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Central Auditory Processing in Children With a History of Chronic Middle Ear Problems

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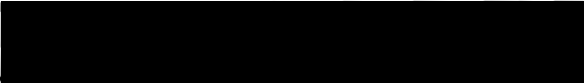
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AN ABSTRACT OF THE THESIS of Beverly S. Schnabel for the Master of Science in Speech Communication presented October 15, 1979.

Title: Central Auditory Processing in Children with a History of Chronic Middle Ear Problems.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:


James F. Maurer, Chairman


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The purpose of this study was to investigate the central auditory processing of children who had sustained chronic middle ear problems during their early language-learning years. A 60% compressed recording of the NU-6 speech discrimination word lists was administered to twenty eight and nine year old normal hearing public school children, reported by their parents to have had repeated middle ear problems during their early years, and to twenty control subjects matched for age from the same public school classes. Differences in compressed and uncompressed word discrimination scores between the experimental and control groups

were not found to be statistically significant. These results indicate that the experimental subjects' ability to process compressed speech was not impaired by early middle ear difficulties. The alternative was suggested that if these children actually sustained central damage due to distorted or degraded input during their hearing deficit episodes, then such effects may be neutralized by subsequent auditory experience and neurological maturity. A significant difference for both groups of children was noted between scores obtained with NU-6 lists 2A and 3A at 60% compression. While apparently equivalent in the uncompressed form, list 3 was found to be significantly more difficult than list 2 when compressed. Implications for further research are discussed.

CENTRAL AUDITORY PROCESSING IN CHILDREN WITH A HISTORY OF
CHRONIC MIDDLE EAR PROBLEMS

by

BEVERLY S. SCHNABEL

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requirements for the degree of

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TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	vi
CHAPTER	
I INTRODUCTION	1
II REVIEW OF THE LITERATURE	3
Sensory Deprivation During Critical Periods	3
Mild Hearing Losses in Children	6
Central Auditory Testing	12
The NU-6 Test	20
Summary	21
PURPOSE	22
Rationale	22
III METHODS	23
Subjects	23
Procedure	23
Instrumentation	24
Calibration	25
IV RESULTS	26
V DISCUSSION	31

CHAPTER

PAGE

Conclusion 34

Implications for Further Research 35

REFERENCES 37

APPENDICES 42

LIST OF TABLES

TABLE		PAGE
I	Average Adults' Speech Discrimination Scores for Five Conditions of Time Compression at Two Sensation Levels for Left and Right Ears	15
II	Mean Percent Correct for WIPI and PB-K50 at Each Percentage of Time Compression for 16 and 32dB SL . . .	18
III	Scores of Experimental and Control Subjects on Uncompressed and 60% Compressed NU-6 Lists	27
IV	Means, Ranges, and Standard Deviations for Performance Scores Obtained in Uncompressed and Compressed Conditions for Two Word Lists, the NU-6 Lists 2A and 3A	30

CHAPTER I

INTRODUCTION

The relationship between hearing loss and subaverage educational achievement in children has been well-known for a number of years. Similarly, hearing impairment has been shown to affect a number of specific areas of intellectual achievement, including speech and language abilities. There is more recent evidence to link the very prevalent childhood middle ear problems and their accompanying mild hearing loss to both educational and learning disabilities. But little is known about this relationship. Katz (1978) regards a conductive hearing loss as a mild, long term form of sensory deprivation. If this is the case, it is important to know what kind of deficits result from this mild deprivation and how lasting they are. These and other questions remain to be answered by research.

The audiologist is in a position to contribute to the development of both new and old tests for specific auditory disabilities, such as those affecting the learning disabled child. This area has been referred to as "an unmet area of responsibility which demands our attention" (Willeford and Billger, 1978). Peripheral testing is not enough to identify the "hidden" dysfunctions of the central auditory nervous system. The finding of normal hearing sensitivity for pure tones along with normal speech discrimination is not enough to rule out auditory perceptual problems. More in-depth testing of central auditory abilities

must be done as well. A number of central tests are currently available, and normative data for children is being gathered for some of them.

Information obtained from auditory testing could prove to be invaluable to educators who must provide remediation for children suffering from such specific disabilities. But this is largely a goal for the future and not one which can be adequately met at the present time.

CHAPTER II

REVIEW OF THE LITERATURE

Sensory Deprivation During Critical Periods

Prolonged sensory deprivation can have many detrimental effects upon human and animal behavior. These effects are particularly noticeable when the deprivation occurs during a developmental learning period. Since human infants exhibit an "age-linked emergence of behavior", Lenneberg (1967) suggests that some types of human behavior, such as language-learning, may take place during "...periods of peculiar sensitivities, response-propensities, or learning potentials." During such a "critical" period, certain types of stimuli are used most efficiently for learning.

The theory of a critical period for language development, discussed by Northern and Downs (1978), postulates an optimal time period for the reception and utilization of auditory language input for speech and language development. After this critical period, utilization of receptive auditory input is less effective. Northern and Downs believe that sensory deprivation during this critical time could have a serious effect on future speech and language development.

Total auditory deprivation over a period of time has been shown to have irreversible effects on speech and language. Northern and Downs (1978) reported an auditory training program for 17 to 19 year olds with severe hearing losses who had not previously worn hearing

aids. The study revealed that while younger children with similar hearing losses were able to learn speech discrimination, the young adults in their sample did not perform above the chance level on discrimination tasks even after intensive training. Northern and Downs conclude that this finding suggests auditory stimulation must occur during childhood in order for certain central auditory processing structures to develop normally. The idea that auditory stimulation is utilized at a very young age is supported by Lenneberg (1967) who noted that people becoming deaf after an exposure to speech of one year or more have a great advantage in learning speech over congenitally deaf individuals, again suggesting that the foundation for language skills is built at a very young age.

The age boundaries of a critical language period have not been precisely delineated. Lenneberg (1967) suggests that they are set by cerebral immaturity at one end and loss of cerebral plasticity when one hemisphere becomes dominant at the other end of the critical period. While learning a first language can still take place up until adolescence, evidence indicates that the critical period may end far sooner. Dennis (1973) studied the effect of environmental deprivation on institutionalized orphans. Those adopted before the age of two reached a normal IQ level, while children adopted into homes after age two did not achieve their expected IQs. If the same effect holds true for auditory deprivation, the first few years of a child's life are indeed critical for future language development. This is supported by Northern and Downs (1978) who note that severely hearing-impaired children, aged 40 months, whose speech and language training began prior to 16 months were consistently superior in all language skills to those whose

training began between 16 and 24 months.

Animal studies have examined the effects of auditory deprivation from birth or shortly after. One deficit found in deprived animals is poorer hearing thresholds (Batkin, Groth, Watson and Ansberry, 1970). These authors claim that a certain level of acoustic stimulation is necessary for normal auditory development. However, they did report some recovery of threshold sensitivity in animals which were subsequently exposed to sound.

Sensory deprivation may affect complex auditory skills as well as auditory acuity. In another study (Tees, 1967) two groups of rats were raised in a sound-resistant locker, where one group received two hours of auditory stimulation with white noise every other day until the rats reached maturity. Later, it was determined that both these groups of deprived rats took far longer to reach criterion in learning a tonal pattern discrimination task than did a non-deprived control group.

Two sensory deprivation studies (Wolf, 1943; Gauron and Becker, 1959) temporarily subjected one group of young rats to auditory deprivation and one to visual deprivation. At maturity, some time after termination of deprivation, pairs of the rats were put in competition for food utilizing an auditory or visual signal. All animals previously deprived of hearing were more successful on the visual task than were the visually deprived and poorer in response to the auditory signal. That is, responses which depended upon the previously deprived modality were either slower or weakened.

Partial deprivation caused by a conductive hearing loss (mechanical obstruction) has been shown to cause abnormal changes in structures

of the central nervous system. Audiogenic seizures and other super-sensitivity to sound was found in rats fitted with ear plugs during their critical periods (McGinn, 1975). McGinn suspected that disuse during the critical period produced observable changes in the neural elements receiving major auditory inputs. This is supported by a morphological study of mice isolated from sound and mice with surgically induced conductive hearing losses (Webster and Webster, 1977). These authors' surgical examination revealed deficits in the ventral cochlear nuclei and trapezoid bodies. Webster and Webster maintain that their findings support the theory of a critical period during which sounds must be received for normal development of the central auditory system.

Mild Hearing Losses in Children

In humans, deafness from birth is certain to affect development of the brainstem and cortical structures. For instance, profound changes and atrophy are found in brainstem auditory nuclei of congenitally sensorineural deaf humans (Webster and Webster, 1977). Moreover, it may be conjectured from lower animal studies that less severe hearing losses may also affect the human higher auditory pathways (Northern and Downs, 1978).

Goetzinger (1962) reported a case study of twelve children with mild bilateral hearing losses of 20 to 35dB HL from birth or acquired prior to speech development. He concluded that hearing losses in this mild range appear to have an adverse effect upon speech, language, and auditory discrimination in children. Speech and language were about one year delayed for his sample, and while discrimination improved with time, Goetzinger suggested that it might never reach the level attained

by normal hearing children.

After reviewing case studies, Eisen (1962) concluded that temporary sensory deprivations during critical developmental stages may have irreversible effects. Further, he noted behavioral characteristics in several children who previously suffered intermittent middle ear infections in their first three years of life including slow development of speech, poor adjustment, learning disabilities, poor attention and delayed responses to verbal commands. He attributed these characteristics along with poor discrimination and poor localization of sound to the temporary auditory deprivation at an earlier age. Eisen felt these effects might possibly be overcome with age or further auditory experience.

Intelligence quotient may also be affected by a reduction of high quality language input. Experiential deprivation in the first two to three years of life can result in an eventual 30 to 50 point IQ deficit (Downs, 1976). Howie (1977) found evidence that even a mild hearing loss, such as that accompanying otitis media may affect IQ. When comparing a group of second graders who had three or more otitis media episodes in their first year of life with a matched control group, he noted significantly lower IQ scores among the otitis media group.

Educational abilities may also be deleteriously affected by chronic middle ear problems. Ling, McCoy and Levinson (1969) found the incidence of active ear disease to be 30.8% among children up to age nine in one Alaskan community. The children with middle ear disease were more likely to be poor achievers at school than were those without middle ear problems. The authors suggest that the high incidence of ear disease and hearing loss found in this study may be contributing to

educational retardation.

The verbal achievement scores of children with a history of repeated otitis media episodes and accompanying mild hearing losses were found to be poorer than the scores of their non-affected peers (Kaplan, et al., 1973). As a result of their ten-year study, the authors conclude that an early history of recurrent otitis media should indicate the possible need for special services and teaching methods in school.

Holm and Kunze (1969) investigated the effects of fluctuating hearing losses from otitis media on speech and language development with children aged five-and-a-half to nine, having their first episode of otitis media prior to age two. In an extensive battery of standardized tests, the experimental subjects demonstrated a delayed acquisition of all language skills and were deficient in tests requiring reception, processing of auditory stimuli, or verbal expression. However, the performances of the two groups on visual and motor skills were not significantly different. Holm and Kunze believe that this study provided strong evidence of the far-reaching effects of conductive hearing impairment.

Lewis (1976) found poor auditory processing skills in culturally-disadvantaged 7.5 to 9.4 year old subjects who had consistently failed audiometric or tympanometric screening examinations over a four year period of study. Scores obtained on measures of auditory discrimination and phonemic synthesis were significantly poorer than those obtained by classmates who consistently passed audiometric screening. Lewis concluded that middle ear disorders may promote poor listening

skills and create serious educational difficulties.

Needleman (1977) investigated articulation and auditory discrimination abilities of children three to eight years old who had reportedly experienced two or more years of chronic otitis media with the initial episode prior to 18 months of age. The control group obtained significantly higher performance scores on the test battery which included phoneme production, auditory discrimination, and sound blending. The only exception to this trend was on a phonemic closure test. Needleman attributed the experimental subjects' comparable or even higher scores on this test to their experience with similar conditions of missing message segments during periods of fluctuating hearing loss. Performance differences tended to lessen with age, suggesting that children with early hearing loss may "catch up" in certain phonological skills. However, phonologic development is only one of the problem areas encountered by children with a history of early otitis media. Needleman noted that with other skills and academic achievement in general, these children may or may not catch up with their normal hearing peers.

Assessments of populations of children with a high incidence of middle ear problems demonstrate an overall delay in speech and language abilities. In the cleft palate population, language comprehension and usage deficits were found to persist up to at least the six year level (Philips and Harrison, 1969). These deficits could prove to be related to the fluctuating hearing loss from otitis media found in 100% of cleft palate infants (Paradise, Bluestone and Felder, 1969) and preschool children (Harrison and Philips, 1971). Similarly, a median delay of two years in speech and language abilities was found in children with

cystic fibrosis, who, as a group, sustained a 48% incidence of conductive hearing loss (Forcucci and Stark, 1972).

There is evidence to indirectly correlate hearing problems and poor academic achievement. In a group of young learning disabled children aged six to fourteen years, 33% were observed to have hearing losses, most of them mild to moderate in severity and conductive in nature (Katz and Illmer, 1972). Similarly, Hersher (1978) found a 54% incidence of recurrent otitis media (six or more episodes) in hyperactive learning disabled children as compared to a 15% incidence in a control group matched for age.

Stubblefield and Young (1975) link learning disabilities and central auditory dysfunction. Their study utilized the Staggered Spondaic Word Test to assess central auditory function in seven to eleven year old learning disabled and normally achieving children. All twenty control subjects scored well within the normal adult range on the test, while the learning disabled subjects made consistently more errors, placing their scores outside the normal range.

The previous studies seem to support the notion that the complexity of conductive hearing loss goes beyond a simple mechanical blockage or reduction in the intensity of sound reaching the cochlea. For example, recruitment (an inner ear disorder) has been found in cases of pure conductive loss where it was not found in normal subjects wearing ear plugs (Anderson and Barr, 1966). Harford and Jerger (1959) found a more pronounced reaction to delayed speech feedback in otosclerotics than in normals or in normals wearing ear plugs. Epstein, Katz and Dickinson (1962) found an unusually large temporary threshold shift in

conductively impaired subjects who were exposed to a three-minute 20dB sensation level tone. Recovery from the threshold shift was also slower for conductives than for normals or for other hearing impairments. The authors hypothesize that with reduced stimulation over a period of time, there is a lessened production of the chemicals involved in reception of sound. Further, they noted that there was not a sudden recovery of normal responses when the conductive block was removed.

A hearing loss, especially a fluctuating one, produces both a deprivation and a distortion of the stimulus. Even a slight 15dB loss may be handicapping when one considers the significance of the low energy unvoiced consonants. Normal hearing people miss many unvoiced sounds and fill them in mentally. But a child who has not mastered language may not achieve closure (Downs, 1976). Learning difficulties may result or be compounded when, due to hearing fluctuations, the auditory input is not received in a consistent manner over a period of time. Thus, a young child's brain may be forced to use these distorted bits of information for language development (Katz and Illmer, 1972).

Speech perception involves a series of neural connections within the cortex, with a message unit represented by a stream of neuronal impulses leaving behind a permanent facilitation (Penfield and Roberts, 1959). Thus, when the same message unit is subsequently received, it is processed more readily. This facilitation may not occur as easily, however, for the child who is receiving inconsistent messages. Given the rapid nature of speech and language development, it is not difficult to see how reductions in the quality and intensity of verbal input during the critical period could lead to confusions and learning

disabilities (Katz, 1978). Whether the resultant deficits are permanent due to the poor and variable quality of input during the critical period, or whether they are overcome once the middle ear problems are corrected is an important, and as yet unanswered question.

Dalzell and Owrid (1976) conducted a follow-up study on the speech and language skills and hearing thresholds of a group of children who had conductive hearing losses five years previously. In general, the authors concluded that improvement was made in both hearing sensitivity and linguistic skills. While there were individuals who continued to have mild hearing losses after the five year period, the mean pure tone averages of the group improved from 32dB HL to 15dB HL. Similarly, three out of four vocabulary and reading tests revealed improvement from scores obtained earlier. However, not one of the children performed above the average range on any of the four tests. Although general improvement was found, these findings did not rule out the possibility of residual effects for some or even all of the experimental subjects.

Since it is believed that a central auditory processing deficit impairs the reception and interpretation of auditory information (Wilford and Billger, 1978), it may well be that the poor speech and language ability and the higher than average incidence of learning disability among children with chronic middle ear problems are related to auditory processing deficits. That is, the speech, language, and learning difficulties of children with chronic middle ear problems may be the result of residual damage to higher auditory processing centers.

Central Auditory Testing

A number of audiological tests are used to differentiate the site

of lesion in auditory testing. However, the auditory manifestations become more subtle as the site of lesion moves from peripheral to central (Jerger, 1960). The tests required to identify subtle lesions in the higher pathways must put a heavy demand on the auditory system. Most central tests employ a speech stimulus which is degraded by competing speech or noise, selective filtering, or accelerating (Jerger, 1960).

Bocca, Calearo, and Cassinari (1954) observed normal pure tone thresholds and speech discrimination in patients with temporal lobe tumors. These researchers filtered speech so that words were less recognizable, in order to involve more central integrative processes. Their experimental data revealed poorer discrimination in the ear contralateral to the site of lesion.

Accelerated speech was used by Calearo and Lazzaroni (1957) to degrade speech stimuli. These authors reported the potential of accelerated speech for identifying both unilateral lesions, such as a tumor, as well as the more subtle, generalized lesions found among aging people. The bilateral reductions in speech discrimination ability which were observed in aging subjects have been verified by another investigator, deQuiros (1964). Calearo and Lazzaroni believed that this inability to understand speech at an accelerated rate could be a sign of cortical dysfunction or of an increase in synaptic transmission time along the central auditory pathways.

Time compression as a method of degrading the speech stimulus was developed in 1954 by Fairbanks, Everitt and Jaeger (Sticht and Gray, 1969). The process of compression involves periodic time sampling of the input signal, cutting out small segments. The remaining segments

are compressed in frequency and recorded as a continuous signal. They are then reproduced at a speed appropriate to restore the original input frequencies, eliminating the frequency distortion found in accelerated speech (Fairbanks, 1957). Time compressed speech has been used in differential site of lesion testing with results similar to those obtained using accelerated speech (Oelschlaeger and Orchik, 1977).

Sticht and Gray (1969) support the use of compressed speech as a central rather than peripheral test. Using young and old subjects with normal hearing and sensorineural hearing losses, they attempted to isolate the effects of diffuse central changes while controlling for cochlear lesions. Their data indicated that compressed speech discrimination scores decreased with age for all subjects at a similar rate, regardless of peripheral hearing sensitivity.

Normative data collected with adult listeners' performance on 30% to 70% time compressed NU-6 monosyllables (Beasley, Schwimmer and Rintelmann, 1972) revealed that intelligibility decreased with the amount of time compression (See Table I). At 30% compression, discrimination scores were essentially as good as those obtained with no compression and from 30 to 60% compression, intelligibility was gradually reduced until 70% where it broke down severely.

Sensation level (SL) appears to be an important consideration when using time compressed materials. Beasley, Schwimmer and Rintelmann (1972) noted that the articulation function for time compression of 0% to 60% steadily improved as the sensation level of the material was increased from 8 to 32dB SL. Presenting the same material at a higher sensation level (40dB SL) failed to show any further improvements in

TABLE I

AVERAGE ADULTS' SPEECH DISCRIMINATION SCORES FOR FIVE
 CONDITIONS OF TIME COMPRESSION AT TWO SENSATION
 LEVELS FOR LEFT AND RIGHT EARS
 (BEASLEY AND FREEMAN, 1977)

Sensation Level		Percentage Time Compression					
		0	30	40	50	60	70
32dB	L	95.8%	96.8%	94.8%	91.2%	90.8%	69.2%
	R	97.0	96.5	93.2	93.5	90.0	61.5
	\bar{X}	96.4	96.6	94.0	92.3	90.4	65.5
40dB	L	97.5	96.8	96.0	93.5	92.0	75.5
	R	98.8	98.0	98.3	97.5	96.3	85.3
	\bar{X}	98.2	97.4	97.2	95.5	94.2	80.4
Mean Performance Improvement Utilizing the Higher Sensation Level (40dB)		1.8	0.8	3.2	3.2	3.8	14.9

discrimination (Beasley, Forman and Rintelmann, 1973).

Konkle, Beasley and Bess (1977) investigated performance with time compressed monosyllables utilizing a population of aging subjects. Discrimination scores were found to decrease with age, amount of compression, and reduced sensation level. The subjects aged 60 and above showed significant discrimination score reductions at 40% compression, with the greatest reductions at 60% compression. Reductions at 20% compression were not found to be significant, which supports an earlier study by Luterman, Welsh and Melrose (1966). Thus, it appears that compression ratios of 40% or more are required to produce significant reductions in discrimination performance, at least for normal and aging subjects.

If time compressed speech is sensitive to such degenerative changes in the central auditory processing of adults, it appears propitious to examine it with children. It cannot be assumed that the normal child's performance is comparable to that of an adult. The maturation of auditory abilities in children is thought to be gradual, reaching its maximum by age thirteen, or even by age ten in some cases (Fior, 1972). Performance scores on speech discrimination and filtered speech tests are higher for teenagers than for eight to nine year olds (Palva and Jokinen, 1975). Thus, caution should be exercised when interpreting children's discrimination scores using adult norms.

Beasley, Maki and Orchik (1976) provide normative soundfield data for children age 3.5 to 8.5 on open set 50-word speech discrimination lists (PB-K50) and closed set Word Intelligibility by Picture Identification (WIPI) material compressed at 0%, 30%, and 60%. Their data

revealed that as time compression increased, word intelligibility decreased, with the poorest discrimination scores occurring at 60% compression. This reduction in discrimination scores was partially offset by increasing the presentation level up to 32dB SL. Closed set WIPI tests were found to be much easier than the PB-K50 lists and performance on all measures improved with age. (See Table II). The authors suggest that closed set measures such as the WIPI would be most appropriate for younger children and that the PB-K50 or more difficult NU-6 tests could be used with older children. It was noted that the discrimination score variability increased as a function of the test difficulty, especially when the most difficult test conditions were presented first.

The performance of selected groups of children on time compressed measures was investigated by Orchik and Oelschlaeger (1977) who utilized normal hearing five and six year old children whose speech contained varying numbers of articulation errors. The test items on the WIPI were presented soundfield at 0%, 30%, and 60% compression. Children with four or more articulation errors were found to score poorer on the compressed discrimination test than those with no errors or one to four errors. According to the authors, these children exhibited a developmental lag in the ability to process time compressed speech. This "developmental lag" occurred at a 60% compression rate, with performances at 30% compression nearly equalling or even exceeding those at 0% compression. The correlation between articulation errors and difficulty with compressed speech, while apparently significant, was far from perfect. Some children with no articulation errors also scored poorly, and some children with many articulation errors did well.

TABLE II

MEAN PERCENT CORRECT FOR WIPI AND PB-K50 AT EACH PERCENTAGE
OF TIME COMPRESSION FOR 16 AND 32dB SL.
(BEASLEY AND FREEMAN, 1977)

WIPI Materials

<u>% Time Compression</u>	<u>6 Years</u>	<u>8 Years</u>
0	88.1%	94.3%
30	88.1	83.8
60	72.8	81.8

PB-K50 Word Lists

<u>% Time Compression</u>	<u>6 Years</u>	<u>8 Years</u>
0	76.3%	82.6%
30	66.9	74.3
60	46.2	51.6

Manning, Johnston and Beasley (1977) administered 0, 30 and 60% compressed PB-K50 words soundfield to seven and eight year old children with auditory perceptual disorders. These children performed at least one year below the norms for their age on two or more auditory subtests of the ITPA, or on one subtest and on a vocabulary test. Experimental data revealed no reduction in speech discrimination performance from 0 to 30% compression, and a marked reduction in discrimination scores at 60%. In a comparison of this data for 60% compression with Beasley, Maki and Orchik's (1976) data on normal children, the authors noted that those who were learning disabled performed 10.9 percentage points lower. However, at 30% compression the discrimination performance of the two groups was essentially the same.

Freeman and Beasley (1978) found significantly better performances on compressed speech material by normal-reading children than by those who were reading-impaired. All children in this study were aged 8 to 14 years and all had normal hearing (15dB HL or better). The test stimuli were 0 and 60% compressed WIPI lists at 24dB above the speech reception threshold. On both measures, the normal-reading subjects performed significantly better than the poor readers, with the greatest differences at 60% compression.

There appears to be ample documentation for the use of compressed speech in detecting central auditory nervous system changes in children (Oelschlaeger and Orchik, 1977; Orchik and Oelschleager, 1977; Manning, Johnston and Beasley, 1977; Freeman and Beasley, 1978). It is suspected that children with conductive hearing losses may demonstrate a long lasting or permanent neurological deficit as a consequence of the

reduction in quality and quantity of auditory input during their crucial speech and language learning years. Compressed speech tests are believed to be sensitive to subtle central auditory deficits. The Northwestern University Auditory test #6 (NU-6) in a compressed or uncompressed version was developed for use with adults and older children.

The NU-6 Test

The Northwestern University Auditory test #6 was designed to remedy some of the criticisms directed at the commonly used PAL PB-50 and CID W-22 discrimination word lists (Goetzinger, 1978). There were complaints that the PB-50 lists may not be phonetically balanced and that they contained a number of relatively unfamiliar words. Also, the W-22 lists are said to be too easy to make fine differentiations.

The NU-6 is based on Lehiste and Peterson's (1959) compilation of 1263 consonant-nucleus-consonant (CNC) monosyllables which occur at least one per million words. The four 50-word NU-6 lists are randomized and show high intertest reliability. The NU-6 test is reported to be the most carefully prepared and thoroughly researched lists of CNC words published to date (Davis and Silverman, 1978).

Normative studies utilizing NU-6 lists with children 7.5 to 11.5 years of age (Sanderson-Leepa and Rintelmann, 1976) revealed only minimal differences in mean scores as a function of age and all children performed best at the highest sensation level used, 32dB. It was the recommended test for children over 7.5 years when differences in auditory discrimination are to be determined.

Speech discrimination scores obtained in quiet with the NU-6 lists

have been found to be comparable for normal children and adults (Larson, Petersen and Jacquot, 1974). A group of children aged 5.5 to 6.5 years obtained discrimination scores 2.2 percentage points below the adults' mean score with the same range of 88 to 100%. With the addition of noise, however, the scores showed an increasing divergence. It could be expected that other degrading conditions, such as time compression, could likewise cause a reduction in the speech discrimination scores of normal children.

Summary

Auditory deprivation can result in degeneration of brainstem and cortical structures. This is particularly true if the deprivation occurs during an early "critical period" of development. Chronic middle ear problems which are prevalent in young children may create a mild to moderate form of sensory deprivation. The quantity of sensory input is decreased and the quality may vary and become distorted with fluctuations in hearing threshold levels. Assessments of populations of children with a high incidence of middle ear problems reveal educational difficulties and an overall delay in speech and language abilities.

If faulty central processing is a correlate of these educational and speech and language difficulties, such a deficit could possibly be verified by an audiologic test of central auditory function. Compressed speech discrimination tests have been used to identify cortical lesions as well as the more diffuse changes accompanying aging. Further, normative data is available for children's performance on compressed speech measures and children with learning disorders, articulation errors and

reading difficulties have been shown to perform below the norm on these measures.

PURPOSE

The purpose of this investigation was to determine whether nine and ten year old children with an early history of chronic middle ear problems would demonstrate degraded performances during compressed speech testing.

Rationale: Chronic otitis media in young children is a very prevalent condition and one which is not always given prompt medical attention. Even when a physician is consulted, the treatment given may not totally alleviate the problem. Follow-up appointments are not always made and kept.

During periods of middle ear inflammation, the child may be receiving a poor quality speech and language input. If this distorted input is utilized as a basis for later learning, some difficulties may be expected. That is, the child may fall behind his peers in speed and accuracy of auditory processing.

If it can be demonstrated that children with an earlier history of middle ear problems continue to score lower than the control subjects on a test of degraded speech, this information would support the seriousness of early chronic otitis media. In addition, it would suggest a need for better detection at an early age, more thorough medical treatment, temporary use of amplification, and other remedial methods.

CHAPTER III

METHODS

Subjects

The subjects for this study consisted of public school children 8.0 to 9.10 years of age, currently attending third or fourth grade at the Powell Valley elementary school in Gresham, Oregon. A permission slip for a hearing test was sent home with all third and fourth grade children, requesting permission to test the child and asking questions concerning any early middle ear or hearing difficulties experienced (See Appendix A). Children were selected on the basis of parent consent, responses to the questionnaire, and normal hearing as determined by pure tone testing.

All experimental subjects were reported by a parent to have had a significant history of middle ear problems, but no such problem currently. A control group of twenty children from the same elementary classes matched for age had no reported history of significant ear problems. All were tested and found to have normal air conducted hearing threshold levels, 20dB HL or better at 500, 1000, 2000, 3000, and 4000 Hz (ANSI, 1969).

Procedure

Pure tone air conduction thresholds were determined under ear-phones for both ears. All discrimination test material was administered binaurally at 40dB HL above the subject's pure tone average (500, 1000

and 2000 Hz) for each ear. The children listened to two recorded lists, NU-6, lists 2 and 3, Form A. One list was uncompressed and the other was 60% compressed. Presentation and list order of compressed and uncompressed material was randomized. Prior to data collection with compressed material, subjects were given three practice items selected from an alternate compressed list. Subjects were instructed to repeat the words they heard on the tape and to guess if they were not sure of a word. The experimenter recorded errors and tape recorded the responses for a subsequent evaluation. All data was tabulated on individual scoring sheets and expressed in percentages of correct responses.

Instrumentation

The speech discrimination testing material consisted of prerecorded uncompressed NU-6 word lists 2A and 3A (Auditec of St. Louis) and a 60% compressed recording of the same lists.

All tests took place in a single walled sound treated room (International Acoustics Corporation, Model 1201) in a mobile test van, and all tests were conducted through a clinical audiometer (Grason Stadler 1701). All stimuli were presented through a standard clinical set of earphones (Telephonics, Model TDH-49) mounted in foam rubber cushions (Acoustic Research, Model MX41/AR). The tape-recorded stimuli were presented from a reel-to-reel stereo tape recorder (Sony, Model TC-377) through the audiometer's tape circuit.

The audiometer's talk-back system was utilized to monitor subject responses. In addition, all subjects' responses were recorded on a cassette recorder (JVC Model CP-1602).

Calibration

The audiometer output at the earphones was electroacoustically calibrated to reflect current ANSI standards for pure tones (S3.6-1969) using a precision sound level meter (Bruel and Kjaer, Model 2203) and an artificial ear (Bruel and Kjaer, Model 4152). The calibration stability was verified by daily electroacoustic checks throughout the investigation. The tape-recorded stimulus material was presented through the audiometer's tape circuit with the calibration tone centered at 0dB HL on the VU meter.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effects of time compression on the speech discrimination abilities of children with a history of chronic middle ear problems. Twenty third and fourth grade children comprised the experimental group with twenty control subjects from the same school matched for age.

A high incidence of reported middle ear problems was found for the third and fourth grade students. Of the 134 parents giving permission for their child to receive a hearing test, over half (52%) reported a history of ear aches, ear infections, or draining ears. Nineteen percent (25) reported their child had one or more of these problems "many times".

Conventional, uncompressed speech discrimination scores obtained binaurally using NU-6 lists 2A and 3A for the forty experimental and control subjects ranged from 88% to 100% for each group. Mean performance scores for the two groups were essentially the same, 95% for the experimental group and 96% for the control group. (See Table III).

These averages compare favorably with those found by Sanderson-Leepa and Rintelmann (1976) for nine and one half year old children on NU-6 lists. They are also comparable to discrimination scores of normal adults on NU-6 lists (Larson, Petersen and Jacquot, 1974; Beattie, Edgerton and Svihovec, 1977).

TABLE III

SCORES OF EXPERIMENTAL AND CONTROL SUBJECTS ON
UNCOMPRESSED AND 60% COMPRESSED NU-6 LISTS

Experimental N=20		Control N=20	
<u>Uncompressed</u>		<u>Uncompressed</u>	
Range	88-100%	Range	88-100%
Mean	95%	Mean	96%
Median	96%	Median	96%
<u>Compressed</u>		<u>Compressed</u>	
Range	44-74%	Range	50-82%
Mean	58.7%	Mean	62.9%
Median	59%	Median	63%

No significant response differences were observed between experimental and control groups exposed to time altered speech. Scores of the experimental group, having a significant history of middle ear problems, ranged from 44 to 74%, with a mean of 58.7% and standard deviation of 7.5. Control subjects' scores ranged from 50 to 82%, with a mean score of 62.9% and standard deviation of 8.3. (See Table III). The difference between the two means, examined statistically by means of a t-test (Mendenhall, 1975) indicated that the mean difference of 4.2 points was not significant at the .05 level of confidence. Further statistical treatment, involving examining the difference scores obtained by subtracting each subject's compressed from uncompressed word discrimination score, similarly failed to yield significant differences between experimental and control groups. All raw scores for experimental and control subjects are presented in Appendix B.

Considerable variability was found in the scores of normal hearing children exposed to 60% compressed speech discrimination material. Moreover, all subjects obtained scores considerably poorer than those reported for normal adult listeners, whose mean score was above 90% (Beasley, Forman and Rintelmann, 1973). The present study supports the finding (Beasley, Maki and Orchik, 1976) that time compression has a more adverse effect on intelligibility scores for children than for adults.

The 62.9% group average score obtained by control subjects on the 60% compressed NU-6 compared reasonably well with the mean score of 68.6% obtained in an earlier study by eight year old children on the 60% compressed PB-K50 (Beasley, Maki and Orchik, 1976). The slightly higher average performance score found by these authors is likely to be

due to the simplified vocabulary of the PB-K50 word lists employed in that investigation.

Beasley, Maki and Orchik (1976) also found that subjects given the most difficult listening condition first, i.e. the compressed condition, showed greater score variability. In other words, performance scores for their compressed first condition were consistently poorer than those for the uncompressed first condition. This was not found to be the case in the present study, where mean scores were essentially the same regardless of presentation order. No significant order effect was observed in the present study.

Results of this study support earlier suggestions that the NU-6 lists, while apparently equivalent in the 0% compressed form, may not be equivalent at 60% compression (Beasley, Schwimmer and Rintelmann, 1972). While these authors investigated NU-6, Form B, the same is apparently true for Form A, lists 2 and 3. With half of the experimental and half the control subjects receiving each list, the mean scores for uncompressed lists were very similar (95.8% for list 2A and 95.2% for list 3A). The range of scores was the same (88 to 100%) for each list. At 60% compression, however, the lists no longer remained equivalent. The mean score for list 2A was 64.4% compared to 57.2% for list 3A. (See Table IV). A t-test (Mendenhall, 1975) revealed this score difference to be significant to the .001 level. In other words, lists 2A and 3A did not appear to be functionally autonomous for the eight and nine year old children in this study. Raw scores obtained on both lists are presented in Appendix C.

TABLE IV

MEANS, RANGES AND STANDARD DEVIATIONS FOR PERFORMANCE SCORES
OBTAINED IN UNCOMPRESSED AND COMPRESSED CONDITIONS FOR
TWO WORD LISTS, THE NU-6 LISTS 2A and 3A.

Uncompressed N=20		Compressed N=20	
<u>List 2A</u> *		<u>List 3A</u> **	
Mean	95.8%	Mean	64.4%
Range	88-100	Range	88-100
S.D.	3.24	S.D.	8.48
<u>List 3A</u> *		<u>List 2A</u> **	
Mean	95.2%	Mean	57.2%
Range	88-100	Range	44-68
S.D.	3.00	S.D.	6.07

*Performance differences not statistically significant.

**Performance differences significant at .001 level of confidence.

CHAPTER V

DISCUSSION

This study employed 60% compressed speech as a binaural test of central auditory function in children. Because speech perception is based on temporal aspects, time alteration would appear to be a good method for making speech more taxing to the auditory system without losing important spectral information, as with filtering.

Beasley, Maki and Orchik (1976) provide normative data for eight year old children on compressed PB-K50 material, however, no norms are known to be available for the more difficult compressed NU-6 lists. These authors suggest researching the effects of time altered speech on a variety of hearing impaired and "auditorily perceptually impaired" children in order to expand this normative information. The present study investigated the auditory processing of children who had sustained chronic middle ear problems.

On the basis of compressed speech testing, it cannot be stated that normal hearing children with a chronic history of middle ear problems during their first few years of life sustain a deficit in central auditory processing at the subsequent age of nine or ten. Although earlier investigations have demonstrated 60% compressed speech testing is sensitive to both unilateral lesions as well as diffuse central auditory changes (Oelschlaeger and Orchik, 1977; Konkle, Beasley and Bess, 1977), the present experimental group did not score lower on compressed

material than did a matched control group. While there was a trend toward poorer performance scores among experimental children, the difference between experimental and control group means was not statistically significant.

Score variability was noted within both groups and could not be accounted for by previous middle ear difficulty. Some, but not all score variability was previously accounted for by Orchik and Oelschlaeger (1977), who found poorer scores among children with articulation errors. Manning, Johnston and Beasley (1977) found lower performance scores among learning disabled children. In the latter study, the learning disabled group obtained a mean score of 57.3 (10.9 points below control subjects) on PB-K50 words, however, the study does not report on the statistical significance between experimental and normative group means. It seems plausible that normal hearing children in regular classes such as those in the present study would show less score reduction than would the learning disabled group.

Because of the score variability which cannot yet be accounted for among apparently normal children, compressed speech cannot be recommended as a routine clinical measure for children unless it is part of a more comprehensive central test battery. Further research is necessary to identify other factors contributing to score variability on compressed speech measures and degraded performance by normal hearing children.

This study has relied upon parent report for the identification of an experimental group. The limited reliability of this method could be a factor in the comparable scores of experimental and control groups. There is great variability in what parents consider to be a problem

their child has sustained "many times". One parent related frequent draining ears and visits to a physician for ear infections, yet marked "no" when asked whether their child had ever had any ear or hearing problems. Other parents may consider an ear ache or two to be a serious problem.

Another difficulty of this study could be in the identification of "normal" control subjects. Some parents may be inclined to mark perfunctory "no's" to all questions concerning their child's health problems without caring to elaborate upon them. Lewis (1976) notes that protracted normalcy of middle ear function cannot be assumed, even with parent testimony. Some forms of middle ear disease can occur without parent detection.

There is also the possibility that, in spite of probable conductive impairment during their critical years of speech and language development, the experimental children in this study may not have sustained resultant auditory processing deficits. While all of them had reported middle ear difficulties on many occasions, the hearing problems for most may not have been severe or long lasting enough to cause a permanent deficit. All twenty parents reported that they had obtained medical treatment for their child's ear problems. In some cases this treatment may have been successful in ameliorating the problem, or at least in lessening its effects.

The children in this study were from middle or upper middle class backgrounds, a position which offers certain advantages for them. Besides being more likely to receive adequate medical care, they are also likely to receive adequate environmental and language stimulation. In

this environment, a mild sensory deprivation may be compensated for by the more-than-adequate auditory input, and only a more severe hearing loss would result in an auditory deprivation. According to Lewis (1976) the handicap resulting from sensory deprivation is more evident among culturally disadvantaged children whose language-learning opportunities are deficient. A pronounced sensory deprivation would then occur either with a severe hearing loss, or with a mild loss along with a reduction in auditory stimulation. One might expect to discover greater deficits among such children than among those with no hearing loss or with a mild loss only.

As an alternate hypothesis, auditory deficits may have been sustained by the experimental subjects in this study, but were overcome by later auditory experience or simply with age. All of the subjects had normal hearing at the time of the study and most had been free of middle ear problems for a number of years. Within this time period, their auditory skills may have matured to the level achieved by their classmates. This recovery could also have been due to the aforementioned ample auditory stimulation received by this experimental group. Evidence of recovery in function by children with chronic otitis media is offered by Needleman (1977) in articulation ability and by Dalzell and Owrid (1976) on tests of linguistic achievement.

Conclusion

The purpose of this study was to investigate the central auditory processing of children who had sustained chronic middle ear problems during their early language-learning years. A 60% compressed recording of the NU-6 speech discrimination word lists was administered binaurally

to twenty normal hearing public school children aged eight and nine, reported by their parents to have had repeated middle ear problems during their early years, and to twenty control subjects matched for age from the same public school classes. Differences in compressed and uncompressed word discrimination scores of the experimental and control groups were not found to be statistically significant. These results indicate that the experimental subjects' ability to process compressed speech was not impaired by their early middle ear difficulties. The alternative was suggested that if these children actually sustained central damage due to distorted or degraded input during their hearing deficit episodes, then such effects may be neutralized by subsequent auditory experience and neurological maturity.

A significant difference was noted between scores obtained with NU-6 lists 2A and 3A at 60% compression for both groups of children. While apparently equivalent in the uncompressed form, list 3A was found to be significantly more difficult than list 2A when compressed. The order of presentation of compressed and uncompressed lists did not seem to affect scores. Score variability was not greater when the more difficult condition was presented first, as has been previously reported. In other words, there was no significant difference between scores achieved in the compressed first condition and those obtained during the compressed last condition.

Implications for Further Research

The results of the present study suggest many areas for future research. The study of children with chronic otitis media, documented by physician or audiologist records, would determine whether central

processing problems are evident in these children. Experimental samples with current middle ear difficulties and at various intervals after the problem has been resolved would suggest whether there was improvement in auditory abilities after the hearing sensitivity was restored. The use of other central auditory tests with such children would support or contraindicate the use of compressed speech to identify auditory processing changes in children. Testing of children with untreated otitis media or of those from lower socioeconomic groups is necessary to determine whether the results obtained in the present study are valid outside of an upper middle class sample.

Further use of compressed speech with populations of children might serve to explain the score variability seen in a number of studies. The only groups of children tested with compressed speech that have been reported in the literature are those with articulation errors, learning or reading disabilities. Testing each ear separately would determine whether a significant difference is often evident between ears. Also, further testing with compressed NU-6 lists, Form A, would determine whether the score disparity found in lists 2 and 3 is also true for lists 1 and 4.

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APPENDIX A

FREE HEARING TEST

Dear Parent:

Portland State University is providing free hearing tests for children at your school during the week of August 20, 1979. Each child participating in the test will be given both a pure tone test and one that measures speech understanding. The test will be conducted on our mobile van which will be parked adjacent to the school grounds. Each test will take approximately 15 minutes of your child's time.

If you wish a free hearing test for your child, please answer the following questions and sign this consent form. If you wish additional information, please call Ms. Beverly Schnabel, 288-xxxx. You will be provided with the test results.

-
1. Has your child ever had ear or hearing problems? Please explain.

 2. Have you ever had to take your child to the doctor for an ear problem?

 3. Has he/she ever had draining or running ears?

 4. Would you say your child has had this problem:

 _____ once
 _____ more than once
 _____ many times

 5. At what age did you first discover the problem? _____ At what age did it seem to go away? _____

_____ has my permission to participate in the hearing testing project.
Name of child

Signature (Parent or Guardian)

APPENDIX B

RAW SCORES OF EXPERIMENTAL SUBJECTS
AND MATCHED CONTROLS

Subject Pair	Experimental Subjects		Control Subjects		
	Uncomp	60%	Uncomp	60%	
1	98	54	94	60	
2	94	74	92	52	
3	94	60	94	64	
4	94	66	92	52	
5	96	56	96	68	
6	90	44	98	66	
7	96	56	96	68	
8	96	60	98	50	
9	100	52	98	62	
10	98	60	96	60	
11	92	52	100	82	
12	98	66	94	64	
13	92	62	90	66	
14	88	54	96	56	
15	96	70	98	54	
16	98	70	96	58	
17	98	56	98	60	
18	98	54	100	68	
19	96	58	96	78	
20	88	50	98	70	
Mean	=	95	58.7	96	62.9
S.D.	=	3.46	7.54	2.68	8.35

APPENDIX C

SCORES OBTAINED BY ALL EXPERIMENTAL AND CONTROL SUBJECTS ON
 NU-6 LISTS 2A AND 3A, UNCOMPRESSED
 AND 60% COMPRESSED

	Uncompressed		60% Compressed	
	<u>List 2A</u>	<u>List 3A</u>	<u>List 2A</u>	<u>List 3A</u>
	92	98	58	60
	96	90	78	54
	96	94	70	68
	92	96	62	60
	94	96	82	60
	98	94	66	68
	98	98	64	50
	100	100	68	52
	98	98	56	52
	98	96	64	58
	94	96	66	56
	90	94	70	52
	96	94	50	60
	96	96	70	54
	100	92	54	66
	98	92	52	56
	98	96	62	54
	88	98	56	60
	98	98	74	60
	<u>96</u>	<u>88</u>	<u>66</u>	<u>44</u>
Mean	95.8	95.2	64.4	57.2
S.D.	3.24	3.00	8.48	6.07