 Hz and other frequencies decreased towards the end as the music is mostly low frequencies. The frequency and amplitude dBV graph discloses a lower than zero dB or -100 dBV because of the random music choices. Therefore, the results are -20 dBV lower than expected. This is not a concern since the music had variable amplitudes and the level difference is related to sampling. The amplitude differs from 60dBV to 80 dBV.

The female voice data coming from the Lynks Reader device is exhibited in Figure 29. The female voice has a fundamental frequency of about 220 Hz as the vocal cords bang together. Any data before 220 Hz is considered an artifact. The harmonic frequencies are multiples of 220 Hz. This is caused by the vocal cords acting like a resonator. This is displayed in the frequency verse magnitude graph. The frequency and intensity in dBV graph depicts a flat response, just below the MCL (zero dB), for the subject speaking who has a lower voice level than the most comfortable listening level.

4.2.5 Vibrotactile Wrist Lynks Reader

An accelerometer, placed on the vibrotactile watch on the wrist, with the vibrations activated, produced a strong fundamental frequency at an average of 116 Hz with the dB V at an average of 66. This fundamental frequency demonstrated repetition with harmonics at 232 Hz, 348 Hz, and 464 Hz where the frequencies start to decrease. This is caused by the wrist acting as a damper, decreasing the energy going through the device to the accelerometer.

4.2.6 Conclusion

The object of this trial with each of the Lynks Reader devices, DSP and Analog board, was to determine their best operational parameters and most effective use. Determining how to use the Lynks Reader devices more effectively was completed by measuring achievement scores via dichotic listening test, three nonsense Fluency test, and one fluency comprehension test. Each of the nonsense syllable test were created, as was another dichotic listening test. This development was performed to prevent any

infringement issues when the device is put into production. Furthermore, questionnaires and surveys were administered to each individual subject to determine best equipment and devices to use with the Lynks Readers. Determining the best way these devices process information was accomplished by investigating voice and music coming in and out of the device along with vibrations made by the device.

The determination was made that it takes about four sessions for individuals to start getting comfortable with the Lynks Reader, be it the wrist vibrotactile Lynks Reader, the wrist and analog Lynks Reader, the analog Lynks Reader or the DSP Lynks Reader. Moreover, the longer the individual subject worked with the device, the more they thought it helped them read faster while still comprehending material. However, most individuals thought that the clicking produced from switching from music to voice was a distraction. The changing of music from one song to the next was distracting at points. To prevent this from occurring a MP3 file or a burned CD having continuous music can be created. Furthermore, the best two headphone choices of the individuals that used the device were the KOSS and Optimus. The operational and use parameters, therefore, have been established by this study.

The dichotic listening test for the pre and post test proved that there was not an increase in REA or left hemisphere dominance. There are a number of reasons as to why the dichotic listening test did not demonstrate an increase in REA. The fact that the volunteers for this study were all engineers could have played a role in the results. Engineers usually demonstrate a bilateral hemisphere dominance which means they use both the right and left hemisphere equally. Since engineers are good at spatial awareness

(viewing circuit diagrams), a right hemisphere function, and at analyzing problems, a left hemisphere function, could have caused the shift in hemisphere dominance. Differences between men and women, discussed earlier, could have played a role along with the differences in women's hemisphere dominance during their menstrual cycle.

However, the three nonsense Syllable test proved about a four percent increase in fluency above the control group. The device with the most increase in reading fluency, over the control, was the Analog Lynks Reader and the wrist vibrotactile Lynks Reader with an approximate increase of ten percent. The Comprehension Fluency test demonstrated a greater increase of 26 percent over the control group. The device that had the most increase in reading comprehension fluency was the wrist vibrotactile Lynks Reader and Analog Wrist Lynks Reader with over a 35 percent increase. An increase over the control group was portrayed by the analog Lynks Reader with an increase over 20 percent and the DSP Lynks Reader over 15 percent. This demonstrates that all the devices revealed an increase over the control group who did not use the devices.

The top three devices, in order of increase in Fluency, are the Wrist, Analog Wrist and Analog Lynks Readers. The foremost reason the wrist vibration on the right wrist helps reading comprehension and fluency can be contributed to the mechanoreceptors in the wrist. The Pacinian and Meissner corpuscles are activated at a certain frequency, transferring information (with in their receptive field) processed in the parietal lobe of the brain. The parietal lobe, on the left side of the brain, specializes in comprehension of written and spoken words; likely contributing to the large increase in both fluency and comprehension in trial where the wrist vibrotactile device was used singularly or in

combination with the analog device. In addition, the mechanoreceptors activate the left frontal lobe which can trigger attention mechanisms increasing concentration. This will enhance the individual's attention span while taking the test, therefore, increasing their reading fluency.

However, previous data collected provided an increase in REA, grade reading level and reading fluency for Army recruits and an increase in grade reading level with high school students. Even though the dichotic listening test did not demonstrate an increase in REA in this study, the increase in reading fluency demonstrates an increase in left hemisphere work. Left hemisphere functions control language processing, logic and speech. The left hemisphere controls the vocal track for speech thus phonically pronouncing words while the right hemisphere is where sight words are remembered. Therefore, the nonsense syllable fluency test not only was demonstrating an increase in the amount of words an individual can read over time, but an increase in left hemisphere operation. Even thought the dichotic listening test did not reproduce this REA, or left hemisphere dominance, the left hemisphere was more active after four weeks of eight fifteen minute sessions. This has proven the hypothesis that the Lynks Readers improve reading proficiency and left hemisphere dominance.

The safety of the Lynks Readers is within OSHA and American National Standards requirements. The music and voice levels coming into the headphones is well below 80 dB which is the OSHA regulation requirement for an eight hour day to prevent hearing damage. The only OSHA information on vibration level is not to have excessive vibration over a long period of time. However, the American National Standards stipulates that

vibrations lasting four to six hours per day can produce vascular symptoms in the hand after ten to twenty years of exposure. Vibration exposure less than half an hour a day rarely causes any damage or problems. The maximum allowable vibration for 16minutes is 225 Hz with an acceleration of 120 ms^{-2} rms.(Griffen, 1990) The vibration produced by the wrist vibrotactile Lynks Reader was about 116 Hz and -66 dBV which is within vibration level standards.

4.2.7 Future Research and Implication

Follow up research is needed to determine if the increase in reading fluency persists after months without further use of the Lynks Readers. Such research will likely determine if the Lynks Reader must be utilized over a longer period of time to maintain increased level of left hemisphere activation.

There are other applications for these devices. For instance, they may be effective with children between the grades of 2^{nd} and 4^{th} grade with learning disabilities, illiterate adults, adults with English as a second language, and with the military. Individuals in the military have an average reading level of about the fourth grade, and many have English as a second language. It has already been demonstrated in previous research that the Lynks Reader helps individuals in the military with English as a second language. Therefore, by using the Lynks Reader, individuals with a lower than average reading level will improve their grade reading level and left hemisphere dominance.

The reason children in grades of 2^{nd}, 3^{rd} and 4^{th} with reading disabilities might benefit from the Lynks Readers is because they have not fully developed all of their neural

pathways to the right and left hemisphere. These pathways to the left hemisphere are needed to develop beyond the 4th grade reading level. The Lynks Reader device, along with testing procedures like the dichotic listening test and nonsense fluency test, can give us more information as to how much their neural pathways have been developed. This movement into the left hemisphere will help them with reading difficulties and attention problems. Further research with the Lynks Readers will definitely benefit these groups of individuals.

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Literature Cited

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APPENDICIES

APPENDIX A

A) **Language Acquisition Survey**

Name____ Date________________.

Answer the following items as best you can

1. Is English your First Language? Yes________ No________
    a. If not: What is your native language?____________________

2. Have you learned a foreign language(s)? Yes________ No________
    a. When did you learn the language(s)? ____________________
    b. What was the language(s)? ____________________
        i. Was it very difficult for you? Yes________ No________
        ii. Somewhat difficult? Yes________ No________
        iii. Not much of a problem? Yes________ No________
        iv. Very easy? Yes________ No________

3. Are you Right handed? Yes________ No________

4. Do you have siblings that are left handed? Yes________ No____________
    Brother(s) Yes________ No________ #______
    Sister(s) Yes________ No________ #______

5. Do you have parents that are left handed?
    Mother Yes________ No________
    Father Yes________ No________

6. Did your parents ever refer to you as:
    a. As late talker as an infant Yes________ No________
    b. As a late walker as an infant Yes________ No________

7. In Elementary school did you enjoy reading for pleasure?
    Most of the time Some Rarely

8. Currently how many books have you read in the past year? #__________

9. When you were in elementary and middle school, where you ever tutored in reading?
    a. Elementary Yes________ No________

b. Middle school Yes ____________ No ____________

10. Do you have a diagnosed learning disability? Yes ____________ No ____________

a. If yes, describe: ____
____
____
____

11. Do you recall learning to read? If so was it:

a. Very easy for you: Yes ____________ No ____________
b. Somewhat difficult Yes ____________ No ____________
c. Difficult Yes ____________ No ____________
d. Very difficult Yes ____________ No ____________

12. Do you play a Musical instrument? Yes ____________ No ____________

a. What instrument?______________________________________

13. As a child, when learning to skip, was it:

a. Very easy for you: Yes ____________ No ____________
b. Somewhat difficult Yes ____________ No ____________
c. Difficult Yes ____________ No ____________
d. Very difficult Yes ____________ No ____________

14. What school grade would you give yourself for the following:

A+ A A- B+ B B- C+ C C- D+ D D- F

a. Reading__________________
b. Spelling__________________
c. Handwriting______________
d. Drawing__________________
e. English Grammar__________
f. Writing essays_____________
g. Motor skills (running, skipping, marching, doing exercises to music)_____
h. Posture___________________
i. Vision____________________
j. Paying attention to things/not forgetting___________
k. Use of Oral Language__________________________
l. General Intelligence___________________________
m. Math Problems(numbers only)__________________
n. Math word Problems____________________________
o. Memorizing telephone numbers_________________

B) Questionnaire

Name: ____ Date: ________________.

1. Which device are you using?
2. How many times have you used the device?
3. How did the device work for you (was it easy to operate or were their problems)?
4. When did you stop hearing the music in the right ear?
5. Did stop noticing the music in your Left ear? If yes, how long?
6. Did the music in the right ear distract you from reading out loud or hearing what you were reading? Explain.
7. What type of reading material are you using?
8. Which headphones did you use?
9. Did the headphones fit?
10. How was the sound level?
11. What did you think of the device?
12. If using the vibrotactical wrist device.
    a. How was the vibration level?
    b. Did you stop noticing the vibrations on the wrist?
    c. Was it distracting?

C)

<u>Nonsense Syllable Test(1)</u>

1.	SEV	GER	VEL	MOR	LOL	DIF	TES
2.	NIM	DIN	MOR	CAL	REN	COM	CAL
3.	TOD	NIM	VER	COR	VER	GIF	SEV
4.	MAL	LUD	CAL	DIN	JAV	MOR	LIG
5.	KIN	LOS	MEM	HUM	SAV	TAL	SAV
6.	CAM	DIF	TER	COM	PAR	SAV	WER
7.	VER	TES	VOS	LUD	COM	LIG	KIV
8.	NIM	HIL	MON	CEN	TES	MAR	HIG
9.	RIC	COR	BEC	KIN	JEC	HIL	DIN
10.	PAP	TAS	PER	SAV	WER	PEC	SES
11.	VEL	CID	NES	DIR	CEN	REN	LIG
12.	CAL	VIS	RIC	CEN	TAN	VEL	PEC
13.	GUR	JEC	SIP	JEG	LUD	TES	LUC
14.	NUM	GAV	LUD	NES	VIS	NAL	SUP
15.	TAL	TES	COR	TAS	DAR	TAM	PAC
16.	MON	MAR	PAC	GUR	BES	MEM	CAF
17.	MER	TER	COM	COR	CAL	DIZ	DAR
18.	TED	TOD	NES	DIF	SEV	LIK	FER
19.	TAL	SUP	GUR	NES	SUC	ROR	HEG
20.	COM	PAP	COR	NIM	VOS	POR	GIF
21.	GUR	HAB	DIN	HIL	MUC	JEC	SAV
22.	COR	RES	TAT	DIN	SAV	LUD	GER
23.	PAS	TER	TIS	COM	CED	RAR	POR
24.	NES	LAT	TAT	LUD	PAS	TED	CES
25.	MAR	MER	MEN	GEK	HIG	WER	LEX
26.	PEC	TAL	CES	HAL	LUC	BES	MAR
27.	GEN	COL	SAR	GUR	DIR	GER	POR
28.	LAT	GUR	CED	LOS	DAR	COL	MUC
29.	TUR	CID	GUS	TES	TES	LAT	FER
30.	TES	SIM	PEC	VEL	CEN	TAN	HOL
31.	FIC	NID	TAL	ZAM	PAR	MAR	SAR
32.	HIL	MAK	RIC	TAS	TUR	GAV	LUD
33.	VEL	HUL	GEN	VEL	JEC	POP	VEL
34.	VER	VER	KAM	VER	GAV	MEN	ROR
35.	VIS	BAS	PAS	GIF	CID	GED	GER
36.	LEX	LEL	VIS	TES	TUR	HIG	TAS
37.	TIF	TAT	PAP	NAL	LUD	HAV	HOS
38.	CAL	NES	TOD	MEM	TER	DIF	MEM
39.	HAV	VER	LEX	DIZ	VIS	NAL	DIV
40.	MOR	HIL	COM	ROR	LAV	GAV	TUR
41.	VER	COM	NES	POR	TUR	TED	TAN
42.	KIN	GUR	NIM	JEC	CAL	BES	PUL
43.	COM	SAV	TIF	WER	TAS	FER	PER
44.	NES	LOS	VER	HOS	VEL	VOS	DIZ
45.	COR	TES	GUR	MAR	PAC	DIF	DIN
46.	SAV	MAR	TED	MAL	NES	HAV	SED
47.	CEN	VEL	LUL	VEL	TAS	PUL	VOS
48.	GUR	CEN	GER	HIL	VER	LAR	POP
49.	GUR	PAP	HAV	LUD	HOS	HIG	LEX
50.	HAV	PAR	GUR	MOR	COL	BAS	DAR

D)

Nonsense Syllable Test(2)

1.	SEVNIM	MAR LUC	GERPOR	KINNES
2.	KINVER	GIFTES	MARPAR	COMSAV
3.	VELGUR	LUDWER	JECTAS	CENMAR
4.	MONNIM	BESTED	VELGIF	VELGUR
5.	MALTAL	GAVNAL	MARMOR	CAMRIC
6.	CALNUM	MEMDIZ	COMSAV	PAPPAS
7.	TURRIC	RORPOR	CENLUD	PECVIS
8.	PAPTOD	JECGER	CALTES	LEXMOR
9.	CAMPAS	COLLAT	WERVIS	VERTIF
10.	PECGEN	TANDAR	BESSUC	GURGEN
11.	VISLEX	POPDIN	TEDGAV	PACCID
12.	TIFGUR	PECFER	NALPEC	TERVIS
13.	TESFIC	VOSPUL	TISVER	TURHOS
14.	HILVER	DIVCAL	NUMBAL	HUMCOL
15.	COMCOR	SEVLIG	LATBES	VERTAL
16.	CERTAL	SAVHIG	VISWER	NESHIL
17.	TEDMAR	LUCSUP	TESSEV	PARDIF
18.	VELMOR	PACFER	GIFJEC	GAVPEC
19.	VERHAV	HEGGIF	PULKIN	RENLIG
20.	GURLOS	DIFHAV	MACMUC	TAMVEL
21.	KINCOM	MARHIG	CANHAV	SAVTAS
22.	NESSAV	BASSED	LUCFER	TASJEC
23.	CENGUR	TATTIS	VOSTAN	GIFMAR
24.	CORDIN	TATMEN	DARMUC	LUDTES
25.	NIMLUD	CESSAR	SEVNES	BESWER
26.	GERTES	CEDGUS	RICCED	TEDTED
27.	HILVER	RENHUM	LATSUP	CORLUD
28.	COMPAP	COMMAL	PAPRES	GERDIN
29.	CORTOD	VEL FER	TERHAB	NIMHAV
30.	VISCAL	LEXPAS	MERTAL	GURGAV
31.	HAVLAT	TURTES	COLVER	LOSCAL
32.	NESTES	CESSAR	CIDTER	TESTOD
33.	LUDGAV	MENHOL	VOSPER	VERCOR
34.	TURCAL	SEDHIG	LIGSIP	PAPCAL
35.	PACHOS	MARHAV	MONBEC	VISNAL
36.	COLVER	DIFNAL	CORSIM	HAVHIL
37.	NESTAS	GAVTED	VIDLUD	TESLAT
38.	DIFHIL	BESWER	HIGSED	NESLUD
39.	PARJEC	LUDVEL	BASMEM	GAVTUR
40.	GAVCID	TASHOS	VELTAT	MEMCOM
41.	TERVIS	GERROR	MAKHUL	TANPUL
42.	TURHUM	PERDIZ	GURHOD	DIVPOP
43.	TALSAV	MEMDIN	NERWEG	SEVSUP
44.	LIGPEC	POPDAR	LUNSAV	DARLIG
45.	REN HIL	TANLAT	PORLUC	PACHIG
46.	VELTAM	DIVPUL	PASTUR	LUCFER
47.	TASVEL	VOSFER	TESDIV	DINFER
48.	CALLUD	PECTES	DARMUC	VOSPEC
49.	CENSAV	TURPAS	SESLIG	CAL GIF
50.	COMMOR	LUCLEX	CAFDAR	SAVMAR

E)

NONSENSE SYLLABLE TEST(3)

1.	SEVNIMTOD	TESVELTAM	HIGBASTES
2.	MALKINCAM	TASVELVER	CALSEVLIG
3.	VERNIMRIC	GIFTESNAL	SAVWERKIV
4.	PAPVELCAL	MEMDIZROR	HIGDINSES
5.	GURNUMTAL	PORJECWER	LIGPECLUC
6.	MONMERTED	HOSMARMAL	SUPPACCAF
7.	TALCOMGUR	VELHILLUD	DARFERHEG
8.	CORPASNES	MORCOLREN	GIFSAVGER
9.	MARPECGEN	VERJAVSAV	PORCESLEX
10.	LATTURTES	PARCOMTES	MARPORMUC
11.	FICHILVEL	JECWERCEN	FERHOLSAR
12.	VERVISLEX	TANLUDVIS	LUDVELROR
13.	TIFCALHAV	DARBESCAL	GERTASHOS
14.	MORVERKIN	SEVSUCVOS	MEMDIVTUR
15.	COMNESCOR	MUCSAVCED	TANPULPER
16.	SAVCENGUR	SUPPAPHAB	DIZDINSED
17.	GURHAVGER	RESTERLAT	VOSPOPLEX
18.	DINNIMLUD	MERTALCOL	DARLATLUC
19.	LOSDIFTES	VERBASVEL	PECLATPAS
20.	HILCORTAS	TATMEMGUR	WERPARBES
21.	CIDVISJEC	CIDSIMVID	SEVTESFER
22.	GAVTESMAR	MAKHULTER	LUCTURVIS
23.	TERTODNES	VOSMONBEC	PASTESHIL
24.	VERHILCOM	PERNESRIC	TEDWEGPEC
25.	PAPPARVEL	SIPLUDCOR	GAVNALNER
26.	MORVERCAL	PASHIGLUC	TISLUNJEC
27.	PACKINCOM	DIRDARTES	PULGIFSED
28.	NESGURCOR	CENPARTUR	HODVERMUC
29.	DINTATTIS	JECGAVCID	NUM KINMAC
30.	TATMENCES	TURLUDTER	CANBALJEC
31.	SARCEDGUS	VISGAVTUR	FERTASVEL
32.	PECTALRIC	CALTASVEL	GIFHAVLUC
33.	GENKAMPAS	PACNESTAS	TURVIDNUM
34.	VISPAPTOD	VERHOSCOL	HODLUCDAR
35.	LEXCOMNES	DIFCOMGIF	DARVANBIK
36.	NIMLULGER	MORTALSAV	CESNUMROR
37.	HAVGURSAV	LIGMARHIL	LUBGUSJEC
38.	LOSTESTIF	PECRENVEL	HUMVOSPAP
39.	VERGURTED	TESNALTAM	LARWIPLAT
40.	MARVELCEN	MEMDIZLIK	SUPHIGCOR
41.	GURMORCAL	RORPORJEC	TALVERTER
42.	CORDINHUM	LUDRARTED	MERHUMCOM
43.	COMLUDCEN	WERBESGER	MALTATSED
44.	KINSAVDIR	COLLATTAN	POSMONTUR
45.	CENJEGNES	MARGAVPOP	LIGCORCAL
46.	TASGURCOR	MENGEDHIG	CIDMERHOD
47.	DIFNESNIM	HAVDIFNAL	DIZPARHIL
48.	HILDINCOM	GAVTEDBES	JECGUSLUC
49.	LUDGEKFER	FERVOSDIF	LEXPORGIF
50.	HALGURLOS	HAVPULLAR	BALMARSAV

APPENDIX B

A) Dichotic Listening Test: Example of Test Sheet

TEST 45

	Right		Left		Double correct	error		Right		Left		Double correct	error
1	KA		GA				37	GA		KA			
2	GA		TA				38	TA		GA			
3	TA		PA				39	PA		TA			
4	BA		KA				40	KA		BA			
5	PA		BA				41	BA		PA			
6	TA		TA				42	TA		TA			
7	TA		KA				43	KA		TA			
8	BA		PA				44	PA		BA			
9	PA		PA				45	PA		PA			
10	BA		TA				46	TA		BA			
11	TA		BA				47	BA		TA			
12	BA		DA				48	DA		BA			
13	KA		DA				49	DA		KA			
14	GA		DA				50	DA		GA			
15	PA		TA				51	TA		PA			
16	GA		GA				52	GA		GA			
17	DA		BA				53	BA		DA			
18	TA		DA				54	DA		TA			
19	DA		TA				55	TA		DA			
20	GA		PA				56	PA		GA			
21	PA		KA				57	KA		PA			
22	PA		GA				58	GA		PA			
23	DA		GA				59	GA		DA			
24	BA		BA				60	BA		BA			
25	PA		DA				61	DA		PA			
26	KA		PA				62	PA		KA			
27	KA		BA				63	BA		KA			
28	KA		TA				64	TA		KA			
29	DA		KA				65	KA		DA			
30	GA		BA				66	BA		GA			
31	BA		GA				67	GA		BA			
32	DA		PA				68	PA		DA			
33	TA		GA				69	GA		TA			
34	GA		KA				70	KA		GA			
35	KA		KA				71	KA		KA			
36	DA		DA				72	DA		DA			
						TOTAL							

VITA

Anne Marie Reamey was born in Richmond, VA, USA on the 13th of January 1976. She received her Bachelors of Biochemistry in May of 2000 from Old Dominion University. She worked for Wyeth Consumer Healthcare (contract (June 2000-Oct 2001), full time(Oct 2001-July 2005) and temporary(June 2006-Oct 2006) employment) doing analytical chemistry, writing validation protocols, validation reports and test methods for ICP-AES, GC, and HPLC instrumentation for Wyeth products. Finally, she graduated from Virginia Commonwealth University in August of 2007 with a Masters in Biomedical Engineering.