



7-2000

# Time of Day Effects on the Performance on the Screening Test of Auditory Processing

Christine Anne MacKenzie

Follow this and additional works at: <https://commons.und.edu/theses>

 Part of the [Psychology Commons](#)

---

## Recommended Citation

MacKenzie, Christine Anne, "Time of Day Effects on the Performance on the Screening Test of Auditory Processing" (2000). *Theses and Dissertations*. 973.

<https://commons.und.edu/theses/973>

This Thesis is brought to you for free and open access by the Theses, Dissertations, and Senior Projects at UND Scholarly Commons. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of UND Scholarly Commons. For more information, please contact [zeinebyousif@library.und.edu](mailto:zeinebyousif@library.und.edu).

TIME OF DAY EFFECTS ON THE PERFORMANCE  
ON THE SCREENING TEST OF  
AUDITORY PROCESSING

by

Christine Anne MacKenzie  
Bachelor of Arts, University of Alberta, 1997

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of


Master of Science

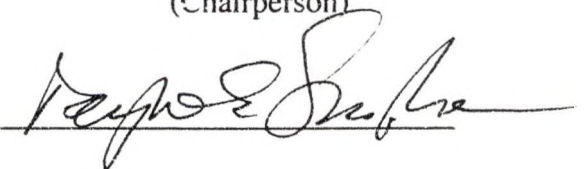
Grand Forks, North Dakota

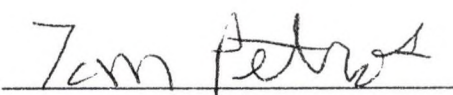
July

2000

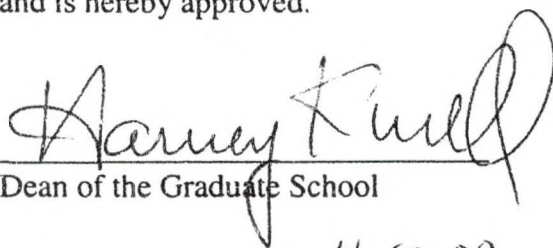
This thesis, submitted by Christine Anne MacKenzie in partial fulfillment of the requirements for the Degree of Master of Sciences from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

  
\_\_\_\_\_  
(Chairperson)

  
\_\_\_\_\_

  
\_\_\_\_\_

This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

  
\_\_\_\_\_  
Dean of the Graduate School  
4-5-00

\_\_\_\_\_  
Date

## PERMISSION

Title            Time of Day Effects on the Performance on the Screening Test of  
                    Auditory Processing

Department    Communication Sciences and Disorders

Degree         Masters of Science

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota. I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the chairperson of the department or the dean of the Graduate School. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of and material in my thesis.

Signature C. M. Zet

Date March 30, 2000

## TABLE OF CONTENTS

LIST OF FIGURES.....	vi
LIST OF TABLES.....	vii
ACKNOWLEDGEMENTS.....	viii
ABSTRACT.....	ix
CHAPTER	
I.    INTRODUCTION.....	1
Statement of Purpose.....	2
II.   REVIEW OF RELATED LITERATURE.....	4
Peripheral Auditory System.....	4
Central Auditory Nervous System.....	7
Central Auditory Processing.....	11
Time of Day.....	24
Summary.....	27
III.  METHODOLOGY.....	29
Subjects.....	29
Instruments.....	30
Procedures.....	33
Data Analysis.....	36
IV.  RESULTS AND DISCUSSION.....	37

Description of Variables.....	37
Descriptive Statistics of Variables.....	38
Inferential Statistics.....	46
Summary.....	64
<b>V. SUMMARY AND CONCLUSION.....</b>	<b>67</b>
Limitations of the Study.....	69
Suggestions for Future Research.....	69
<b>APPENDICES</b>	
Appendix A.....	72
Appendix B.....	74
<b>REFERENCES.....</b>	<b>77</b>

## LIST OF FIGURES

Figure	Page
1. The effect of test time on performance on the Filtered Word subtest in the left ear.....	52
2. The effect of subject type on the performance of Filtered Word subtest in the left ear.....	55
3. The effect of test time on performance on the Filtered Word subtest total score of the left and right ear.....	56
4. The effect of subject type and test time on performance on the Competing Word subtest in the left ear.....	63

## LIST OF TABLES

Table	Page
1. Means, Standard Deviations (SD) and Ranges for Morning-Type Person Tested in the Morning.....	39
2. Means, Standard Deviations (SD) and Ranges for Morning-Type Person Tested in the Evening.....	40
3. Means, Standard Deviations (SD) and Ranges for Evening-Type Person Tested in the Morning.....	41
4. Means, Standard Deviations (SD) and Ranges for Evening-Type Person Tested in the Evening.....	42
5. Pearson Correlation Coefficient for the Subtests of the SCAN.....	44
6. Pearson Correlation Coefficient for Morning-Type Person Tested in the Morning.....	47
7. Pearson Correlation Coefficient for Morning-Type Person Tested in the Evening.....	48
8. Pearson Correlation Coefficient for Evening-Type Person Tested in the Morning.....	49
9. Pearson Correlation Coefficient for Evening-Type Person Tested in the Evening.....	50
10. General Linear Model of Filtered Word Subtest on the SCAN.....	54
11. General Linear Model of Auditory Figure Ground Subtest on the SCAN.....	59
12. General Linear Model of Competing Word Subtest of SCAN.....	61



## ACKNOWLEDGEMENTS

I would like to express my gratitude to all of the people involved in helping with the completion of this thesis. First, I would like to thank Dr. Fire for his support, patience, and help during the entire process of constructing and writing this thesis. Second, I would like to thank Dr. Swisher and Dr. Petros for their guidance and support. Third, I would like to thank my family and friends for their support and encouragement through my education. Finally, I would like to thank the subjects who volunteered their time to participate in my study.

## ABSTRACT

The purpose of this study was to determine if any significant relationships existed between time of day and central auditory processing using a screening test of central auditory performance. The study specifically addressed the following research questions:

1. Is there a difference in the scores of morning and evening type individuals on the Filtered Word subtest, the Auditory Figure-Ground subtest, or the Competing Words subtest of the SCAN?
2. Is there a difference between morning and evening test time for differing types of individuals on the Filtered Word subtest, the Auditory Figure-Ground subtest, or the Competing Words subtest of the SCAN?
3. Are the effects of time of day the same for morning and evening type people on the Filtered Word subtest, the Auditory Figure-Ground subtest, or the Competing Word subtest of the SCAN?

Sixty-six college students participated in this study, 50 females and 16 males.

The subjects who participated in this study ranged in ages from 18 to 34 years old. The mean age was 20.6 years. In order to classify subjects as morning and/or evening type, Horne and Ostberg's Self-Assessment Questionnaire (1976) was used. Thirty-three subjects were selected that were morning-type and thirty-three subjects were evening type. Approximately half of the morning-type individuals were tested in the morning and

the other half were tested in the evening. Likewise, approximately half of the evening type individuals were tested in the morning and the other half were tested in the evening.

Prior to testing, each subject had his or her hearing screened to ensure normal hearing sensitivity. Normal hearing sensitivity was defined as auditory thresholds of equal to or better than 20dBHL at octave intervals from 1000Hz to 4000Hz. In addition, middle ear functioning was screened using tympanometry. Individuals who showed normal middle ear mobility and pressure were included in this investigation. After the determination of adequate hearing sensitivity, all subjects were administered the SCAN.

The SCAN, a Screening Test for Auditory Processing Disorders (Keith, 1986), was used to assess central auditory processing of the subjects. The SCAN has three subtests: Filtered Words (FW), Auditory Figure-Ground (AFG), and Competing Words (CW), which are designed to screen auditory perceptual abilities of an individual.

Descriptive statistics and inferential statistics were used to analyze the data. The following were the results:

1. Significant differences were found on the Filtered Word subtest in the left ear for the main effect of time of day and type of person. In addition significant differences for the effect of test time were found on the total test score for Filtered Word subtest.
2. No significant differences were found for the Auditory Figure Ground subtest.
3. Significant differences were found in the performance of the subjects in the Competing Word subtest for the right ear. Specifically, an interaction between the main effects of time of day and type of person was noted.

## CHAPTER I

### INTRODUCTION

There is a great deal of confusion about central auditory processing (CAP). This is not surprising due to the size and complexity of the system. The founding work in CAP assessing came from Bocca in the 1950s (Katz, 1994). Early attempts examined lesions of the central auditory nervous system through different types of stimulus presentations such as monotic stimuli, dichotic presentations and the use of filtered speech. Also, subjects with brain lesions were used to validate this testing of CAP (Bocca, Calero, Cassinari & Migliavacca, 1955). Central auditory processing disorders (CAPD) has been long defined in terms of the behaviors observed with the central nervous system (CNS) lesions. Furthermore, it was noted that when there is no evidence of a lesion the subjects with functional deficits have been compared to the patients with lesions (McFarland & Cacace, 1995a). It is from this testing that the presumed etiology of central auditory processing disorders arose.

According to the statement of the Task Force on Central Auditory Processing Consensus Development committee (1996), central auditory processing disorders are defined as an observed deficiency in one or more of the following behaviors: (a) sound localization and lateralization, (b) auditory discrimination, (c) auditory pattern recognition, (d) temporal aspects of audition, (e) auditory performance with competing

acoustic signals and/or from more general dysfunction that affects performance across modalities. Children with CAPD have been reported as having deficits including understanding speech in the background noise, distractibility, reduced auditory attention, inconsistent awareness of auditory stimuli, poor concentration and academic achievement lower than predicted by intelligence measures (Chermak & Musiek, 1992; Emerson, Crandall, Seikel & Chermak, 1997).

Despite the Task Force on CAP definition, there still is a lack of strict diagnostic criteria. This is one of the factors which makes CAPD a controversial issue. Another fact that makes CAPD a difficult diagnosis is the nervous system's constantly changing nature, especially when pathologies are present (McFarland & Cacace, 1995b). CAPD tends to be subtle, and difficult to diagnose and treat. As suggested, this could be due to the size and complexity of the nervous system. Another factor that may play into the difficulty in diagnosing this disorder is psychological or other human factors which can affect CAP abilities. These may include such things as circadian preference, memory, and aging. Thus, a number of factors influence performance on CAP measures. This increases the complexity of administration and interpretation of test results.

#### Statement of Purpose

The evaluation of the auditory perceptual system is a complex process, because it depends not only on peripheral hearing ability, but also on central hearing ability and numerous cognitive factors. Central hearing ability includes skills such as memory and the sequencing of sounds. Psychological research has demonstrated that cognitive factors such as memory and alertness are affected differentially by time of day depending

on the type of person tested (i.e., morning versus evening type). As central auditory processing is related to these psychological abilities and these psychological abilities are related to time of day, it would seem logical that auditory processing is related to time of day.

An earlier investigation completed by Rozzi (1997) at the University of North Dakota demonstrated that some clinically used auditory perceptual tests are affected by time of day. Also, previous researchers, such as Petros, Beckwith, and Anderson (1990), have demonstrated a relationship between memory and time of day. However, the relationship between time of day and performance testing has never been done with a screening test of auditory processing. Therefore, the purpose of this study will be to determine if there is a relationship between time of day and central auditory processing using a commonly available screening test of central auditory performance.

## CHAPTER II

### REVIEW OF RELATED LITERATURE

An important part of understanding the CAP system is the appreciation of the complexity of the CAP system. The CAP system includes the peripheral mechanisms such as the outer, middle, and inner ear and the eighth cranial nerve, as well as the cochlear nucleus to the cerebral cortex in the central auditory system. If there are problems with the passing of the acoustic message through the peripheral system, this can place a heavy burden on the CANS. The heavy burden is due to the distorted and/or incomplete message the CANS is receiving from the peripheral system. The peripheral mechanisms and CANS are intricate systems that rely on each other to interpret the auditory message. This message starts as sound waves entering the ears and travels through the central auditory system to the final destination of the brain. A breakdown in one of the “relay” stations in the central auditory nervous system can result in problems within the CAP, thus causing CAPD.

#### Peripheral Auditory System

The peripheral auditory system consists of four sections: (1) outer ear; (2) middle ear; (3) inner ear; and (4) eighth cranial nerve. The outer ear is comprised of the auricle and the external auditory meatus. The auricle plays an important role in the localization of high-frequency sounds and front-back localization of sound. Meanwhile, the external

auditory meatus collects and conveys sound vibrations to the middle ear via the eardrum (Naidoo & Feth, 1995). The external auditory meatus, due to its tubular shape, amplifies certain frequencies (2000-5000 Hz) by 16dB (Zemlin, 1998). Also, both the external auditory meatus and auricle have the additional function of being the protector of the middle and inner ear structures.

The middle ear is composed of a tympanic membrane, three ossicles, middle ear muscles and ligaments, and the Eustachian tube. Like the outer ear, the middle ear is filled with air. As the sound leaves the outer ear and approaches the tympanic membrane, the traveling waves of sound start the tympanic membrane into motion. These vibrations are carried into the oval window via the ossicular chain. The ossicular chain is composed of three bones: malleus, incus, and stapes. One of the major functions of the chain is impedance matching between the middle and inner ear. The changing densities of the media through which vibration must pass cause the mismatch in impedance from the air-filled middle ear canal to the fluid-filled inner ear. Vibrations not transferred to the inner ear may result in the potential loss of 30 dB of sound (Naidoo & Feth, 1995). The transfer of sound occurs through two mechanisms of impedance matching: the area ratio and the lever ratio. The area ratio is calculated by the difference in the area of the tympanic membrane in comparison to the stapes footplate. The tympanic membrane is basically 17 times larger than the stapes. This difference in size allows for an increase of about 25 dB in sound. The second mechanism is due to the size difference of the malleus and incus. The malleus is 30% larger than the incus, which creates a lever ratio. This difference in size results in a 2dB increase of sound (Naidoo &



Feth, 1995). Both mechanisms of impedance matching help in minimizing the loss of energy in the transmission process of sound.

The inner ear consists of the utricle, saccule, semicircular canal, and cochlea. The utricle, saccule, and semicircular canal are important for the vestibular functions, which include equilibrium and orientation in space. The organ of main interest is the cochlea, for its functions are important in the peripheral auditory system. The cochlea is a spiral-shaped structure with a base and an apex. The base responds to high frequencies, while the apex is responsive to low frequencies. The cochlea is arranged according to frequency with high frequencies at one end progressing to low frequencies to the other end. The one-to-one relationship or mapping of frequencies to specific locations on the basilar membrane (high to low) is called tonotopic (Bellis, 1996; Naidoo & Feth, 1995).

As sound travels through the stapes footplate onto the oval window, it causes the fluid of the inner ear to move. This wave moves from the base of the cochlea to the apex. The moving waves cause the basilar membrane to move up and down. The basilar membrane which is the lower surface supports the Organ of Corti. As the basilar membrane moves, it causes the tectorial membrane, the upper surface of the Organ of Corti to move. It is the Organ of Corti, which houses the hair cells. This upper surface moves across the top of the cilia. The movement of the cilia is often referred to as a shearing action. The shearing action is believed to start the electrical impulse traveling to the brainstem.

There are two types of hair cells: outer and inner. These hair cells send impulses to the central nervous system and receive information from the central nervous system.

The inner hair cells are in a single row, while there are three rows of outer hair cells. Each ear has, in total, approximately 3500 inner hair cells and there are 13 500 outer hair cells which are in the shape of a 'w' (Zemlin, 1998). The outer hair cells are generally thought to tune the basilar membrane. Each outer hair cell may be supplied by up to six afferent dendrite cells and each neuron branches out to 1000 outer hair cells, while the inner hairs cells are generally thought responsible for the majority of the detection of sound and the passing of the electrical impulses to the cochlear nucleus. Each neuron supplies a dendrite to one inner hair cell (Naidoo & Feth, 1995).

The afferent fibers send information on to the cochlear nucleus. Approximately 25 000 fibers arise from the inner ear (both vestibular and cochlea) and journey to the cochlea nucleus in the brainstem (Willeford & Burleigh, 1985).

An important aspect of the hair cell's composition on the cochlea is the tonotopic arrangement. This organization of cells is carried out throughout the central nervous system originating from the inner ear.

#### Central Auditory Nervous System

The central auditory nervous system (CANS) begins at the cochlear nucleus. The impulses arrive ipsilaterally from the auditory nerve to the cochlear nucleus. The cochlear nucleus (CN) complex is a bilateral nuclei located on the posterolateral surface of the brainstem between the cerebellum and the medulla. This area is also known as the cerebellopontine angle which is a common location for tumors ( Bellis, 1996; Musiek & Lamb, 1992). The cochlear nucleus complex has three parts: anterior ventral CN, the posterior CN, and the dorsal CN. It is believed that initial coding of various properties of

the auditory signal takes place here. Furthermore, the agreement between the type of cell and pattern of responses suggests that cells within the CN may provide the initial mechanism for central auditory processing and analyzing various properties of the acoustic signal (Musiek & Lamb, 1992). The tonotopic arrangement of the cochlear is maintained within the CN with low frequencies being represented ventrolaterally, while the high frequencies are represented dorsomedially (Musiek & Lamb, 1992). A pathway, the tuberculovent, connects the ventral and dorsal cochlear nuclei and there are three pathways which connect the cochlear nucleus complex to the next station of the CNS—the superior olivary complex. The three neural tracts are the dorsal acoustic stria, the intermediate acoustic stria, and the ventral acoustic stria. The largest fiber comes from the ventral acoustic stria, along with fibers from the intermediate acoustic stria and dorsal ventral stria, travels contralaterally to the superior olivary complex. Damage occurring in the CN can result in ipsilateral pure tone deficit and mimic auditory nerve dysfunction (Musiek & Lamb, 1992).

The superior olivary complex (SOC) is located in the caudal portion of the pons, which is ventral and medial to the cochlear nucleus (Bellis, 1996; Musiek & Lamb, 1992). It is composed of five nuclei: (1) lateral superior olivary nucleus, (2) medial superior olivary nucleus, (3) nucleus of the trapezoid body, (4) lateral preolivary nuclei, and (5) medial preolivary nuclei. The SOC is an important relay system with different nuclei for analyzing each input received. Information arrives ipsilaterally prior to contralaterally, which implies localization, lateralization, and binaural integration of the signal at the level of the SOC. Specifically, it is believed that the medial superior olivary

nucleus responds to the differences in time arrival, while neurons in the lateral superior olivary nucleus respond to slight differences in amplitude of sounds from the two ears (Heffner & Masterton, 1990; Zemlin, 1998).

The lateral lemniscus projects from the SOC to the inferior colliculus in the midbrain. There are two groups of cells comprising the lateral lemniscus: ventral and dorsal nuclei. It extends to the inferior colliculus contralaterally and receives information from both uncrossed and crossed fibers of cochlear nucleus and SOC (Bellis, 1996; Musiek & Lamb, 1992). The function of the lateral lemniscus is believed to continue with the bilateral representation of the signal from the SOC.

The next step in the CANS is the inferior colliculus, which is the largest structure of the auditory structures of the brain. The inferior colliculus is located on the dorsal surface of the midbrain. It consists of two divisions: central nucleus and the pericentral nucleus. According to Musiek & Lamb (1992) the central nucleus is composed of auditory fibers while the pericentral nucleus is made up of both somatosensory and auditory fibers. Somatosensory system responds to sensations of the body through the proprioceptive, exteroceptive, and interoceptive systems (Pinel, 1997). Auditory information received in the inferior colliculus is projected to the superior colliculus, reticular formation, and cerebellum. The cerebellum, specifically, receives somatosensory information. Information travels to the medial geniculate body ipsilaterally.

The medial geniculate body is situated on the inferior dorsolateral surface of the thalamus and serves as the relay station for auditory information going to the internal capsule. The medial geniculate body contains a ventral, a dorsal, and a medial division.

The neurons of the ventral branch are responsive only for the auditory signal, while the other two branches respond to both somatosensory and acoustic information (Musiek & Lamb, 1992). The ventral branch sends information to the cerebral cortex and dorsal division of the associated area of the auditory cortex.

The reticular formation forms the central core of the brainstem, which contains two systems: sensory and motor activating systems. According to Musiek & Lamb (1992) the reticular formation is connected to both the spinal cord and cerebrum. It has been suggested that the reticular formation prepares the brain to act on the incoming auditory signals.

The primary auditory cortex in the cerebrum is important for central auditory processing. Also known as the Heschl's gyrus, it is located on the posterior upper surface of the temporal lobe (Bellis, 1996). The primary auditory cortex is the site which receives information from the medial geniculate body through the internal capsule. Tonotopic organization of the cochlea is maintained. The information is passed from the temporal lobe to Broca's area (frontal lobe) via the arcuate fasciculus.

Finally, the left hemisphere may play the dominant role in language, sequencing, and analysis of auditory signal. However, the right hemisphere controls the "acoustic contour reception and perception of gestalt" (Bellis, 1996). Information is passed over the corpus callosum, which connects the two hemispheres of the brain. According to Bellis (1996) the corpus callosum has been identified as having five parts: anterior commissure, rostrum, genu, body, and splenium. Auditory information crosses through the

posterior portion (splenium) of the corpus callosum and from the right hemisphere to the left hemisphere of the brain or vice versa.

The CANS is a complex and large system. There still is a lack of knowledge of the exact functions of each structure on central auditory processing. The complexity of the system contributes to confusion in the ability to diagnosis central auditory processing disorders.

### Central Auditory Processing

Little is known about the analysis or coding of the auditory signals in the auditory system beyond the peripheral level (Stark & Bernstein, 1984). Often the effects of central auditory nervous system (CANS) disorders are not very noticeable and may be overlooked. In addition, there is a lack of standardization in central auditory tests and procedures, which contributes to problems and confusions in CANS testing (Musiek & Lamb, 1994). This confusion leads to problems in agreement as to what test is appropriate or most effective in determining the presence of central auditory processing disorders (CAPD). When reviewing CANS tests there are five categories used most often: (1) monaural low redundancy speech tests, (2) dichotic speech tests, (3) binaural interaction tests, (4) monaural temporal ordering tasks, and (5) electrophysiological tests (Musiek, Baron & Pinheiro, 1994). Most CANS battery tests include a subtest of each with the exception of the electrophysiologic tests. However, to be considered a thorough exam of the CANS, all categories should be examined.

In general, auditory processing tests reduce the redundancies by degrading, filtering, and distorting the linguistic signal (Sanger, Keith, Deshayes & Stevens, 1990) in

order to test CANS function. Various tasks are analyzed when testing CANS function, for example, selective attention, auditory analysis, synthesis, closure, discrimination, sound blending, non-linguistic and linguistic sequencing, and short-term and long-term memory for linguistic symbols (Keith, 1984). In addition, the tests evaluate central listening abilities, which include items such as temporal sequencing, interhemispheric interaction, localization, figure-ground, memory, sound blending, discrimination, closure, attention, association, and aspects of cognition (Musiek & Geurkink, 1980).

Some of the founding work in understanding central auditory processing came from the Staggered Spondaic Word test (SSW). It is ten-minute test originally used to study site of lesion in adults with tumors and strokes (Katz, 1992). From this use of the SSW, it was noted that the same signals that were found from brain damaged adult patients were found among children with learning disabilities. These abnormal test results could represent slower development and/or different patterns of neural operation in associated regions. It was found that lesions in the posterior temporal region (Heschl's gyrus) and the auditory cortex resulted in a greater number of errors on the second half of test stimulus items in comparison to the first half of the stimulus items. This is termed a low/high error order effect (Katz, 1992). People with these problems appear to have difficulties with receptive language and phonemic decoding. The opposite pattern was associated with problems in the anterior and frontal regions. These regions are associated with expressive language, memory, and behavioral problems. Specifically, damage to the anterior temporal region is linked to problems of auditory-figure ground function and/or speech-in-noise.

The SSW requires the listener to repeat the spondee words that are presented to both ears (Keith, 1981). Each spondee is presented in both a competing and non-competing condition. The SSW is administered in the right ear followed by the same routine in the left ear. An analysis is completed on four conditions: (1) right competing, (2) right noncompeting, (3) left competing, and (4) left noncompeting.

Several variables are important when looking at the CANS. Aging has been shown to result in deficits in the CANS. Also, maturation effects have been noted on almost all central auditory tests (Musiek, Gollegly, Lamb, & Lamb, 1990). Thus it is important that children be tested within their normative age group, and age appropriate norms are necessary in central auditory assessment.

Another important variable to consider in the evaluation of central auditory processing is hearing. Peripheral performance of the outer, middle, and inner ear is important to evaluate along with central auditory testing. Peripheral hearing loss has been suggested to cause decreases in central auditory test scores (Musiek & Lamb, 1994). Without proper functioning of the peripheral mechanisms, there would be a heavy burden placed on the CANS, making the tasks harder to complete (Katz, Stecker & Henderson, 1992).

According to ASHA (1992), central auditory disorders are deficits in information processing of audible signals not attributed to impaired peripheral hearing sensitivity or intellectual impairment. Thus, children who have CAPD "have deficits in the comprehension of speech in competing background noise, distractibility, reduced auditory attention, inconsistent awareness of auditory stimuli, poor concentration and



academic achievement lower than predicted by intelligence measures” (Chermak & Musiek, 1992; Emerson, Crandell, Seikel & Chermak, 1997). The SCAN was developed by Keith (1986) to identify those children. Children with CAPD are at great risk for academic problems, so the earlier they are identified the better the prognosis. With identification, treatment can begin and the classroom environment can be modified if needed to help the child. Modifications may include items such as an FM system, which can improve the signal to noise ratio to +30dB.

The SCAN was developed as a screening test for auditory processing disorders in order to combat some of the previously mentioned problems, such as the lack of standardization in CANS testing. The test was designed to provide a uniformly and rapidly administered, normative method for determining possible auditory processing problems related to a child’s language and academic performance (Keith, 1986). The SCAN is a quick screening tool with three main purposes. According to Keith (1986) the first purpose is to determine auditory maturation in order to see if there are possible disorders. The second purpose is to identify children at risk for auditory processing or receptive language problems. The last purpose is to identify those who may benefit from specific management strategies in central auditory processing.

People with central auditory processing disorders may be viewed as having difficulties in perceiving speech when the signal is not optimal, for example, in background noise. Problems with central auditory processing may signal a delay or deficit in the development of auditory pathways of the children. Central auditory processing disorders can be used to describe individuals who have communication

disorders or learning disabilities due to an inability to perform well on listening tasks. The listening tasks include the impaired ability to attend to, discriminate, recognize, or comprehend information presented auditorily (Keith, 1986). Children with central auditory processing problems typically have normal intelligence and hearing sensitivity. Their difficulties are more noticeable in certain environments such as when listening to distorted speech, while listening in background noise, and when listening with competing messages (Keith, 1981; 1986)

Based on the environments that cause the primary auditory difficulty with persons with CAPD, Keith developed the subtests of the SCAN. The SCAN has three subtests: (1) Filtered Words, (2) Auditory Figure Ground, and (3) Competing Words (1986). The Filtered Word subtest consists of 40 monosyllabic words presented monaurally. These words are filtered so only the low frequency information remains and is presented monaurally. The Auditory Figure Ground subtest also consists of 40 monosyllabic words but in contrast, the words are nonfiltered and presented in the background of multitalker babble. The monosyllabic words are presented at 8dB above background noise. Finally, the Competing Words subtest consists of 100 monosyllabic words presented as 50 dichotic word pairs. This means that two different words are presented simultaneously to the two different ears.

The three subtests can be administered in 20 minutes. The resulting scores from the test are expressed as the number correct and can be calculated as a raw score, standard score, percentile ranks, and age equivalent scores. Composite scores may also be gathered by the sum of the raw scores of the three subtests. The use of these scores

can help to show the child's auditory strengths and weaknesses and suggest potential areas for further assessment and/or remediation (Amos and Humes, 1998).

The Filtered Word subtest task assesses auditory closure, since part of the acoustic message is not available for the listener (Keith, 1984). The listener is required to fill in the missing portions of the stimulus word. The speech is electronically filtered to produce an acoustic signal that is low-passed filtered. Bocca and his colleagues (1955) were the first to use low passed filtered speech to measure central auditory functioning. They found that an individual demonstrated poorer perception of filtered speech contralaterally to the hemisphere with the lesion.

In the second subtest of Auditory Figure Ground, the message is presented in the presence of background noise. The message on this task is identified in the presence of background noise. The level of the stimulus word as compared to the level of the background noise is described as the signal to noise ratio. This 8dB signal to noise ratio means the words are 8dB above the background noise. This appears to be a particularly valid test for CAP because the most common complaint of individuals with CAPD is the inability to process speech in background noise (Stecker, 1992).

The last subtest is a test of the perception of competing words. This is a test of dichotic listening in that it involves the simultaneous presentation of two different signals to both ears (i.e., different words to each ear). The listener is required to respond by repeating back what is heard in one ear and then what is heard in the other ear. Kimura (1961) reported that the contralateral pathways are more numerous and stronger than ipsilateral pathways. In monaural presentation either pathway is capable of initiating an

appropriate response, but in dichotic presentation the stronger contralateral pathways will take precedence over the weaker ipsilateral ones and may even cause suppression of the ipsilateral pathway. This stronger pathway in the dichotic presentation is commonly cited as the right ear advantage. Usually, the right ear advantage reflects a dominant left hemisphere due to the strength of the contralateral auditory pathway (Keith, 1984). Individuals with CAPD often show a higher right ear advantage than other individuals.

The SCAN has been compared against a series of other clinical tests. A study by Sanger and DeShayes (1986) used 31 first through third graders to whom they administered the SCAN, the Staggered Spondee Word (Arnst & Katz, 1982), the Goldman-Fristoe Woodcock Auditory Skills Battery (Goldman, Fristoe & Woodcock, 1970) and the six subtests of the Clinical Evaluation of Language Fundamentals (CELF): (1) Linguistic Concepts, (2) Relationships and Ambiguities, (3) Oral Directions, (4) Spoken Paragraphs, (5) Word Association, and (6) Model Sentences (Semel & Wiig, 1980). The results showed significant correlations between the SCAN composite score and the Staggered Spondee Word (SSW) Right Competing condition, the Sound-Symbol Association of the CELF, and the Sound and Model sentences subtest of the CELF. This shows that the SCAN measures concepts similar to the SSW Right Competing condition, the Sound-Symbol Association and Sound, and Word Structure of the CELF. These subtests measure the auditory processing as compared to language abilities. In addition, the subtests of the CELF that focus on language skills and the SCAN had a low positive correlation, because these subtests of the CELF focus on specific language abilities.

Keith, Rudy, Donahue and Katbamna (1989) published a study that replicated the Sanger and DeShayes original study. The researchers chose the SCAN, the SSW test, and the Competing Sentence Test of the Willeford Battery (Willeford, 1977) as the measures to assess central auditory processing. The central auditory tests were then compared to the following speech-language measures: Peabody Picture Vocabulary Revised test (PPVT-R) and the CELF (all six subtests). The results verified Sanger and DeShayes' study. There were significant correlations between the Competing Word subtest of the SCAN, the Competing Sentence Test (CST) dichotic listening test, and the SSW. A lower correlation was found between the Filtered Word and the Auditory Figure Ground subtests. The same was found for the SSW and the CST. This showed that dichotic word pairs and low redundancy speech measures (Keith, Rudy, Donahue, & Katbamna, 1989) test different auditory processing abilities.

The most interesting correlation was between the SCAN and PPVT-R. Children with language problems may score poorly on auditory processing. This correlation suggests that it may be important to screen for central auditory problems among children with receptive language difficulties.

The central auditory processing tests did not correlate significantly with the CELF. This indicates that the assessments are measuring different aspects of auditory and language processing. "The SCAN attempts to assess the primary reception stage" (Butler, 1981) and de-emphasizes cognition and comprehension (Keith, Rudy, Donahue and Katbamna, 1989). The CELF may require more secondary linguistic skills such as syntax, semantics, and memory.

Keith and Novak (1984) have suggested a relationship between auditory processing disorders and language disorders. The link between the two has been given the name of auditory-language processing problems. Sanger, Keith, and Maher (1987) looked at 46 normally functioning and achieving first and second graders and administered a series of test to them. The tests included selected subtests of the Clinical Evaluation of Language Function (Semel & Wiig, 1980), the Goldman-Fristoe-Woodcock Memory (GFW) for Sequencing Test, the GFW Sound Mimicry, and the GFW Sound-Symbol Association (Goldman, Fristoe & Woodcock, 1970). The results showed that 87% of the 46 children had auditory-language problems. One year later 42.5% of the children were identified by the schools and qualified for special services. In 1983, Butler stated that auditory-language processing refers to the perceptual and cognitive activity required for abstracting meaning from an acoustic signal and, furthermore, the comprehension and effective use of the meaning. From this it could be speculated that these language deficits are why some children perform poorly on CANS testing and do not have CAP problems. In the testing, a great deal of the acoustic signal is absent, so the task requires the child to fill in the missing part of the signal. If the child does not have the missing language in his or her vocabulary, he or she may have to guess on what is missing. The child instead then is having problems with their language system rather than their central auditory processing system.

Sanger, Keith, Deshayes and Stevens (1990) did research on the relationship between a battery of auditory-language testing and SSW (test of auditory processing). The researchers found no significant relationships between the two tests. These findings

suggest the tests analyze different aspects of linguistic performance. In other words, language tests are administered with different stimuli and require different cognitive processes for formulating a response, unlike audiological tests, which do not rely on language skills.

Amos and Humes (1998) tested the psychometric aspects of the SCAN. Specifically, they researched the test - retest reliability. Test – retest reliability is very important for consistency of the clinical tool. When using a tool, the clinician wants to know if the score they receive from the tool is a true representation of the child's performance. Does the test give you the same results each time it is administered? Is there consistency between administrations? Without test – retest reliability, it is very hard to make accurate interpretations of the results. The evaluator must question whether the results reflect the child's true performance and abilities.

Test – retest reliability was investigated using 25 first graders and 22 third graders. The raw score, standard score, and composite score improved from the first test administration to the second test administration. There was also significant improvement in the percentiles and age equivalents. The results suggested that the children could learn how to take this test better on the second trial. There was significant learning from the first administration of the test to the second administration. The Auditory Figure Ground subtest was the only subtest in which a significant test – retest difference did not emerge. The lack of improvement could be due to this section being considerably more difficult than the other two subtests. Due to its complexity as a test, the children are not able to

learn and improve their score from one administration to the next. It could be speculated that this subtest more accurately reflects the child's true auditory perceptual performance.

If test – retest reliability had been very high, one administration would adequately reflect the child's true performance. Perhaps a solution to the lack of test – retest reliability would be to administer the SCAN twice to obtain a better estimate of the child's best performance (Amos & Humes, 1998). This score would have to be compared to the first time administration norms. This still may not be a sound representation of the child's true performance. More research needs to be done in order to determine the correct use and interpretation of this test so that the administration correctly reflects the child's actual performance. The second way to interpret the results would be to report the scores with the knowledge that the reliability has been questioned.

Another analysis performed on the SCAN during this study was the principal components factor analyses (Amos et al., 1998). The subtests were compared to each other to determine whether they are independent. The results indicated one independent, underlying factor. This underlying factor could be identified as general auditory processing. This investigation supports that the SCAN can be used to screen general auditory processing abilities.

A study was completed by Emerson, Crandell, Seikel and Chermak (1997) on how successful the SCAN is at identifying an at-risk population for central auditory processing disorders. The particular population chosen was children with a history of otitis media. The PPVT-R and the SCAN were administered to elementary children. There was a significant difference seen between the children with otitis media and



children without otitis media on the administration of the PPVT-R. The difference between the SCAN scores on children with a history of otitis media and children without otitis media was not seen as significant. Thus, the children with the history of otitis media and without otitis media have a difference in receptive vocabulary but do not have an increased risk for auditory processing disorders.

A second variable Emerson, Crandell, Seikel and Chermak (1997) studied was whether results of the SCAN varied depending on the environment it was administered in. The children were tested in an audiometric booth and in the school setting. The largest difference in the settings is the amount of background and/or competing noise. The results seemed to indicate that the children performed more poorly on the SCAN composite score when the SCAN was administered in the school setting. This is not surprising in that background noise typically impairs children diagnosed with central auditory processing disorders (CAPD). One common technique to help children with CAPD is to reduce the background noise in any situation, which requires large amounts of auditory processing such as in a school setting.

The SCAN has been criticized on a number of levels. The first is the absence of a measure of temporal processing. Temporal processing refers to "time-related aspects of the acoustic signal" (Bellis, 1996). For speech processing, temporal processing is necessary for the discrimination of subtle cues such as voicing. It allows the listener to discriminate between /koʊt/ and /goʊt/. Hirsh (1959) studied the effects on interstimulus interval on perception of temporal order. He determined a listener needs only two milliseconds to perceive the detection of two sounds versus one sound. This temporal

processing occurs in the central auditory system. If a listener requires more than 15 to 20 msec to determine two consecutive stimuli, a possible central auditory processing problem should be evaluated. Therefore, temporal processing should be included in central auditory testing as a criterion for determining problems that may exist in the central auditory system.

A second criticism of the SCAN is in the lack of “documented validity of the test with listeners with known lesions or disorders of the central auditory nervous system” (Bellis, 1996). The lack of lesions is important because CAPD has been defined by the presence of lesions in the central auditory system (McFarland & Cacace, 1995).

The third point of criticism for the SCAN is the limited number of test items, which may not allow for an adequate evaluation of the complete CANS. Though one subtest, Competing Word, is superior to the other two subtests, the limited number of items poses a problem in the test – retest study of Amos and Humes (1998). The Competing Word subtest was the only subtest that exhibited a strong positive correlation between itself and its composite raw score. High strong positive correlations may result from a greater number of test items.

It could also be speculated that the Competing Word subtest’s high correlation with both the SSW and CST dichotic test could also be related to the number of test items. The larger the number of test items, the more accurate picture an examiner is able to gather of the client. A test needs to ensure that there are enough items to test for the disorder.

Despite the criticisms of the SCAN, it is a useful screening tool to identify children with central auditory processing problems. More research needs to be done on the SCAN to improve the psychometric principles of the test. It is with this research that imperfections can be ameliorated in further editions of the test. Since it is relatively new tool on the market, much more research needs to be done on variables that may affect the testing such as memory and time of day.

### Time of Day

Time of day has been a topic of interest especially in the school systems. In particular, interest has focused on students' performances dependent on the time of the administration of the test. Time of day has been long studied in regards to its effect on short-term memory and long-term memory.

Learning which occurs in the morning is associated with better short-term recall in comparison to afternoon or evening learning (Blake, 1967). However, long-term recall shows an advantage for retrieval when presented in the afternoon as compared to the morning (Hockey et al., 1972). The researchers found that long-term semantic classification tasks do appear to be affected by the time of day at which retrieval occurs. It has been proposed that this has to do with circadian fluctuations in the individual's level of chronic arousal (Millar, Styles & Wastell, 1980).

Folkard et al. (1977) also found that children who were read a story at nine in the morning had better immediate memory than those who were read the story at three in the afternoon. Likewise, children who were read the story at three in the afternoon had higher scores on memory test (long-term memory) than those children who were read the

story at nine in the morning. Laird (1925) found the same results in college students. Short-term memory appears to decrease throughout the day. Blake (1967) was able to demonstrate the same effects.

However, Karvelis (1987) found no significant effect in the child's performance scores on tests of immediate memory in the morning versus the afternoon. Also, no difference was found in delayed memory. A possible explanation is the differing test procedures used between the studies. A second explanation could be the circadian systems of the subjects' were at different stages of development.

Folkard (1979) examined time of day and its effect on the level of processing. He found that subjects engage in more maintenance processing based on the physical characteristic of the items in the morning as compared to the evening. In the evening, the subjects processed more on the meaning of the items. But at this point it still is unclear whether or not this difference can be attributed to basal arousal over the day as suggested by Colquhoun (1971).

Arousal can be defined as the state of alertness, vigor, peppiness, and activation (Humphreys & Revelle, 1984). Arousal exists on a continuum with drowsiness at one end and excitement at the opposite end. There are two kinds of arousal: macro and micro levels. The macro level, which is of interest, examined the whole person and his or her general feelings of alertness and activity, body temperature, and hormonal excretions (Humphreys et al., 1984). Time of day is related to the macro level of arousal. The micro level examines the small changes in the body such as pupil dilation. Physiological arousal of the macro and micro levels is the result of both internal and external

stimulation (1984). High levels of arousal are associated with high levels of stimulation, for example, loud noises. Eysenck (1975) found that loud noise could influence the speed of recall.

More recent studies such as Folkard and Monk (1980) have looked at the effect of time of day on immediate memory and whether time of day affects recall or retrieval. Time of day appears to have little effect on people's ability to retrieve information. This lack of association could be due to two reasons. The first reason is the nature of information being recalled. Petros et al. (1990) showed that time of day effects may be related to the difficulty of the task because time of day effects were only noted with the difficult passages and not the easier passages. The second reason is that Folkard and Monk did not take into account individual time of day preference.

Based on some of the preliminary research on circadian performance, a questionnaire investigating morning or evening preference has been developed. Horne and Ostberg (1976) took 150 people and used their oral temperatures as external validation of their questionnaire. It was found that morning-type people had higher temperatures in the morning, whereas evening-type people had higher temperatures in the evenings. Also it was determined that the average morning-type person appears to start the day nearly two hours before the evening-type people. In addition, Horne and Ostberg (1976) noted that morning type people's temperature rises rapidly and plateaus. In contrast the evening type people's temperature has a more steady temperature elevation until its plateau. The questionnaire asked questions about rise time, alertness, peak performance, and bedtime to determine the circadian preference for each individual. The

maximum score of 86 indicates morning preference, whereas the minimum score of 16 indicates evening preference. Each circadian preference (i.e., morning, evening, or neither) represents a range of scores.

### Summary

The evaluation of the auditory perceptual system is a complex process, because it depends not only on peripheral hearing ability, but also on central hearing ability. Central hearing ability includes skills such as memory and sequencing of sounds. Psychological research has demonstrated that cognitive factors such as memory and alertness are affected differentially by time of day depending on the type of person tested (i.e., morning versus evening type). As central auditory processing is related to psychological abilities and psychological abilities are related to time of day, it would seem logical that auditory processing is related to time of day.

An earlier investigation completed at the University of North Dakota demonstrated that some clinically used auditory perceptual tests are affected by time of day. However, this testing has never been done with a screening test of auditory processing. The most commonly administered screening test of auditory processing is known as the SCAN (Keith, 1986).

The importance of this study is to facilitate our understanding of the relationship between central auditory processing and time of day. This understanding will better help professionals to diagnosis and treat central auditory processing disorders. In the course of this study the following research questions will be addressed:

1. Is there a difference in the scores of morning and evening-type individuals on the Filtered Word subtest of the SCAN?

2. Is there a difference between morning and evening individuals on the Auditory Figure-Ground subtest of the SCAN?
3. Is there a difference between morning and evening type individuals on the Competing Word subtest of the SCAN?
4. Is there a difference between the morning and evening test times for the type of individuals on the Filtered Word subtest of the SCAN?
5. Is there a difference between the morning and evening test times for type of individuals on the Auditory Figure-Ground subtest of the SCAN?
6. Is there a difference between the morning and evening test times for type of individuals on the Competing Word subtest of the SCAN?
7. Are the effects of time of day the same for morning and evening-type people on the Filtered Word subtest of the SCAN?
8. Are the effects of time of day the same for morning and evening-type people the Auditory Figure Ground subtest of the SCAN?
9. Are the effects of time of day the same for morning and evening-type people on the Competing Word subtest of the SCAN?

## CHAPTER III

### METHODOLOGY

The purpose of this study was to determine if there are time of day effects on an individual's performance on the Screening Test of Auditory Processing (SCAN) (Keith, 1986). The researcher through the Departments of Psychology and Communication Sciences and Disorders solicited sixty-six subjects. Thirty-three morning-type and thirty-three evening-type individuals were included in the investigation. Half of the morning-type individuals were tested in the morning and half in the evening. Likewise, half of the evening-type individuals were tested in morning and half in the evening.

#### Subjects

The sixty-six subjects who participated in this study were volunteers solicited from the Departments of Psychology and Communication Sciences and Disorders at the University of North Dakota. The subjects were college students ranging in age from 18 to 34 years old with a relatively equal number of males and females. All subjects were screened for their normal hearing sensitivity prior to the investigation. Normal hearing sensitivity was defined as auditory thresholds of equal to or better than 20dBHL at octave intervals from 1000Hz to 4000Hz. This was in accordance with American Speech-Language and Hearing Association (ASHA's) guidelines for the screening of hearing.



Before inclusion in this investigation, subjects were evaluated to determine if they were a morning-type or evening-type person. Horne and Ostberg's Self-Assessment Questionnaire (1976) was used to determine if the subject is a morning or evening-type person. Thirty-three individuals were selected who were morning-type and thirty-three who were evening-type people. Those who agreed to participate were randomly assigned to be tested at either eight in the morning or four in the afternoon. Thirty-one students were tested at 8am and the other thirty-five at 4pm. The thirty-one subjects tested at 8am consisted of a group of approximately one half of the morning type people (15) and one half of the evening type people (16). At 4pm, the thirty-five subjects tested were tested with approximately one half of the morning-type people (18) and approximately one half of the evening-type people (17). Each person had an equal probability of being tested in the morning or the afternoon. Subjects who were students in the Communication Science Department received extra credit for participation in this study from the Department of Communication Science and Disorders. Psychology students received class credit in psychology classes for their participation in this investigation.

### Instruments

Subjects were tested prior to the study for the physiological variable of circadian preference. Horne and Ostberg's Self-Assessment Questionnaire (1976) was used to determine time of day preference for each subject. This questionnaire consisted of a series of 19 questions. It addressed issues such as rise time, alertness, and peak performance. The questionnaire was used to classify potential subjects along a continuum of morningness and eveningness. A maximum score of 86 indicated a strong morning

type circadian pattern. Likewise, the minimum score of 16 on the continuum indicated a strong evening-time preference. Morning-type individuals were operationally defined as those who score above 70 and evening-type individuals were those who score below 41. Individuals who scored in between 42 and 58 were not classified as either strong morning-type or evening-type. These mid-range individuals were not included in the investigation.

Pure tone audiometric screening, using American Speech-Language and Hearing Association (ASHA's) hearing screening standards (1986), was administered prior to the central auditory processing testing to ensure adequate hearing sensitivity. Bilaterally, the ears were screened at 1000, 2000, and 4000 Hz at 20dB. Normal hearing was defined as an individual's ability to hear all the tones at 20dB.

The pure tone audiometric screening was conducted in a quiet room with a GSI 1704 audiometer using TDH-50 headphones mounted in MXAR-41 cushions. The audiometer was calibrated to ANSI (1989) standards.

In addition, middle ear functioning was screened using tympanometry. Individuals who showed normal middle ear mobility and pressure were included in this investigation. Normal middle ear function was operationally defined as type A tympanogram classification. These classifications consisted of a static admittance of 0.3 to 1.4 mhmo/cm<sup>3</sup>, ear canal volume of 0.6 to 1.5 cm<sup>3</sup>, and air pressure of -150 to 100daPa. The tympanogram width had to fall in the range of from 50 to 110daPa. The tympanometer used was a Grason-Stadler GSI 38.

After the determination of adequate hearing sensitivity and middle ear status, all

subjects were administered the SCAN. The SCAN: a Screening Test for Auditory Processing Disorders (Keith, 1986) was used to assess central auditory processing of the subjects. The SCAN has three subtests: Filtered Words (FW), Auditory Figure-Ground (AFG), and Competing Words (CW) which are designed to screen auditory perceptual abilities of an individual. The SCAN test was administered via headphones from tape-recorded stimuli. The subjects were asked to repeat the stimulus word back to the researcher in the presence of distracting stimuli. The individual listened to the tape at a comfortable listening level. The test in its entirety took 20 minutes to administer.

The SCAN required a stereo cassette player with a speed of  $1 \frac{7}{8}$  inch/sec (4.75 cm/sec) and four tracks along two stereo channels. The audible signal was delivered through high quality headphones. Equipment met criteria for administration of the SCAN as specified by Keith (1986).

The Filtered Words subtest consisted of two lists of 20 monosyllabic words which were each low-passed filtered at 1000Hz, with a filter roll-off of 32dB per octave (Keith, 1986). Two words were presented first in the right ear and then in the left ear as practice items. In the actual test 20 words were presented to the right ear and then 20 to the left ear. After hearing each word, the subject had to repeat the word. Responses were recorded as correct if the whole word was correctly identified and no score was given to incorrect repetition.

The Auditory Figure Ground subtest consisted of two lists of 20 monosyllabic words in the presence of multi-talker speech babble noise at 8dB over the speech to noise ratio (Keith, 1986). The noise and stimulus item were presented into the same ear.

Again, two words were presented first in the right ear and then in the left ear as practice items. After the practice items, 20 words were presented to the right ear and then 20 to the left ear. The subject had to repeat each word. Responses were recorded as correct if the whole word was correctly identified and no score was given to incorrect repetition.

The final subtest of Competing Words consisted of two lists of 25 monosyllabic word pairs. Each pair was presented into the right and left ear in synchrony. Each pair of words were not semantically related. The practice items consisted of two words in each listening condition, right and left ear. The first 25-paired words were presented with one in the right ear and one in the left ear. The subject was to first repeat what he or she heard in the right ear followed by the left ear. The second 25-paired words were presented in a similar fashion, but the subject was to repeat first what was heard in the left ear. The subject's responses were scored as correct if they repeated either of the pair of words or if they repeated the pair in any order.

#### Procedures

All subjects were volunteers solicited by the researcher through the Departments of Psychology and Communication Sciences and Disorders. Each subject had the purpose and procedures of the study discussed with him or her and signed a written consent prior to participating in the study.

Before inclusion in this investigation, subjects were evaluated to determine if they were a morning-type or evening-type person. Horne and Ostberg's Self-Assessment Questionnaire (1976) was used to prescreen individuals to determine if they were morning or evening-type people. The Horne and Ostberg's Self-Assessment

Questionnaire was administered during a regular class period. The questionnaire was used to classify potential subjects along a continuum of morningness and eveningness. Those who agreed to participate were randomly assigned to be tested at either eight in the morning or four in the afternoon. Thirty-one students were tested at 8am and another thirty-five at 4pm. The individuals were assigned to one of two groups and then contacted by the researcher via the telephone. The individuals were given the meeting time and place of testing. The researcher met them at the lab and gave them each a consent form to fill out. The thirty-one subjects tested at 8am consisted of a group of approximately one half of the morning-type people (15) and approximately one half of the evening-type people (16). At 4pm, the thirty-five subjects also consisted of approximately one half of the morning-type people (18) and approximately one half of the evening-type people (17).

All subjects were screened to ensure that they had normal hearing sensitivity. Normal hearing sensitivity was defined as auditory thresholds of better than 20dBHL at octave intervals from 1000Hz to 4000Hz. This was in accordance with American Speech-Language and Hearing (ASHA) guidelines for the screening of hearing. Normal hearing was defined as an individual's ability to hear all the tones at 20dBHL tested. If an individual failed the hearing screening, they were told they could receive an audiological exam at no cost to them from the University of North Dakota Speech, Language and Hearing Clinic. Testing took place on an individual basis in a noise free environment. Each individual was asked to wear a set of headphones and indicated by the raising of his or her hand when each heard a faint tone.

Following the pure tone assessment, middle ear functioning was screened using tympanometry. The tympanogram was conducted by inserting a soft rubber probe tip into the ear creating an airtight seal in the ear canal. This probe changed the air pressure a small amount and measured the transmission of sound through the middle ear. This test is commonly used clinically and the pressure change is equal to pressure exerted at approximately the depth of 8 inches of water. If an individual did not have normal middle ear pressure, he or she could receive a tympanogram recheck at no cost from the University of North Dakota Speech, Language and Hearing Clinic. After the determination of adequate hearing sensitivity and middle ear pressure, all subjects were administered the SCAN.

The SCAN, a Screening Test for Auditory Processing Disorders (Keith, 1986), was used to assess central auditory processing of the subjects. The SCAN has three subtests, Filtered Words (FW), Auditory Figure-Ground (AFG), and Competing Words (CW), which are designed to screen auditory perceptual abilities of an individual. The SCAN test was administered via headphones from tape-recorded stimuli. The subjects were asked to repeat the stimulus word, in the presence of distracting stimuli, back to the researcher. The individual listened to the tape at a comfortable listening level. The test in its entirety took 20 minutes to be administered.

All subjects who chose to participate were allowed to drop out of the study at anytime for any reason without prejudice. Only the primary researcher and graduate advisor reviewed the results. These results were kept confidential and locked in a filing cabinet at all times.

### Data Analysis

Descriptive and inferential statistics were reported as levels of analysis in this study. Descriptive statistics included the means, standard deviations, and the ranges of all variables. Inferential statistics included a 2 (person type) x 2 (time of day) between subjects analysis of variance (ANOVA). The outcome measures were performance on the auditory perceptual subtests. Factors (type and time) were compared between subjects for the effects of time of day or auditory performance. In addition, interactions between the main effects were also examined.

## CHAPTER IV

### RESULTS AND DISCUSSION

This study examined whether there was a relationship between time of day and central auditory processing. Central auditory processing was examined through the administration of a common clinical tool, the Screening Test of Auditory Processing (SCAN). The data collected from the investigation will be examined and discussed in this chapter.

#### Description of Variables

Sixty-six college students participated in this study, 50 females and 16 males. The subjects who participated in this study ranged in ages from 18 to 34 years old. The mean age was 20.6 years.

Prior to testing the subjects the researcher administered, the Horne and Ostberg's Self-Assessment Questionnaire (1976) to determine time of day preference (i.e., morning versus evening) of each subject. Thirty-three of the subjects tested were morning-type and thirty-three were evening-type. Fifteen morning-type people were tested in the morning and 18 morning-type people were tested in the evening. Sixteen evening-type people were tested in the morning and seventeen were tested in the evening. Each subject was randomly assigned to his or her test time. The morning test period had two test times of 7:30 a.m. and 8:00 a.m. The evening test period also had two test times, which were 4:30 p.m. and 5:00 p.m. The selection of these test times was because in a clinic auditory



perceptual testing is conducted typically at the earliest test time of 8:00 a.m. and the latest test time of 5:00 p.m.

A pure tone audiometric screening was completed on each potential subject prior to the administration of the central auditory evaluation. Each subject was bilaterally screened at 1000 Hz, 2000 Hz, and 4000 Hz at 20dBHL in both ears. Normal hearing sensitivity was defined as the subjects' abilities to hear all of the test tones at 20dBHL. In addition, all subjects had their middle ear function, screened by using tympanometry. Only individuals who showed normal middle ear mobility and pressure were included in this study.

### Descriptive Statistics of Variables

#### Measures of Central Tendency and Variability

The means, standard deviations (SD), and ranges were calculated for each variable in this study (see tables 1 to 4). Table 1 shows the mean, SD, and ranges on each variable within the group of morning-type people tested in the morning. Table 2 demonstrates the means, SD, and ranges of all the variables tested in the morning for evening-type people. Table 3 illustrates the means, SD, and ranges on all variables tested for evening-type people tested in the morning. Lastly, table 4 shows the means, SD, and ranges for evening-type people tested in the evening.

As seen in Tables 1 through 4 the subjects performed better on right ear tasks in comparison to left ear tasks with the exception of the morning-type people tested in the morning on the subtests of filtered words and competing words (see Table 1). For these subjects, their performance was superior in the right ear as compared to the left ear only

on the subtests of Auditory Figure Ground for all test times and types of people tested. In addition, for morning-type people and evening-type people tested, their right ear scores exceeded the left ear scores on all subtests. Lastly for evening-type people tested in the morning, the right ear scores were superior to the left ear scores on all subtests.

Table 1. Means, Standard Deviations (SD) and Ranges for Morning-Type Person Tested in the Morning

<u>Variables</u>	<u>N</u>	<u>Means</u>	<u>SD</u>	<u>Minimum</u>	<u>Maximum</u>
FWTRE	15	18.53	1.36	16.00	20.00
FWTLE	15	18.60	0.83	17.00	20.00
FWTOT	15	37.07	1.67	33.00	39.00
AFGTRE	15	18.07	1.10	16.00	20.00
AFGTLE	15	16.87	2.10	13.00	20.00
AFGTOT	15	35.00	2.39	30.00	39.00
CWTRE	15	45.60	3.20	37.00	50.00
CWTLE	15	46.00	2.80	42.00	50.00
CWTOT	15	91.73	4.68	83.00	99.00

These findings lend support to the research on dichotic listening tasks. Most normal subjects show right-ear superiority on dichotic listening tasks (McFarland & Cacace, 1995). Even though several of those tasks were not dichotic in nature, there still was improved performance in the right ear as compared to the left ear. This appears to

support that there might be a right ear advantage for other complicated listening tasks other than dichotic listening tasks.

Table 2. Means, Standard Deviations (SD) and Ranges for Morning-Type Person Tested in the Evening

<u>Variables</u>	<u>N</u>	<u>Means</u>	<u>SD</u>	<u>Minimum</u>	<u>Maximum</u>
FWTRE	18	19.00	1.19	17.00	20.00
FWTLE	18	18.94	0.80	17.00	20.00
FWTOT	18	37.94	1.47	35.00	40.00
AFGTRE	18	17.67	1.24	16.00	20.00
AFGTLE	18	17.44	1.34	15.00	19.00
AFGTOT	18	35.11	1.97	32.00	39.00
CWTRE	17	47.65	1.69	45.00	50.00
CWTLE	17	45.18	2.77	38.00	48.00
CWTOT	17	92.71	3.58	84.00	98.00

Generally as can be seen in Tables 1 through 4, the means for morning-type people increased through the day. The mean performance for the evening people also appeared to increase throughout the day with the exception of the Competing Word subtest. Earlier research completed by Horne and Ostberg (1976) found subjects' basal arousal to increase through the day for both morning and evening-type individuals. However, the earlier researchers found the morning people's arousal plateaus earlier in the day than evening-type people's. This increase in arousal reported by Horne and

Ostberg through the day appears to be supported by the current study which showed that both the morning and evening-type individuals' scores increased throughout the day relative to their morning performance.

Table 3. Means, Standard Deviations (SD) and Ranges for Evening-Type Person Tested in the Morning

<u>Variables</u>	<u>N</u>	<u>Means</u>	<u>SD</u>	<u>Minimum</u>	<u>Maximum</u>
FWTRE	16	18.93	1.00	17.00	20.00
FWTLE	16	18.06	1.18	15.00	20.00
FWTOT	16	37.00	1.03	35.00	38.00
AFGTRE	16	17.75	1.24	15.00	19.00
AFGTLE	16	16.87	1.31	15.00	19.00
AFGTOT	16	34.63	1.63	31.00	37.00
CWTRE	15	46.87	2.56	39.00	49.00
CWTLE	15	44.67	2.55	40.00	48.00
CWTOT	15	91.53	3.44	83.00	96.00

#### Association Among the Variables

In addition to the descriptive statistics, a correlation analysis using the Pearson  $r$  correlation coefficient was completed on the nine dependent variables: FWTRE, FWTLE, FWTOT, AFGTRE, AFGTLE, AFGTOT, CWTRE, CWTLE, and CWTOT. This analysis allowed the level of association among the dependent variables to be compared. The Pearson product moment correlation can range from +1 to -1. Values near 0 show

no degree of association. Values near  $-1$  show a strong negative association. This indicates that as one variable increases the other variable decreases. Finally, values near  $+1$  demonstrate a strong positive correlation. This indicates that as performance on one variable increases so does performance on the other variable.

Table 4. Means, Standard Deviations (SD) and Ranges for Evening-Type Person Tested in the Evening

<u>Variables</u>	<u>N</u>	<u>Means</u>	<u>SD</u>	<u>Minimum</u>	<u>Maximum</u>
FWTRE	17	18.94	1.20	16.00	20.00
FWTLE	17	18.65	1.06	17.00	20.00
FWTOT	17	37.59	1.50	35.00	40.00
AFGTRE	17	18.00	1.06	16.00	20.00
AFGTLE	17	17.05	1.92	14.00	20.00
AFGTOT	17	35.06	2.22	32.00	40.00
CWTRE	16	45.13	4.38	32.00	49.00
CWTLE	15	43.87	4.50	30.00	48.00
CWTOT	15	88.87	8.15	62.00	97.00

In order to see if these relationships were consistent for both types of participants and test times, degree of association was calculated within each type of person (i.e., morning or evening) and for time of day tested. The purpose of this correlation analysis was to establish the degree of association between the different measures of auditory performance.

Tables 5 through 9 examine the correlations of the variables. Table 5 reports the correlation of the dependent variables (i.e., the subtests of the SCAN) against each other. As was expected in the data, a high degree of association was found between the performances of a given test in one ear as compared to the performance of the same test in the other ear. This is not surprising as the same test procedure was followed for both ears, and it would be expected that a person who scored higher on one of the central auditory measures in one ear would also show high performance in the other ear. Therefore, the high degree of association in performance between the ears could be predicted.

The highest degree of association was found when examining the combined score for performance in both ears, which was created by averaging the results in both ears, and then correlating the results from this average performance to each individual ear's performance. These combined variables have "TOT" in their names. For instance, CWTOT is the competing word performance averaged across ears, AGFTOT is the auditory figure ground performance averaged across ears, and FWTOT is the performance on filtered words averaged across both ears. For example, CWTOT was highly correlated with the left ear scores (0.826) and the right ear scores (0.844). AFGTOT was also found to highly correlate with AFTLE (0.821). This finding may support that an examiner only has to test one ear's performance due to the high degree of association between the average score on a subtest and the right and left ear score. This high degree of association supports that the total score gives a valid assessment of each ear, thus an examiner would not have to test each ear individually.

Table 5. Pearson Correlation Coefficient for the Subtests of the SCAN

	FWTRE	FWTLE	FWTOT	AFGTRE	AFGTLE	AFGTOT	CWTRE	CWTLE	CWTOT
FWTRE	1.000	-0.115							
FWTLE	-0.114	1.000							
FWTOT	0.735**	0.58*	1.000						
AFGTRE	0.271	0.069	0.256	1.000					
AFGTLE	0.217	0.193	0.316	-0.003	1.000				
AFGTOT	0.333	0.194	0.402	0.566*	0.821***	1.000			
CWTRE	0.004	0.116	-0.069	0.004	-0.116	-0.694	1.000		
CWTLE	0.074	-0.059	0.015	0.118	0.193	0.221	0.401*	1.000	
CWTOT	0.045	-0.107	-0.035	0.054	0.336	0.298	0.526***	0.844***	1.000

±

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

However, other variables were found to correlate only mildly such as FWTOT and FWTRE with a correlation of 0.58. Also a moderate correlation was noted when the collapsed was examined score across both ears with FWTOT and FWTLE (0.735). The AFGTRE had a mild correlation of 0.566 with AFGTOT. This lower degree of association between the right and left ear scores was demonstrated with both Auditory Figure Ground subtest and the Filtered Word subtest. These discrepancies between the average score and correlations with each ear appear to not support a strong degree of association in performance between an individual's ability to hear right ear and left ear words as compared to the averaged total of both the right and left ear. The low degree of correlation between right and left ear scores may suggest that it is important to give each ear in all subtests to get valid results. Therefore, an examiner will have to give both the right and left ear portion of the test because the total score of some of the subtests were not strongly correlate with the right and left ear.

Performance in the right and left ears on a number of central auditory test was not correlated with each other. An example would be the right ear scores did not highly correlate with the left ear scores on the subtest of Filtered Word and Auditory Figure Ground. This difference in correlation on these subtests as compared to the Competing Word subtest appears to support the fact that these central auditory processing tests are evaluating different domains of processing. Therefore, it is important to test both ears on each subtest due to the lack of association between the right and left ear scores on each individual subtest. Each test may be measuring different auditory processing abilities.



Tables 6 through 9 deal with the correlations of the subtests while collapsed across time of day and type of person. Many correlations were observed. Strong correlations were typically found when variables were examined that were the same subtest presented to both ears; for example, FWTOT correlated strongly with FWTRE in Table 6. All correlations found between the variables within one subtest were high. Moderate or mild correlations were found between other subtests such as AFGTLE correlated with FWTLE (0.682) in Table 7. This seems to suggest that each subtest may be measuring different aspects of central auditory processing (CAP). It would be expected that, if the subtests were measuring the same aspect of CAP, high correlations would be found between performances on all of the subtests.

#### Inferential Statistics

In order to determine whether a significant difference in performance on any of the auditory subtests was found between the morning and evening-type individuals or performance in the morning and evening test times, or an interaction between these two main effects (type of person and time of test), a two by two analysis of variance was conducted. This two by two analysis of variance had one factor (person type) having two cells and the other factor (time of day) having two cells. As there were not exactly equal cell sizes for each of the main effects a general linear model type of analysis was used. The purpose of using this general linear model analysis of variance, instead of a more traditional analysis of variance, is the general linear model does not require the cell sizes to be equal. This study did not have equal cell sizes for each level of the factors. All of the research questions were analyzed using the general linear model analysis of variance.

Table 6. Pearson Correlation Coefficient for Morning-Type Person Tested in the Morning

---

	FWTRE	FWTLE	FWTOT	AFGTRE	AFGTLE	AFGTOT	CWTRE	CWTLE	CWTOT
FWTRE	1.000								
FWTLE	0.140	1.000							
FWTOT	0.899***	0.538*	1.000						
AFGTRE	0.501*	0.502*	0.621**	1.000					
AFGTLE	0.529*	-0.361	0.268	0.004	1.000				
AFGTOT	0.705**	-0.108	0.520*	0.462*	0.882***	1.000			
CWTRE	0.069	-0.469	-0.156	-0.378	0.650**	0.392	1.000		
CWTLE	-0.150	0.308	0.031	0.023	0.206	0.171	0.366	1.000	
CWTOT	-0.058	-0.122	-0.089	-0.218	0.526*	0.345	0.821***	0.827***	1.000

---

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

Table 7. Pearson Correlation Coefficient for Morning-Type Person Tested in the Evening

---

	FWTRE	FWTLE	FWTOT	AFGTRE	AFGTLE	AFGTOT	CWTRE	CWTLE	CWTOT
FWTRE	1.000								
FWTLE	0.062	1.000							
FWTOT	0.840***	0.594*	1.000						
AFGTRE	0.240	0.158	0.280	1.000					
AFGTLE	0.000	0.682**	0.371	0.166	1.000				
AFGTOT	0.151	0.563*	0.428*	0.742**	0.785**	1.000			
CWTRE	-0.227	0.014	-0.183	0.124	0.115	0.153	1.000		
CWTLE	0.154	-0.078	0.088	0.123	-0.258	-0.092	0.334	1.000	
CWTOT	0.039	-0.058	0.001	0.118	-0.258	-0.032	0.703**	0.894***	1.000

---

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

Table 8. Pearson Correlation Coefficient for Evening-Type Person Tested in the Morning

---

	FWTRE	FWTLE	FWTOT	AFGTRE	AFGTLE	AFGTOT	CWTRE	CWTLE	CWTOT
FWTRE	1.000								
FWTLE	-0.562*	1.000							
FWTOT	0.323	0.601**	1.000						
AFGTRE	0.148	-0.171	-0.051	1.000					
AFGTLE	0.096	0.178	0.296	-0.185	1.000				
AFGTOT	0.190	0.013	0.198	0.612**	0.664**	1.000			
CWTRE	0.050	-0.070	-0.031	0.432*	-0.012	0.324	1.000		
CWTLE	0.018	-0.140	-0.144	0.177	-0.168	0.011	-0.095	1.000	
CWTOT	0.051	-0.156	-0.130	0.453*	-0.134	0.250	0.674**	0.672**	1.000

---

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

Table 9. Pearson Correlation Coefficient for Evening-Type Person Tested in the Evening

---

	FWTRE	FWTLE	FWTOT	AFGTRE	AFGTLE	AFGTOT	CWTRE	CWTLE	CWTOT
FWTRE	1.000								
FWTLE	-0.116	1.000							
FWTOT	0.715**	0.611**	1.000						
AFGTRE	0.295	0.000	0.235	1.000					
AFGTLE	0.083	0.288	0.269	0.031	1.000				
AFGTOT	0.213	0.249	0.345	0.504*	0.879***	1.000			
CWTRE	-0.013	-0.059	-0.052	-0.042	0.448*	0.366	1.000		
CWTLE	0.297	-0.238	0.062	0.154	0.552*	0.549*	0.638**	1.000	
CWTOT	0.142	-0.170	-0.011	0.062	0.548*	0.502*	0.905***	0.905***	1.000

---

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

The outcome variables were established based on the raw scores as a proportion of words correctly identified by the subject for each ear on each subtest of the SCAN. The raw scores then were divided into cells to determine if a relationship existed between and among the independent variables. For instance, these cells would include performance on each of the subtests for the morning-type individuals tested in the morning and also in the evening. The cells would also include the performance on each of the subtests for evening-type individuals tested in the morning and evening. Tables 10 through 12 show the results of the analyses of variance. Table 10 investigates the relationship between the Filtered Word subtest and type of person and test time. Table 11 explores the subtest of Auditory Figure Ground and its relationship to type of person and test time. Finally table 12 examines the relationship between the Competing Word subtest and type of person and test time. Individual analyses were conducted for the right and left ears. Results of the statistical analysis will be discussed in relation to each research question.

#### First, Fourth and Seventh Research Question

Is there a difference between type, time and/or effect of type and time on the Filtered Word subtest of the SCAN?

A difference was noted on the left ear portion of the Filtered Word subtest (FWTLE) for both time of day tested and type of person tested (see Table 10). The time of day tested difference can be seen in Figure 1.

A significant difference was found in the performance for the Filtered Word subtest in the left ear between morning and evening test time. The FWTLE ( $p=0.0587$ ) was significant at the  $p>0.10$  level. The evening-type individuals performed better

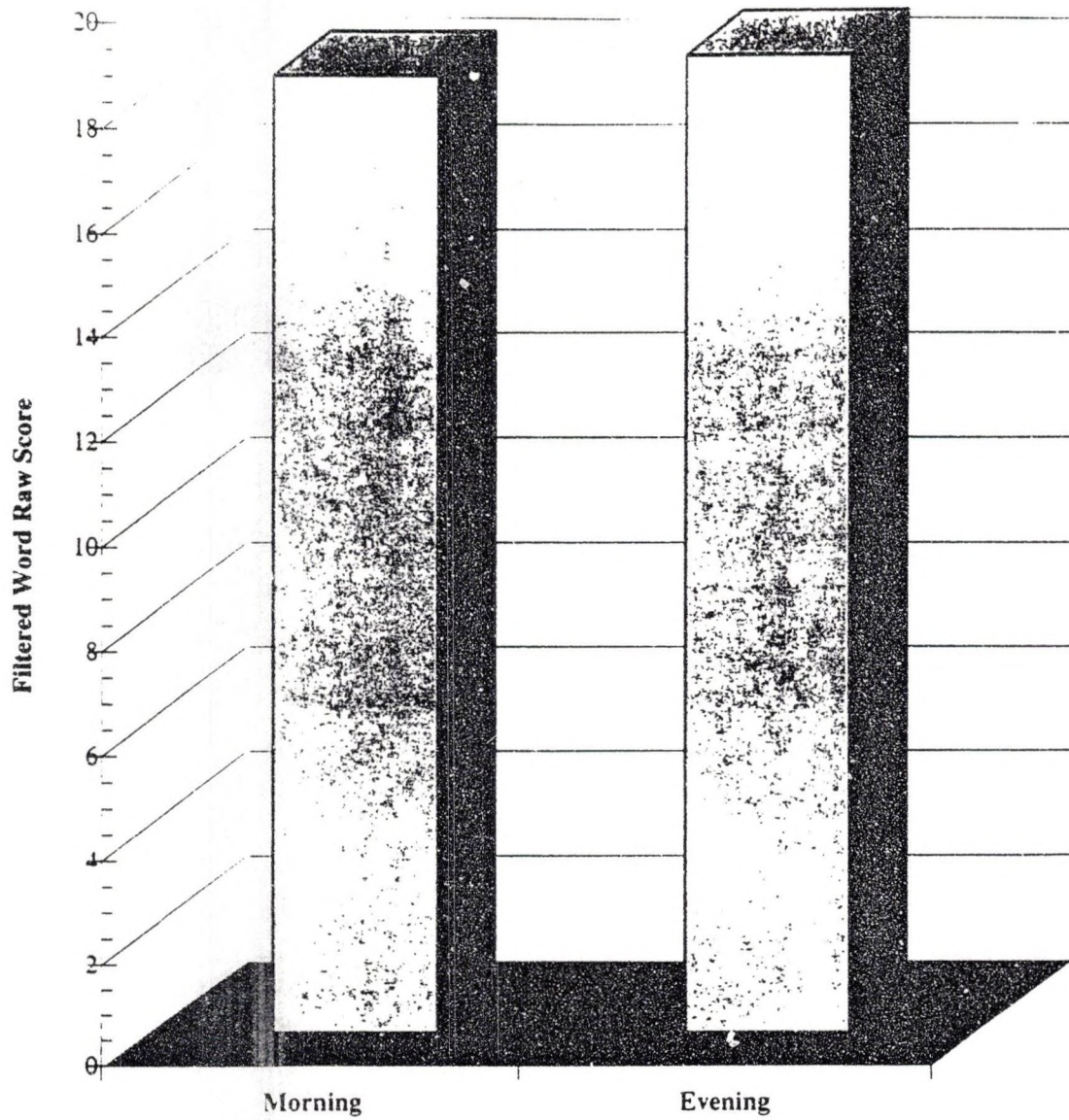


Figure 1. The effect of test time on performance on the Filtered Word subtest in the left ear.

in the morning, while the morning-type people performed superior in the evening.

Table 10. General Linear Model of Filtered Word Subtest on the SCAN

	<u>Variable</u>	<u>F-test</u>	<u>D.F</u>	<u>p</u>
FWTRE	Type	0.35	1, 65	0.5582
	Time	0.64	1, 65	0.4258
	Type X Time	0.62	3, 65	0.4330
FWTLE	Type	3.10	1, 65	0.0831*
	Time	3.71	1, 65	0.0587*
	Type X Time	0.25	3, 65	0.6208
FWTOT	Type	0.47	1, 65	0.4957
	Time	4.27	1, 65	0.0429*
	Type X Time	0.17	1, 65	0.6844

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Rozzi (1997) also found significant differences in left ear performance in the Filtered Speech task. This earlier investigation found morning-type people performed better in the morning and evening people performed better in the evenings. Other researchers such as Petros et al. (1990), Anderson et al. (1992) also have found that evening people's performance improved throughout the day while morning people's performance decreased through the day. The opposite effect was found for the Filtered Word subtest. The morning-type people did better when tested in the evening with a mean of 18.94 and only a mean of 18.60 in the morning, and the evening-type people did better when tested in the morning with a mean of 18.65 as compared to a mean of 18.06 in the morning. This opposite effect may be attributed to extra concentration in the



period of day that is outside the optimal period of arousal.

Another explanation for the difference between Rozzi and the current study, is different measures of Filtered Speech were used. Rozzi utilized filtered words from the Willeford Battery and the current study used filtered words from the SCAN. Thus, there may be a difference in the difficulty level of the stimuli used between the two tests. This difference in difficulty level may account for the differing results.

Performance on the FWTLE was found to be significantly different depending upon the subject type tested (0.0831). Morning-type people performed better on the FWTLE than the evening people as seen in Figure 2. Morning-type people means were higher than the evening-type people tested. Morning-type people had a mean of 18.60 when tested in the morning and a mean of 18.94 during the evening test time. Evening-type people had a mean of 18.06 when tested in the morning and a mean of 18.65 with an evening test time.

In addition, statistical differences were noted when examining the Filtered Word subtest total (i.e., both the left and right ear scores combined). There was a significant difference found in performance between the morning and evening-type individuals on FWTOT ( $p=0.0429$ ). The morning-type people's performance was better in the evening as compared to the morning. The evening-type people's performance was also better in the evening as compared to the morning test time. This statistical difference of the morning-type individuals scoring higher than the evening-type individuals can be seen in Figure 3.

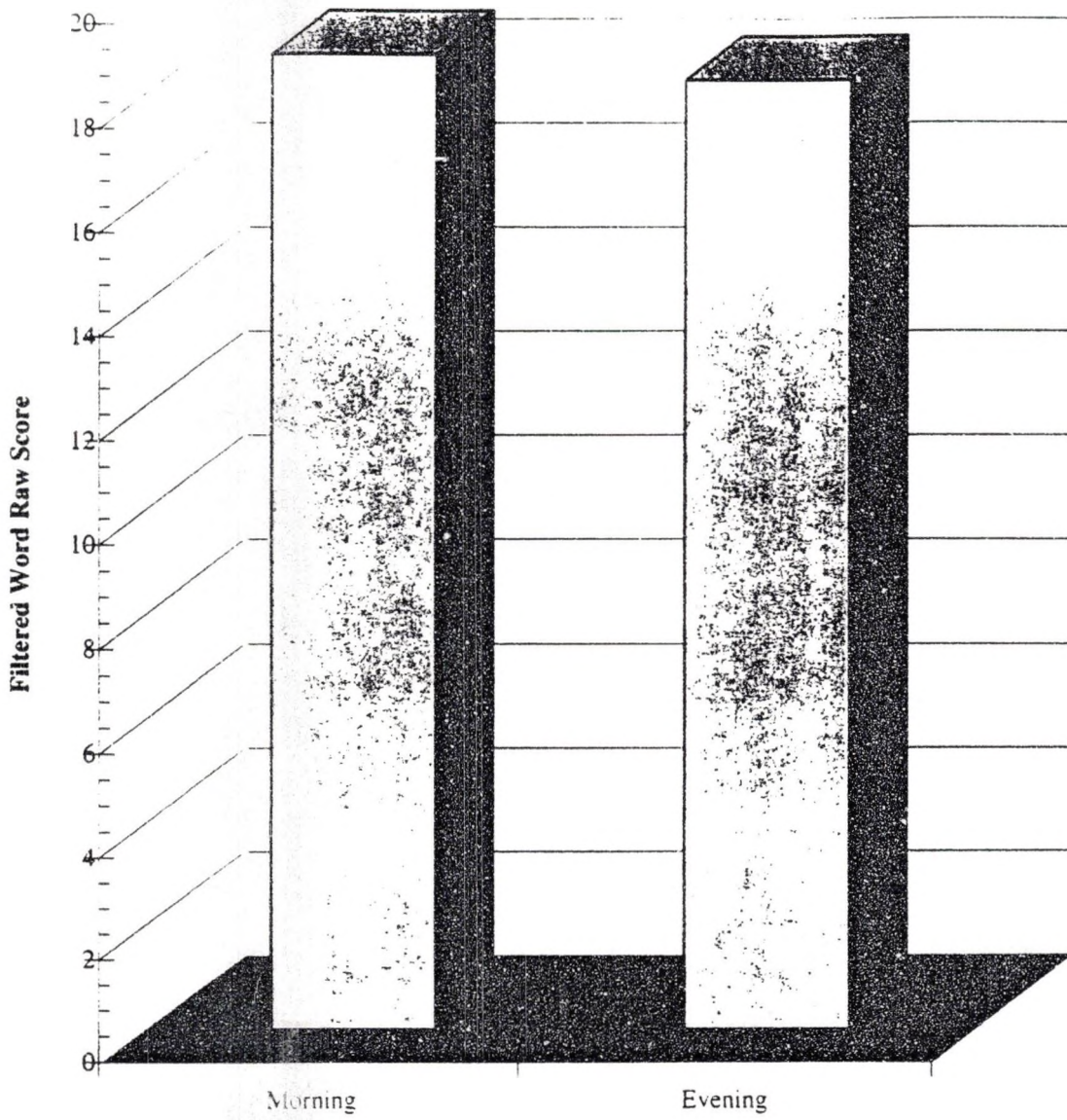


Figure 2. The effect of subject type on performance on the Filtered Word subtest in the left ear.

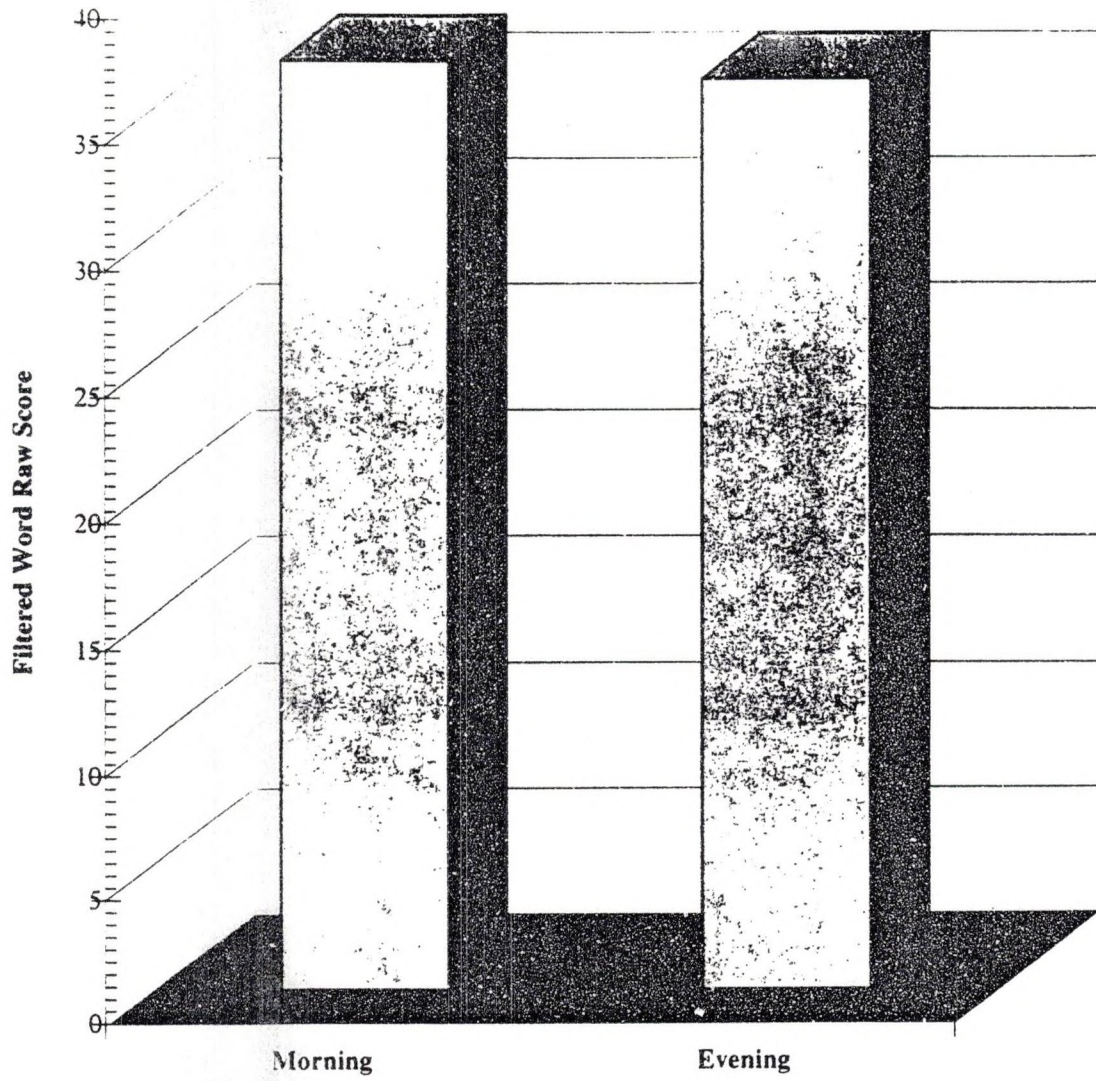


Figure 3. The effect of test time on performance on the Filtered Word subtest total score of the left and right ear.

As with the time of day effect in the FWTLE, the effect was opposite as what was expected to be found. It was expected that the morning-type people would have superior performance in the morning and the evening-type people would have better performance in the evening. The morning-type people performed better during the evening with a mean of 37.94 as compared to a performance in the morning time with a mean of 37.07. The evening-type people performed better in the morning test with a mean of 37.00 as compared to the evening test time with a mean of 34.63.

Again, this opposite effect of time of day could be due to attentional tasks. The subjects may be concentrating harder outside their time of day preference. In addition, perhaps different results would have been found if more difficult test stimuli was used.

More difficult test stimuli could have resulted in increased variability in the data.

Overall, there was a restriction of variability found in the data. The low variability can be seen in the low standard deviations and the closely clustered means resulting in extremely narrow ranges.

No statistical difference was found between the morning and evening type people or the morning and evening test time nor was there an interaction between these factors in the right ear score of Filtered Word Subtest (FWTRE) of the SCAN. Perhaps the lack of statistical significance could be attributed to the right ear advantage for auditory processing. The right ear performance did not demonstrate statistically different performance for the type of person or the test time on the Filtered Word subtest. This might be due to the fact that the right and left ear auditory systems do not follow the same pathways. It is theorized that the language center is located within the left cerebral

hemisphere. Kimura (1961) reported the right ear pathway as a more direct one to the left hemisphere and consequently the right pathway would move quickly to reach the language center than the left auditory pathway. A message traveling up the left pathway is at a disadvantage due to having to make more neural synapses. The increased number of synapses slows the message in its travel to the language center. Thus under more difficult listening conditions, the right ear may be more effectively identifying the stimuli in comparison to the left ear.

Thus, that the left ear demonstrated significant differences across time of day and type of person and the right ear did not, could be due to the fact that the left ear was being challenged more than the right ear because of the less direct pathway to the language center. This appears to be supported by the work of Petros et al. (1990) which showed time of day effects may be related to the difficulty of the task. In summary, the significant differences found in the left ear may be due to the task being a more challenging listening task.

#### Second, Fifth and Eighth Research Question

Is there a difference between type, time and/or effect of type and time on the Auditory Figure Ground subtest?

This analysis of variance using the Auditory Figure Ground subtest as an outcome variability found no statistical differences between type of person tested, time of test, nor an interaction between these main effects (see Table 11). At this time it is not known why there was no statistical difference found for this subtest. The findings that there was not a difference found in the Auditory Figure Ground subtest, although there was a difference found in the Filtered Word Subtest, may support that each subtest is examining

Table 11. General Linear Model of Auditory Figure Ground Subtest on the SCAN

	<u>Variable</u>	<u>F-test</u>	<u>D.F</u>	<u>p</u>
AFGTRE	Type	0.01	1, 65	0.9160
	Time	0.07	1, 65	0.7948
	Type X Time	1.28	3, 65	0.2630
AFGTLE	Type	0.26	1, 65	0.6118
	Time	0.83	1, 65	0.3653
	Type X Time	0.22	3, 65	0.6381
AFGTOT	Type	0.18	1, 65	0.6765
	Time	0.29	1, 65	0.5948
	Type X Time	0.10	3, 65	0.7526

different domains of auditory processing. This is supported by the fact a significant difference was found in FWTOT for the effect of time of day, however, that difference was not found in the Auditory Figure Ground subtest. Since a significant difference was found for time of day in one subtest and not in another appears to support the fact that these subtests are testing different domains of auditory processing.

This lack of significance in the AFG subtest also could be due to the difficulty level of the task. Petros et al. (1990) showed that to find a time of day difference on a reading task, the task must be challenging. The researchers in this earlier investigation only found a time of day difference on the difficult reading passage. The subtest of Auditory Figure Ground may not have been challenging enough for the college students tested. The SCAN is currently normed on a population of 3 to 11 years old. The lack of significance once again could be attributed to the lack of difficulty of the task. Finally,

restricted variability could be accounting for the fact that no statistically significant differences were found.

Perhaps if the study had used more widely spread time of administration of the test, more significance would have been found. However, these times were chosen because traditional audiological testing takes place between 8 a.m. and 5 p.m. Another two factors that could have allowed for significant differences in the subtest of Auditory Figure Ground were the use of more difficult listening tasks or testing people with widely divergent skills such as people with CAP problems. The first factor of a more difficult listening task would have simply made the test challenging to the subjects who had normal CAP abilities in order to find more significant differences. As previously mentioned challenging tasks may be needed to find significant differences. Secondly, if people with more divergent skills had been used in this investigation most likely the SCAN would have been challenging enough to produce more significant differences. For example, people with CAP problems may not have been able to process the words in the three environments tested by the SCAN.

#### Third, Sixth and Ninth Research Question

Is there a difference between type, time and/or effect of type and time on the Competing Word subtest?

When examining the individual factors of time of day and type of person tested there was no statistical difference found, nor was significance found for the interaction of type of person tested and time tested for CWTLE and CWTOT (see Table 12). The morning-type people tested in the morning had a mean of 46.0 and the evening-type people had a mean of 44.67 on the CWTLE. The morning-type people had a mean of

Table 12. General Linear Model of Competing Word Subtest of SCAN

	<u>Variable</u>	<u>F-test</u>	<u>D.F</u>	<u>p</u>
CWTRE	Type	0.85	1, 62	0.3615
	Time	0.05	1, 62	0.8190
	Type X Time	5.85	3, 62	0.0187**
CWTLE	Type	2.48	1, 61	0.1139
	Time	0.97	1, 61	0.3278
	Type X Time	2.58	3, 61	0.9886
CWTOT	Type	2.35	1, 61	0.1309
	Time	0.35	1, 61	0.5565
	Type X Time	1.85	3, 61	0.1795

Note. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

45.18 when tested in the evening and the evening-type people had a mean of 43.87 on the CWTLE. The morning-type people tested in the morning had a mean of 91.73 and the evening-type people had a mean of 91.53 on the CWTOT. The morning-type people had a mean of 92.71 when tested in the evening and the evening-type people had a mean of 88.87 on the CWTLE. The means are closely clustered together especially in the morning test time and thus there was low variability in these results. Perhaps, once again this subtest was not difficult enough so the subjects are experiencing a ceiling effect and thus getting the majority of the words right. This relative simplicity of the task and stimuli may have caused the low variability in performance. Another reason statistical differences may not have been found is that not a large enough sample was used. A larger sample size may have been enough to make some of results significantly different particularly when looking at performance on the CWTOT ( $p=0.1309$ ) and the CWTLE



( $p=0.1139$ ) as the values were nearly significant at the  $p>0.10$  level for type of person tested.

The effect of time of day was different depending on the type of person (morning and evening) for perception of Competing Words in the right ear. This effect is demonstrated by the significant interaction of type of person and time tested found in the right ear portion of the Competing Word subtest of the SCAN ( $p=0.0187$ ). These differences were found to be significant at the  $p>0.05$  level and the effect can be seen in Figure 4. The morning-type people performed better in the evening with a mean of 47.65 as compared to a performance in the morning time with a mean of 45.60. The evening-type people performed better in the morning test with a mean of 46.87 as compared to in the evening test time with a mean 45.13.

As time progressed through the day the morning-type people did better on the CWTRE, while the evening-type people's performance decreased through the day. This is opposed to what is shown in other time of day research. Typically the morning person's performance decreases through the day as they move away from their optimal arousal period, whereas evening-type people's arousal increases through the day along with their performance. A reason for this contradictory finding could be that the morning-type people and evening-type people were concentrating more on the task at hand as they entered their poorer time of day.

It is not surprising that significant differences were found within the portions of the Competing Word subtest due to the increase in the difficulty of listening to a dichotic task. It would be expected for significant differences to be found for the left ear and

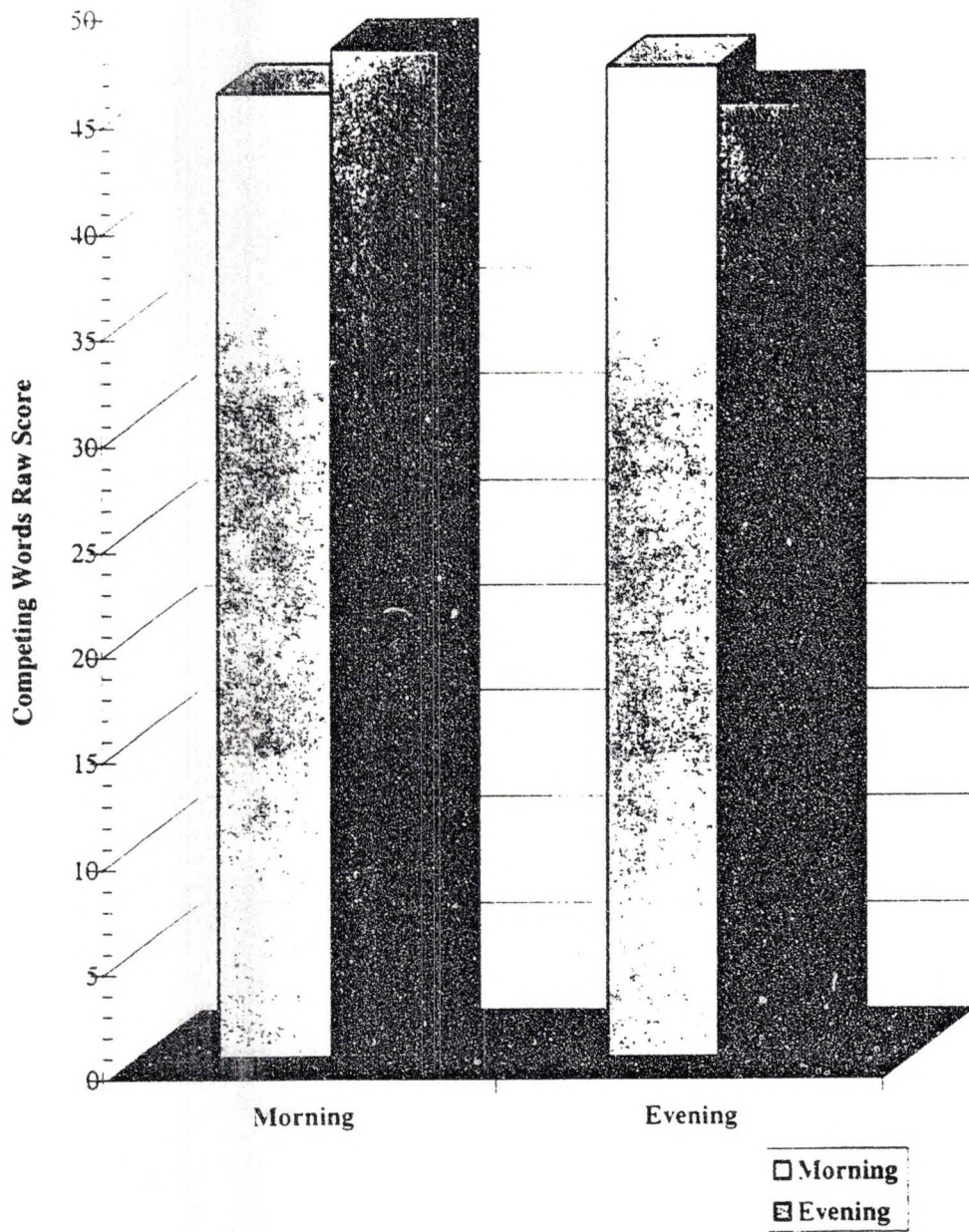


Figure 4. The effect of subject type and test time on performance on the Competing Word subtest in the left ear.

not the right ear and the opposite pattern was found. Given that the research demonstrates a right ear advantage on dichotic listening tasks, it would appear to be more likely that differences would be found while listening to this dichotic listening task with the left ear as compared to the right ear. This was not the case. Significant differences were found only in the right ear and not in the left ear. It is not known why the right ear was found to have significant differences in performance and while the left ear did not.

### Summary

Several findings in this study supported the hypothesis of a time of day effect, but the differences in performance for many of the other outcome measures were not significantly impacted by test time. This lack of statistically significant differences could be due to a number of factors. The first factor limiting significance may be that there was not a great deal of variability in the subject performance. The means were clustered closely together between each type of person tested and the time of day tested. In addition, the variability in performance as indicated by the standard deviations were low. A common statistical finding is that with higher variability in performance it is more likely statistical significance will be found.

The second factor limiting the number of statistically significant findings was that there was a ceiling effect. This ceiling effect meant that the test, the SCAN, was too easy for the population tested. After all, the SCAN is normed on a population of 3 to 11 years old. Thus, the mean performance for the subjects tested did not vary a great deal; for example, FWTOT ranged from 37.00 to 37.94 (with a maximum possible score of 40) across time of day and type of person tested.

There were differences found between this study and previous research in this area. An earlier investigation completed by Rozzi in 1997 at the University of North Dakota demonstrated that some clinically used auditory perception tests are affected by time of day. Specially, Rozzi demonstrated a time of day effect where the morning-type people performed better in the morning and evening people performed worse in the morning time on the filtered speech test in the left ear. However, in the present study the effect was found in the opposite direction, so evening-type people did better in the morning and the morning-type people had enhanced scores in the evening.

Perhaps this opposite interaction between type of person and time tested could be due to attentional effects. The subjects in the study may have simply tried harder to concentrate outside their preferred time of day. The increased concentration may have lead to the morning-type people performing better in the evening, while evening-type people performed superior in the morning. Also this was a different and likely easier task as the SCAN was normed on the population of 3 to 11 years old.

According to Petros, the more difficult the task the more likely time of day effects will be observed. However, this was not the case in this study. A statistically significant difference was found for time of day effect in the Filtered Word subtest and the subjects' overall performance averaged 37 of 40 correct responses. In the Auditory Figure Ground subtest the subjects' mean performance was 35 out of 40 indicating a somewhat more difficult measure. Yet there was no time of day effect found with the Auditory Figure Ground subtest and there was with the Filtered Word subtest. Therefore, this study seems to support that the ability to perceive spectrally altered stimuli varies throughout the time

of day, but the ability to hear speech in noise is not influenced by time of day. Thus this supports that different types of auditory perception are affected by time of day differently due to each subtest testing different domains.

Another finding in this investigation is that not every subject who achieved 100% on one subtest got 100% on the other subtests. No scores in the right and left ear directly corresponded to each other. In addition, the subject may have had a good performance on the right ear and poor on the left. There also is a low degree of association between several of the left and right ear scores.

Additionally, there are relatively low degrees of association between the subtests. One would expect that if a subject were able to perform well on one subtest, he or she would perform well on the rest of the subtests. The findings in this investigation support that if a subject performs well on the Competing Word subtest it does not mean he or she will perform well on the Auditory Figure Ground subtest. Therefore, it is imperative to test both ears and test all subtests. Otherwise if a very high degree of association were found, a simpler test could have been made because if a diagnostician knew a client's performance level, he or she would know all performance levels for the client.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

Time of day has received attention in several fields of research, such as long and short-term memory, although there has been limited research dealing with the effects of time of day and central auditory processing (CAP). Therefore, the purpose of this study was to determine if there were any time of day effects on an individual's central auditory performance. Sixty-six subjects participated in this study tested either in the morning (at 7:30am or 8:00am) or in the evening (at 4:30pm or 5:00pm). The SCAN was used as the central auditory measure. The SCAN evaluated three different listening environments: filtered words (i.e., words that were low-passed filtered), auditory figure ground (i.e., speech in noise) and competing words (i.e., words presented dichotically).

Previous research by Rozzi (1997) has shown time of day effects on the Filtered Word subtest, with morning people's performance decreasing through the day and evening-type people's increasing through the day. Rozzi also found a difference in performance across time of day on a speech in noise test. The following were the results from the current study:

1. The current study found significant differences on the Filtered Word subtest.

However, the results were in direct opposition to those found by Rozzi in an earlier investigation. In this current investigation, significant differences were found in the left ear on both the main effect of type of person ( $p=0.0831$ ) and test timed

( $p=0.0587$ ). No significant differences in performance were found in the right ear. Also, significant differences in performance were found when examining FWTOT for the effect of time ( $p=0.0429$ ). For all of these previous findings in this investigation, evening-type people performed better in the morning, while morning-type people performed better in the evening. The findings in the current study were opposite to what was found by other researchers, such as Rozzi (1997), Anderson et al. (1992), and Horne and Ostberg (1976), who found that morning-type people's performance decreased through the day, while evening-type people's performance increases through the day as they approach their optimal time of day. This difference in performance in the current investigation is speculated to be due to an attentional task such as concentration.

2. No statistical difference was found between type of person tested, time of test, or an interaction of these main effects on the subtest of Auditory Figure Ground. It is interesting to note that interaction between the main effects of type of person and time tested approached significance on AFGTRE ( $p=0.2630$ ).
3. A significant difference in performance was found when examining the subtest of Competing Words. Specifically, a significant interaction between the main effects of type of person and time tested was noted with the CWTRE ( $p=0.0187$ ). Once again as time progressed through the day morning-type people performed better on this task and evening-type people performed more poorly. It is speculated that the subjects used an attentional strategy such as increased concentration so that they performed better outside their optimal time of day. Some subtle non-significant differences were

noted between the type of subject in both the left ear ( $p=0.1139$ ) and total score for both ears ( $p=0.1309$ ).

### Limitations of the Study

There were several limitations in this study. The first limitation was that the SCAN was only normed on a population of 3 through 11 years old. Thus, the test may have been too easy for the subjects. The mean performance of the subjects was clustered closely together leading to low variability in the study.

The second limitation was the population chosen as subjects. The subjects were not representative of general population. As college students, the majority would have normal CAP skills, thus making the SCAN less challenging to them. If subjects with varying CAP abilities were used, it is possible more significant differences could have been found.

The third limitation was that some of the subjects' scores were incomplete on portions of the testing. These incomplete portions lead to the unequal cell sizes. Equalizing cell groups and also increasing the number of subjects may have led to finding additional significant differences. The limitations of this investigation should be addressed in future research.

### Suggestions for Future Research

1. A replication of this study should be done using people with varying levels of central auditory processing abilities.



2. A replication of this study should be done utilizing the SCAN-A which is normed for the ages of 12 years old to adulthood.
3. Future research may consider an analysis of the pattern of errors made on the SCAN by these subjects at varying test times and across type of subject.

## APPENDIX A

### GLOSSARY

- AFGTLE** Auditory figure ground left ear  
A measurement of the number of words identified correctly in the left ear. The words are presented in the presence of multi-talker babble noise at plus 8db speech to noise ratio.
- AFGTOT** Auditory figure ground total  
A measurement of the number of average correct words heard in noise collapsed across the left and right ears.
- AFGRE** Auditory figure ground right ear  
A measurement of the number of words identified correctly in the right ear. The words are presented in the presence of multi-talker babble noise plus 8db speech to noise ratio.
- CAP** Central auditory processing
- CAPD** Central auditory processing disorder
- CWTLE** Competing word left ear  
A measurement of the number of words identified correctly in the left ear when the pairs of words are presented dichotically.
- CWTOT** Competing word total  
A measurement of the number of dichotic words correctly identified

## APPENDIX B

### University of North Dakota Research Subject Consent Form

My name is Christine MacKenzie. I am a graduate student in speech-language pathology at the University of North Dakota under the direction of Kevin M. Fire, Ph.D., CCC-A. I am conducting a study designed to examine the effects of time of day on the performance of a central auditory processing screening test, the SCAN. In particular, my interest is whether the time of day will affect a person who is a morning type person differently than an evening type person. This study may assist Speech-Language Pathologists by giving them a further understanding of a person's central auditory processing abilities and the effects of time of day on it.

As a subject in this study, you will be asked to complete a questionnaire, Horne and Ostberg's Self-Assessment Questionnaire (1976), to determine your time of day preference. This questionnaire will take about 10 minutes to complete and will classify you along a continuum of morningness and eveningness. The questionnaire is 19 questions in length. After completing the questionnaire, if you are classified as either a morning or evening type person, you will be contacted by the researcher and invited to participate further. Filling out the questionnaire does not obligate you to participate in the study; you may decline if you so choose.

At this time if you choose to participate further in the study, you will have your hearing screened to eliminate the possibility of hearing loss. As well, you will have a screening of your middle ear to ensure normal pressure and mobility of your middle ear. The hearing test is a brief test which will consist of wearing headphones and listening to faint tones. The middle ear evaluation will be conducted by the inserting a soft rubber probe tip into your ear which will create an airtight seal in the ear canal. This probe will change the ear pressure and measure the transmission of sound through the middle ear. This test is commonly used clinically and the pressure change is comparable to pressure exerted at approximately the depth of 8 inches of water. After the determination of your hearing and middle ear performance you will have the SCAN administered to you.

The SCAN: a Screening Test for Auditory Processing Disorders (Keith, 1986) will be used to assess your central auditory processing skills. The SCAN has three subtests: Filtered Words (FW), Auditory Figure-Ground (AFG), and Competing Words (CW). The test in its entirety takes 20 minutes to administered. On this task, your auditory processing will be evaluated by having you respond to an auditory stimulus that is presented in the presence of distracting stimuli. Your auditory attention will be measured

at volume levels which are comfortable and safe. No sensitive or offensive materials will be used.

All of the information obtained from this study will remain strictly confidential. Participating in this study cannot identify you. You will be kept anonymous by a number identification given at the time of participation. Individual response forms will not contain any identifying information except a subject number. Individual results will not be reported, only group means. All information will be kept in a locked file for three years with access only permitted to the primary researcher and/or the researcher's advisor, Dr. Fire. After three years has passed all information will be destroyed via a paper shredder.

In addition, you may withdraw from this study at any time for any reason. Should you choose to withdraw from the study you will not be penalized in any way and withdrawal will have no bearing on your relationship with the University of North Dakota or to the Department of Communication Sciences and Disorder or to the Department of Psychology.

It is hoped that information from the present study will give a further understanding into the influence of time of day on auditory processing measures.

Any questions concerning this research may be brought to the attention of my research advisor or me. You may contact Dr. Fire or me at (701)-777-3232.

I, \_\_\_\_\_ have read the above statement and I willingly agree to participate in this study as it was explained to me by the researcher, Christine MacKenzie.

\_\_\_\_\_  
Subject Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Subjects Name (printed)

## REFERENCES

## REFERENCES

- Amos, E. N., & Humes, E. L. (1998). SCAN test-retest reliability for first- and third grade children. Journal of Speech, Language and Hearing Research, *41*, 834-845.
- Anderson, J. M., Petros, V. T., Beckwith, E. B., Mitchell, W. W., & Fritz, S. (1991). Individual differences in the effect of time of day on long-term memory access. American Journal of Psychology, *104*, 241-255.
- Anst, D., & Katz, J. (1982). Central auditory assessment: the SSW test development and clinician use. San Diego, California: College Hill Press.
- Bellis, J. T. (1996). Central Auditory Processing Disorders. San Diego, California: Singular Publishing Group.
- Blake, J. F. M. (1967). Time of day effects on performance in a range of tasks. Psychodynamic Science, *9*, 349-350.
- Bocca, E. C., Calearo, V., Cornacchia, L., & Migliavacca, F. (1955). Testing hearing in temporal lobe tumors. Acta Otolaryngologica, *45*, 289-304.
- Butler, K. G. (1981). Language processing disorder: Factors in remediation. In Keith, W. R (Ed.), Central Auditory and Language Disorders in Children (pp. 160-174). San Diego, California: College Hill Press.
- Butler, K. G. (1984). Language processing. In E. Z. Laksy and J. Katz (Eds.), Central Auditory Processing Disorders (pp. 297-315). Baltimore, Maryland: University Park Press.
- Cacace, T. A. & McFarland, J. D. (1998). Central auditory processing disorder in school-aged children: a critical review. Journal of Speech, Language and Hearing Research, *41*, 355-373.
- Cacace, T. A. & McFarland, J. D. (1995a). Opening pandora's box: the reliability of CAPD tests. American Journal of Audiology, *4*, 61-62.
- Chermak, G. D., & Musiek, F. E. (1992). Managing central auditory processing disorder in children and youth. American Journal of Audiology, *1*, 61-65.
- Cherry, R. (1992). Screening and evaluation of central auditory processing disorders in

young children. In J. Katz, N. Stecker, & D. Henderson (Eds.), Central auditory processing: transdisciplinary view. (pp. 129-140). St. Louis, Missouri: Mosby Year Book.

Colquhoun, W. P. (1971). Circadian variations in mental efficiency. In W. P. Colquhoun (Ed.), Biological Rhythms and Human Performance. London: Academic Press.

Emerson, F. M., Crandell, K. K., Seikel, A. J., & Chermak, D. G. (1997). Observations on the use of the SCAN to identify children at risk for central auditory processing disorders. Language, Speech and Hearing Services in School, 28, 43-48.

Eysenck, W. M. (1975). Effects of noise, activation level, and response dominance on retrieval from semantic memory. Journal of Experimental Psychology: Human Learning and Memory, 104, 143-148.

Folkard, S. (1979). Time of day and level of processing. Memory and Cognition, 7, 247-252.

Folkard, S., & Monk, H. T. (1980). Circadian rhythms in human memory. British Journal of Psychology, 71, 295-307.

Folkard, S., Monk, H. T., Bradbury, B., & Rosenthal, J. (1977). Time of day effects in school children's immediate and delayed recall of meaningful material. British Journal of Psychology, 68, 45-50.

Goldman, R., Fristoe, M., & Woodcock, R. W. (1970). Test of auditory discrimination. Circle Pines, Minnesota: American Guidance Service.

Heffner, H. E., & Masterton, R. B. (1988). Effects of bilateral auditory cortex lesions in monkeys on sound localization. In M. Berkley & W. Stebbins (Eds.), Comparative Perception: Vol. I. Discrimination. New York: Wiley & Sons,

Hirsh, I. J. (1959). Auditory perception of temporal order. Journal of the Acoustical Society of America, 31, 759-767.

Hockey, G. R. J., Davies, S., & Gray, M. M. (1972). Forgetting as a function of sleep at different times of day. Quarterly Journal of Experimental Psychology, 24, 386-393.

Home, A. J. & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International Journal of Chronobiology, 4, 97-110.

Humphreys, S. R., & Revelle, W. (1984). Personality, motivation, and performance: a theory of the relationship between individual differences and information processing. Psychological Review, *91*, 153-184.

Jerger, M. S. (1981). Evaluation of central auditory function in children. In Keith, W. R. (Ed.), Central Auditory and Language Disorders in Children (pp. 30-60). Houston, Texas: College-Hill Press.

Karvelis, Γ. (1987). Time of day and students performance in long and short-term memory tasks. Unpublished doctoral dissertation, University of Bridgeport, Connecticut.

Katz, J. (1992). Classification of auditory processing disorders. In J. Katz, N. Stecker, & D. Henderson (Eds.), Central auditory processing: transdisciplinary view. (pp. 81-91). St. Louis, Missouri: Mosby Year Book.

Katz, J., Stecker, N., & Henderson, D. (1992). Introduction to central auditory processing. In J. Katz, N. Stecker, & D. Henderson (Eds.), Central auditory processing: transdisciplinary view. (pp. 1-8). St. Louis, Missouri: Mosby Year Book.

Keith, W. R. (1981) Audiological and auditory language tests of central auditory function. In Keith, W. R. (Ed.), Central Auditory and Language Disorders in Children (pp. 61-76). Houston, Texas: College-Hill Press.

Keith, W. R. (1984). Central auditory dysfunction: a language disorder?. Topics in Language Disorders, *4*, 48-56.

Keith, W. R. (1998). Comments on the "use of SCAN to identify children at risk for CAPD" by Emerson et al. Language, Speech and Hearing in Schools, *29*, 117-119.

Keith, W. R. (1986). SCAN: a screening test for auditory processing disorders. Dallas, Texas: The Psychological Corporation.

Keith, W. R., & Novak, K. K. (1984). Relationships between tests of central auditory function and receptive language. Seminars in Hearing, *5*, 243-250.

Keith, W. R., Rudy, J., Donahue, A. P., & Katbamma, B. (1989). Comparison of SCAN results with other auditory and language measures in a clinical population. Ear and Hearing, *10*, 382-386.

Keith, W. R., & Talis, P. H. (1970). The use of speech in noise in diagnostic audiometry. Journal of Auditory Research, *10*, 201-204.



Kimura, D. (1961) Some effects of temporal lobe damage on auditory perception. Canadian Journal of Psychology, 15, 157-165.

Laird, D. A. (1925). Relative performance of college students as conditioned by time of day and day of week. Journal of Experimental Psychology, 8, 50-63.

McFarland, J. D., & Cacace, T. A. (1995b). Modality specific as a criterion for diagnosing central auditory processing. American Journal of Audiology, 4, 36-48.

Millar, K., Styles, C. B., & Wastell, G. D. (1980). Time of day and retrieval from long-term memory. British Journal of Psychology, 71, 407-414.

Musiek, E. F., Baran, A. J., & Pinheiro, L. M. (1994). Neuroaudiology Case Studies. San Diego, California: Singular Publishing Group, Inc.

Musiek, E. F., & Geurkink, N. A. (1980). Auditory perceptual problems in children: considerations for the otolaryngologist and audiologist. Laryngoscope, 90, 962-971.

Musiek, E. F., Gollegly, K., Lamb, L., & Lamb, P. (1990). Selected issues in screening for central auditory processing dysfunction. Seminars in Hearing, 11, 372-384.

Musiek, E. F., & Lamb, L. (1994). Central auditory assessment: an overview. In J. Katz, N. Stecker, & D. Henderson (Eds.), Handbook of Clinical Audiology (pp. 197-211). Baltimore, Maryland: Williams and Wilkin.

Musiek, E. F., & Lamb, L. (1992). Neuroanatomy and neurophysiology of central auditory processing. In Katz, J., Stecker, N., & Henderson, D., Central auditory processing: transdisciplinary view. (pp. 11-31). St. Louis, Missouri: Mosby Year Book.

Naidoo, V. S., & Feth, L. L. (1995). In Wall, G. L (Ed.), Hearing for the Speech-Language Pathologist and Health Care Professional (pp. 1-39). Boston, Massachusetts: Butterworth-Heinemann.

Petros, V. T., Beckwith, E. B., & Anderson, M. (1990). Individual differences in the effects of day and passage difficulty on prose memory in adults. British Journal of Psychology, 81, 63-72.

Pinel, J. P. J. (1997). Biopsychology. Boston, Massachusetts: Allyn and Bacon.

Rozzi, M. (1997). The effects of time of day on auditory perception in morning and evening type person. Unpublished master's thesis, University of North Dakota, Grand Forks.

Sanger, D. D., & Deshayes, I. (1986). SCAN criterion-related validity, cited in Keith, R. W: SCAN: a screening test for auditory processing disorders. Dallas, Texas: The Psychological Corporation.

Sanger, D. D., Keith, W. R., Deshayes, L. I., & Stevens, K. P. (1990). A comparison of the SWW and language test results. Journal of Communication Disorders, 23, 433-443.

Sanger, D. D., Keith, W. R., & Maher, A. B. (1987). An assessment technique for children with auditory-language processing problems. Journal of Communication Disorders, 20, 265-279.

Stark, E. R., & Bernstein, E. L. (1984). Evaluating central auditory processing in children. Topics in Language Disorders, 4, 57-70.

Stecker, A. N. (1992). Central auditory processing: implications in audiology. In J. Katz, N. Stecker, & D. Henderson (Eds.), Central auditory processing: transdisciplinary view. (pp. 117-127). St. Louis, Missouri: Mosby Year Book.

Semel, E., & Wiig, E. (1980). Clinical evaluation of language functions. Columbus, Ohio: Charles Merrill Publishing Company.

Task Force on Central Auditory Processing Consensus. (1996). Central auditory processing: current status of research and implications for clinical practice. American Journal of Audiology, 5 (2), 41-54.

Willeford, A. J., & Burleigh, M. J. (1985). Handbook of Central Auditory Processing Disorders in Children. Orlando, Florida: Grune & Stratton, Inc.

Zemlin, R. W. (1998). Speech and Hearing Science. (4<sup>th</sup> ed.) Boston, Massachusetts: Allyn and Bacon.

Zimbardo, P. (1992). Psychology of Life. (13<sup>th</sup> ed.). New York: Harper Collins Publisher.