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<https://doi.org/10.15760/etd.5751>

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AN ABSTRACT OF THE THESIS OF Elisabeth Y. Carter for the Master of Science in Speech Communication, with an emphasis in Audiology, presented February 8, 1989.

Title: Normative Data on the Auditory Memory Test Battery for Ages 9 Through 13 Years.

APPROVED BY THE MEMBERS OF THE THESIS COMMITTEE:

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Auditory short-term memory (STM) is important for speech and language development and for learning new information presented auditorily. Research has shown that auditory STM ability is of a developmental nature in the 5 through 8 year age range for a variety of auditory stimuli. Many tests and subtests are available to measure auditory STM ability, however one test, the Auditory Memory Test Battery (AMTB) measures auditory memory span and memory for sequence for 5 types of stimuli.

The purpose of this study was to collect normative data on the AMTB scores of normal 9 through 13 year old students and young adults ages 20 through 30 years. The main experimental question was: What are the means and standard deviations of the AMTB scores from samples of normal children 9 through 13 years of age and normal young adults 20 through 30 years of age. A secondary question was: Are the differences between the performance scores statistically significant?

Eighty-four subjects were selected from the Portland Public School District and Portland State University on the basis of age, normalcy of speech, language, and hearing development, and a negative history of otitis media. Each subject passed a hearing screening on the day (s)he was administered the AMTB. The AMTB consisted of five subtests: digits, related words, unrelated words, nonsense syllables, and sentences. Each subject received 2 scores for each subtest, a score for memory span, and a score for memory for sequence.

The results of this investigation showed an overall improvement in the mean scores for all subtests except sentences. However, the 9 and 10 year old subjects performed fairly equally for all subtests, and the mean scores of the 11 year olds exceeded those of the 12 and 13 year olds on all subtests for both span and sequence. A detailed look at the standard deviations indicated wide variances within age groups and some overlap between age groups for all subtests

except sentences. A multiple analysis of variance (MANOVA) and a 2-tailed t-test revealed statistically significant age-related differences among the 11 through young adult subjects for the subtests of digits--span and sequence, related words--span and sequence, and unrelated words--span and sequence.

The information obtained in this study revealed a developmental plateau for auditory STM at the 9 to 10 year age range. A developmental change in auditory STM appeared to take place from 11 years of age to young adulthood for all subtests except sentences and nonsense syllables. The results support the evaluation of auditory STM through adolescence, as there appears to be continued maturation of this ability up to young adulthood. The AMTB is convenient in that it measures memory for span and for sequence for a variety of stimuli within one battery. However, the wide variance of scores within age groups indicate that the AMTB may demonstrate too much variance to be useful in its current form in a clinical setting. Further refinement of the AMTB to establish a clearer, homogeneous pattern is needed before it can become a useful clinical tool.

NORMATIVE DATA ON THE AUDITORY MEMORY TEST BATTERY
FOR AGES 9 THROUGH 13 YEARS

by
ELISABETH Y. CARTER

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
SPEECH COMMUNICATION:
with an emphasis in
AUDIOLOGY

Portland State University

1989

TO THE OFFICE OF GRADUATE STUDIES:

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ACKNOWLEDGMENTS

In memory of Shari Kazdoy, who helped elaborate on the idea that started this study, and who supported me every step of the way. Her contribution to this study and to my professional growth was enormous.

To Dr. Maurer for taking over as my thesis director midstream and for his constant encouragement to finish.

To my husband and family for enduring my obnoxious behavior these past couple of years; it could only be love.

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CHAPTER I

INTRODUCTION AND STATEMENT OF PURPOSE

INTRODUCTION

A well-functioning auditory and verbal memory system is necessary for an individual to develop communication competence (Rosenbloom, 1979). Both short- and long-term memory interface with perceptual, linguistic, and cognitive processing, and are an integral part of language processing (Wiig and Semel, 1976).

Auditory short-term memory (STM) includes the two subskills of span (retention of the message in any order) and sequence (retention of the message in the order presented). Both of these skills are important to speech and language development (Witkin, 1971).

Because memory plays a vital role in learning, a disability in this function can impede many areas of learning (Lerner, 1971). Various studies have demonstrated that children and adolescents with learning disabilities exhibit evidence of reduction in auditory short-term memory span and sequence. Paraskevopoulos and Kirk (1969) found evidence of poor performance on auditory and visual STM tests in reading disability cases. Eisenson (1972) cited disorders in auditory perception as a prime causal factor in most language problems.

Many types of stimuli may be used in assessing auditory STM. Tests have classically utilized a digit repetition task (Wechsler, 1974; Terman and Merrill, 1960; Kirk, McCarthy, and Kirk, 1968). Other types of stimuli often used include nonsense syllables (Hainsworth and Siqueland, 1969), unrelated words (Baker and Leland, 1959; Wepman and Morency, 1973a; Goldman, Fristoe, and Woodcock, 1974-1976), letters (Webster, 1981), and sentences (Baker and Leland, 1959; Hainsworth and Siqueland, 1969; Terman and Merrill, 1960).

While many authors have looked at several parameters of auditory STM, it was not until Burford (1976) that a test was available that systematically examined the attributes of span and sequence using 5 stimulus types: digits, unrelated words, related words, nonsense syllables, and sentences. Burford found that performance varied significantly with the type of stimulus used, with scores for sentence recall being the highest, followed in order by digits, related words, unrelated words, and nonsense syllables. There is some question, however, on the reliability of the subtest for related words, as scores may have been affected by unequally weighted item difficulty as stimulus length increased.

Tracing the development of auditory memory capacities in the young child has relied on tests of memory span for a series of digits, words, syllables, or sentences. Terman and Merrill (1937) placed the ability to repeat 2 digits at 2 years of age, 3 digits at 3 years, and 4 digits at 4-1/2 years.

Bates (1977) suggested that there is a very general change in the maturation of memory and attention. These developmental changes in auditory STM have been attributed to spontaneous rehearsal strategies rather than to an increase in the actual capacity of memory storage (Frank, 1972). Siegel and Allik (1973), using tape recorded names of pictures of animals or objects, observed auditory STM to improve with age, with the most marked increase coming between the second to fifth grades. Mountain (1980), in a preliminary normative study of the Auditory Memory Test Battery (AMTB) (Burford, 1976), noted a fairly equal performance between second and third grade children, while fourth graders scored better than the other two grade levels. However, because norms were not extended above the fourth grade, the increase in auditory STM ability observed by Siegel and Allik (1973) up to the fifth grade was not substantiated. Furthermore, neither the Mountain study nor other studies such as that by Siegel and Allik have indicated whether there is an age level above which there is no further increase in auditory STM. Further investigation, utilizing an instrument such as the AMTB, is needed to extend the norms for higher age levels, and to determine what kind of developmental patterns occur in auditory STM.

STATEMENT OF PURPOSE

The purpose of this study is to obtain normative data on the Auditory Memory Test Battery (AMTB) (Burford, 1976)

using a sample of normal children ages 9 through 13 years, from the Portland Public School system and normal young adults, ages 20 through 30 years, from Portland State University Speech and Hearing Sciences Department. The young adult group was used to further define any developmental pattern of auditory STM. The investigation sought to answer the following question: What are the means and standard deviations of the AMTB scores from samples of normal children 9 through 13 years of age and normal young adults 20 through 30 years of age? In addition, a secondary question was: Are the differences between the means of the age levels statistically significant? Therefore, the following null hypothesis was formulated:

Null Hypothesis: There are no statistically significant differences in the means and standard deviations of AMTB scores from samples of normal children 9 through 13 years of age and normal young adults 20 through 30 years of age.

DEFINITIONS

1. Memory Span. The number of items that can be recalled without error (Chalfant and Scheffelin, 1969).
2. Memory for Sequence. The retention of visual or auditory stimuli in correct serial order.
3. Stimulus Type. The auditory events the subject is asked to remember and verbally repeat, e.g., unrelated words

("cat-ice"), related words ("car-bus"), nonsense words ("ort-nar"), digits ("9-1"), and sentences ("Find the glove.").

4. Short-term Memory. A temporary store where incoming visual and/or auditory items persist for a few seconds. It represents the first state of processing between perception and higher order processing (Adams, 1976).

5. Rehearsal Strategies. A subvocal or silent repetition of visual or auditory stimuli after their presentation to aid recall. Also called verbal mediators (Flavell, 1970).

CHAPTER II

REVIEW OF THE LITERATURE

THE IMPORTANCE OF MEMORY

An individual depends on auditory and visual memory for the development of a communication system. The most important aspect of memory for acquiring speech and language skills and for learning new information, especially information presented auditorily, is auditory short-term memory (STM) (Rampp, 1981). The development of auditory capacities becomes the foundation on which language is built (Zigmond, 1969). As speech and language develop, the individual must attend to increasingly complex auditory stimuli, make figure-ground distinctions, discriminate, compare, remember phonetic elements, and recall temporal sequences (Witkin, Butler, and Whalen, 1977).

AUDITORY MEMORY DEVELOPMENT

An infant is capable of responding to auditory stimuli within hours of birth (Northern and Downs, 1978). A pattern of maturation continues as the infant recognizes, identifies, localizes, and discriminates the sound in the environment (Cicci and Zigmond, 1968). Eisenberg (1976) reported that not only older infants, but also newborns, differentiate and

respond selectively to human speech. As these listening skills develop and the child becomes aware of specialized sounds, the differences between sounds and the sequences of sounds in words, auditory language comprehension is realized. The normal development of language comprehension depends on the normal functioning of auditory processes for receiving and transmitting sound, perceiving and remembering sound, and integrating sound experiences (Cicci and Zigmond, 1968). As language skills are developing, so are associated auditory perceptual and memory abilities.

The maturation of auditory processing is seen as the child develops the capacity for storage of auditory symbols and experiences (Cicci and Zigmond, 1968). In order for a child to acquire an oral language code, (s)he must focus on and attend to stimuli that occur in a sequence or order, hold the sequence in mind so that its components can be stored, scanned, and compared, and assign meaning (Witkin, 1971; Eisenson, 1972).

Literature on memory span of children has generally concluded that the memory span of preschool children is relatively limited, but increases with age. This has led to the general assumption that memory capacity undergoes a relatively systematic change in terms of the quantity of material which can be retained (Corsini, 1969a). Harris (1978) noted that it has been known for a long time that digit span exhibits a relatively smooth improvement with age. Wepman and Morency's (1973a, 1973b) research suggested that

auditory STM appears to be of a developmental nature in the 5 through 8 year age range. Their research is supported by two instruments, the Auditory Memory Span Test (Wepman and Morency, 1973a) and the Auditory Sequential Memory Test (Wepman and Morency, 1973b). Baumeister (1974) showed a developmental trend in memory span capacity for a large variety of materials, such as digits, letter sequences, colors, and animal lists. Although this study did not directly address the source of these developmental trends, there was some evidence to suggest that encoding factors, i.e., grouping or chunking strategies, may have been the source of the differential performance.

Huttenlocher and Burke (1976) suggested that the developmental increase in the span of recall is associated with the speed with which subjects can identify and process incoming items, not with an increase in actual storage capacity. Similarly, Olson (1973) proposed that the observed developmental increase in memory span is a result of, not a cause of, increments in information-processing abilities related to the acquisition of grammatical rules. The child can be visualized as having a biologically fixed memory span of some kind which is used in progressively more efficient ways.

Harris (1978) agreed with Olson (1973) that there is no change during development in the basic capacity of memory, but that as children get older, they put their memory systems to work in a more strategic fashion.

Corsini (1969b) found that for children 3-1/2 to 7 years of age, the purely verbal assessment of memory yielded data which paralleled the classical results on digit span; that is, older children are able to remember more than younger children. But if the younger children were tested in a manner which allowed them to use nonverbal cues in retention, the younger children were able to remember just as much as older children, since the dominant form of internal representation in these children is visual imagery.

In an effort to specify the mechanisms responsible for age-related improvements in auditory STM, Frank (1972) studied spontaneous rehearsal strategies. Based on her results that suggested spontaneous rehearsal strategies undergo significant developmental changes, she proposed that developmental changes in the postlinguistic rather than the precategorical storage system make up the primary determinant of age-related improvement in auditory STM.

Piaget and Inhelder (1973) maintained that memory is a developmental phenomenon built on the stages of not only perceptual learning, but also on the stages of motor learning. They suggested that memory is tied to the child's operative schemes. Cross-sectional studies have shown that the ways in which children remember stimuli vary with age, and that these variations generally parallel age differences in operative schemes and cognitive levels.

The debate, so far, is unresolved. But the preceding discussion points out a definite relationship between auditory STM and language performance.

AUDITORY MEMORY AND SPEECH AND LANGUAGE

Since STM interfaces with perceptual, linguistic, and cognitive processing, it is viewed as an integral part of auditory language processing. Memory for auditory verbal input, semantic information, and linguistic structure is also considered to provide a link between auditory language processing and oral language formation and production (Wiig and Semel, 1976; Adams, 1976).

One critical prerequisite to the development of language is the ability to perceive and produce speech under temporal constraints. This includes processing, organizing, and storing linguistic information (Slobin, 1973). From this point of view, memory is central to the child's ability to comprehend and produce language (Kirchner and Klatzky, 1985). Bloom (1970) and Olson (1973) cited memory span as a critical factor in influencing the length or complexity of spontaneous utterances, however the role of memory is not easily defined. Graham (1980) suggested that auditory STM may also account for the order of acquisition of different linguistic structures, particularly in the early stages of development.

Bloom and Lahey (1978) noted the involvement of auditory memory for sequences in using language, and also learning. The sequence of words within a sentence is a major cue for

speech processing by children, but the sequence of words within a sentence is motivated by the semantic relationships among the words.

Masland and Case (1968) cited memory for sequence as being important for learning the syntax of a language. The child learns the syntax of the language partly by remembering the order of the words.

The ability to hold rote information in proper sequence also seems to be important in many classroom tasks. Spelling, following instructions, and ordering phonemes to sound out words all seem to require auditory memory sequencing skills (Dempsey, 1983). Probably the most complex of all sequencing acts is that of articulation in speech (Eisenson, 1972). The speaker must hold the articulatory plan for constituents of sentences until they can be spoken (Kirchner and Klatzky, 1985).

In investigating the temporal dimension in language, Wold (1978) emphasized that language processing takes place in real time:

The first and last part of a phrase, a sentence, or a book are separated in time. As first and last parts interact and are parts of one whole it is necessary that information about certain parts is retained in order to influence and also be influenced by what is to come later (p. 35).

According to Slobin (1973), there is an intimate relationship between linguistics and cognition. Language is used to express the child's cognitions of his environment. A given linguistic form cannot be used meaningfully until its

meaning is understood, i.e., cognition development sets the pace for linguistic intentions. This relationship was used in support of the use of memory span in evaluating mental capacities (i.e., intelligence quotient), even as early as 1887 (Watkins, 1978; Galton, 1887; Jacobs, 1887).

As demonstrated by the above-mentioned research, speech and language performance is prominently influenced by auditory STM. The auditory STM is involved in the development of syntax, in language comprehension, in the combining of sounds into words and words into sentences, in many classroom tasks, and in semantics.

The single most important aspect of STM is its limited storage capacity. There is little disagreement that STM can sustain simultaneously only a limited number of internal units (Baddely and Hitch, 1974; Glanzer, 1972; Adams, 1976; Miller, 1956). This limitation is usually described in terms of a fixed number of storage registers, each of which is capable of accommodating a single unit of information at any one moment. Another view pictures STM as a fluid system with a fixed amount of energy or space capable of being allotted as the storage process demands (Rohwer and Dempster, 1977).

In a classic article on memory, Miller (1956) described some basic characteristics of STM. First, there is some upper limit on the number of informational units that can be retained in STM, and this upper limit is about 7 plus or minus 2 "chunks" of any kind of information. Secondly,

there is flexibility as to how many bits of information is contained in each of these 5 to 9 units. One can increase the number of bits of information that the memory span contains by building larger and larger chunks containing more information than before. This process is known as "recoding."

IMPLICATIONS OF AN AUDITORY MEMORY DEFICIT

If auditory STM is so important to speech and language development, what happens if an individual's STM does not operate properly?

As has been mentioned previously, speech and language performance is prominently influenced by auditory STM. Thus, a deficiency in STM for span or sequence might manifest itself in both expressive and receptive aspects of a language disorder (Kirchner and Klatzky, 1985; Monsees, 1968), as well as in many classroom retention tasks (Dempsey, 1983).

Eisenson (1972) noted that disorders in auditory perception are a prime causal factor in most language problems. In a study on the limitations of auditory memory and delayed language development, Masland and Case (1968) observed a group of preschool children severely delayed in language development, although apparently normal in hearing acuity and intellectual capacity. They noted restriction of auditory memory for span, sequence, patterning of rhythm, stress and inflection, and patterning of phonetic detail. Ability to

focus attention on auditory events was often found to be fluctuating or limited.

Disturbances in sequential memory have serious implications in word order of sentences (Lerner, 1971). Witkin (1971) and Monsees (1968) indicated that poor performance on auditory sequencing tasks and poor speech intelligibility of language expression may be related to reading problems. The child with poor sequencing ability may learn to read with little or no difficulty, or the child may show inaccuracies of production, occasional loss of obtaining the correct meaning, inadequately ordered syntax, or omissions and additions of recalled phrases or sentences (Wepman and Morency, 1973b).

Glanzer (1972) stated that most effects on STM will be found to be on long-term memory (LTM); there is no way to separate one from the other. Therefore, Baddely and Hitch (1974) concluded, disruptions of STM impairs LTM storage processes.

Disturbance in retention, recall, and reproduction of sequentially ordered verbal auditory stimuli have been found in many children classified as having brain damage and/or dysfunction (Chalfant and Scheffelin, 1969; Aten and Davis, 1968). Aten and Davis investigated the auditory perception, retention, and reproduction of verbal and nonverbal auditory stimuli on children with minimal or mild cerebral dysfunction (MCD). Their results revealed the MCD children performed significantly lower than control children in backwards digit

span, serial noun span, multi-syllable word repetition, scrambled sentence arrangement, and oral sequential accuracy. Digits forward and paragraph recall tests failed to reveal significant impaired functioning among MCD children. Impaired performance was characterized by shorter perceptual spans, reduced number of stimuli, and perseverative and bizarre responses as performance demands increased. The researchers provided support for the theory that temporal ordering malfunction may be a factor contributing to communication problems.

Disorders of memory are among the ten most frequently cited characteristics of learning disabled (LD) children (McCarthy and McCarthy, 1969). These children may have difficulty understanding and/or remembering what they hear in a temporal sequence (Tarnopol, 1969; Bloom and Lahey, 1978; Lerner, 1971). It is commonly observed that LD children are unable to recall and reproduce a sequence of numbers, letters, digits, unrelated words, or nonmeaningful symbols, although many of these children can correctly repeat sentences (Bloom and Lahey, 1978; McCarthy and McCarthy, 1969).

Disturbances in auditory STM can thus influence various perceptual, linguistic, and cognitive aspects of auditory language processing as well as oral language production (Wiig and Semel, 1976).

MEASURING AUDITORY STM

The rationale for assessing the immediate memory for verbal material (digits and words) is that a minimum auditory retention span seems to be required for adequate intellectual functioning as well as for the adequate development of linguistic skills (Wiig and Semel, 1976).

Zigmond (1969) supported the use of measures of discrimination, memory, analysis and synthesis, reauditorization, and auditory sequentialization in evaluating children's auditory functioning because of the basic role of audition to language and learning processes. According to Cicci and Zigmond (1968), tests of memory measure not only memory itself, but also a child's understanding of language.

The most widely used measure of memory span is the number of items, e.g., digits, words, objects, which an individual recalls after a single presentation. By increasing the number of stimuli presented to the subject, the examiner is able to test the range of items that the subject is able to retain and retrieve (Chalfant and Scheffelin, 1969).

The measurement of auditory memory span is often a component of the measure of intelligence. Subtests of short-term auditory memory are often found within intellectual, psycholinguistic, and learning aptitude tests.

The Stanford-Binet Intelligence Scale (Terman and Merrill, 1960) has two subtests of auditory STM: digit repetition forward and reversed, and memory for sentences.

The digit repetition subtest forward can be administered from age 2-6 years to adult. The digit repetition reversed is administered from age 7 years to adult. Each of the digit repetition tasks consists of 3 items. The memory for sentences subtest consists of 2 items, and is presented at the age levels 3, 11, and 13 years. The number of words in the sentence and grammatical complexity increases with each level. One score is given for both span and sequence.

The Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1974) contains a subtest of auditory memory span for digits. This subtest is designated as an alternate because of the low correlation with the rest of the scale (Anastasi, 1968). It consists of two parts: forward and reversed repetitions. All items are presented at a rate of 1 per second. Each subtest contains 7 items ranging in length from 3 to 9 digits. The digits reversed ranges in length from 2 to 8 digits. The score consists of the number of digits in the highest series performed correctly. The score reflects combined forward and backward efforts of the subject (Zimmerman and Woo-Sam, 1973). The WISC can be administered to children ages 5 through 15 years. Ages above 15 years are given the Wechsler Adult Intelligence Scale (WAIS), which also includes a subtest of digit repetition forward and reversed.

The Illinois Test of Psycholinguistic Abilities (ITPA) (Kirk, McCarthy, and Kirk, 1968) also evaluates memory span for digits in the auditory sequential memory subtest. It is

normed for ages 2-4 through 10-3 years. The subtest consists of 28 items increasing in length from 2 to 8 digits. Scores are provided for span and sequence separately. All items are presented at a rate of 2 per second, and a second trial is allowed for each sequence failed on the first presentation. According to Paraskevopoulos and Kirk (1969) this allows for finer discrimination of ability level. Sattler (1982) pointed out that "overall, the ITPA appears to have limited use in the assessment battery" (p. 270). Criticisms include inadequate normative sample, use of incorrect reliability procedures, and limited educational usefulness of the test.

The Woodcock-Johnson Psycho-Educational Battery (Woodcock, 1977) covers ages 3 years through adults (however, not all tests are administered at every age), and assesses cognitive ability, achievement, and interest. Numbers reversed and memory for sentences are subtests of Cognitive Ability. In numbers reversed, the subject repeats a series of random numbers in reverse order. The items range in difficulty from 2 to 8 digits. In memory for sentences, the subject repeats sentences that the examiner presents orally. The sentences become longer and more semantically and syntactically difficult as one progresses through the subtest. Each subtest yields 1 score.

Because IQ and chronological age and simple digit span memory are systemically related, digit span is one of the basic indices on children's intelligence and psychological tests, like those tests described above (Olson, 1973).

However, there is some controversy over the use of digit span alone to measure auditory STM. As has already been mentioned, the reliability of the WISC digit subtest is lower than any of its other subtests. In addition, Cohen (1959) found, through factor analysis, that the digit span subtest did not measure general intelligence, memory, or "freedom" from distractability. According to Flowers (1983), speech-language pathologists complained that digits do not truly nor adequately represent verbal language function.

Another concern about the digit repetition in sequence technique is that it may be discriminating against individuals who are not proficient at handling any form of numerical, arithmetic, or mathematical concepts. For such an individual, the digit repetition technique may act as an interference with the individual's ability to store and retrieve this form of acoustic material (Flowers, 1983).

The rate of presentation of digits also seems to be important. In a study by Aten and Davis (1968), presenting digits at a rate of 1 per second, as in the Standard-Binet and the WISC, did not differentiate learning disabled children from matched controls. They noted that the rate of 2 digits per second, as used in the ITPA, is probably more sensitive to sequential disturbances involving reduced retention span for rapid incoming stimuli.

These observations suggest caution in diagnosing auditory STM deficits on the basis of digit span performance alone.

The Detroit Test of Learning Aptitude (Baker and Leland, 1959) contains two subtests using related and unrelated words that assess auditory STM. The auditory attention span for unrelated words consists of 2 sets of 7 word groups increasing in length from 2 to 8 words, and are presented at a rate of 1 word per second. The responses are scored to reflect the number of words recalled on all the items and the relative number of words recalled per word group for the total test. The auditory attention span for related words subtest consists of sentences ranging from 5 words to 22 words. Repetitions with more than 3 errors are counted as incorrect. The sentences are not controlled for syntactic complexity, a factor known to influence sentence recall (Wiig and Semel, 1976). Norms are provided for the age range from 3 to 19 years.

The repeat word subtest of the Meeting Street School Screening Test (Hainsworth and Siqueland, 1968) requires that the subject recall and repeat unknown and familiar sound sequences. It contains 11 items: 4 nonsense words and 5 real-word items and 2 sequences of 3 words. A correct response is a verbatim repetition. The repeat sentences subtest contains 2 sentences of 6 and 11 words, respectively. The repetitions are scored to reflect the number of words that are recalled in correct sequence. There are no norms for individual subtests, therefore these subtests are of limited value unless administered as part of the total screening test.

Wepman and Morency (1973a, 1973b) developed two auditory memory tests using digits and unrelated words. The Auditory Sequential Memory Test is a digit repetition task that progresses from 2 to 8 digits. A response is correct if the child repeats the digits correctly in the order given. The Auditory Memory Span Test consists of single syllable unrelated words of 3 to 6 items per stimulus. Credit is given if the child repeats the words read to him or her, without attention as to order. For each test, stimuli are presented at a rate of 1 per half second. Rating scale values and an age related scale are available for ages 5, 6, 7, and 8 years for both tests.

The Goldman-Fristoe-Woodcock Auditory Skills Test Battery (Goldman, Fristoe, and Woodcock, 1974-1976) contains three auditory memory tests that measure recognition memory, memory for content (span), and memory for sequence. All three subtests use memory for words with the auditory stimuli paired with pictures. Recognition memory assesses the subject's ability to recognize a word heard before. The authors state this ability sharply increases from 4 to 8 years of age, with a gentler slope between 8 and 14 years, then flattening until it begins to decline after 50 years of age. Memory for content requires the subject to listen to from 2 to 9 words and then identify from 4 to 11 pictures which 2 were not named. This ability rises sharply to age 12, a gentler slope to age 18, and then gradually declines with age. In the memory for sequence test, the subject hears

the stimulus, then must place the pictures in the correct order, up to 8 at a time. For this test, 1 point is given for placing the first picture in the series, 1 point for the last picture, and 1 point for each correct pair of pictures that are placed in the correct sequence to each other. It is not necessary for the pair to be in their correct location within the series. This ability also rises sharply to age 12, with a shallower increase to age 20, plateaus between 20 to 40 years of age, and then declines gradually with age. Norms are provided for all tests from age 3 to 80 years. Also available is a performance profile.

The purpose of the Learning Efficiency Test (LET) (Webster, 1981) is to examine how efficiently students age 3 through adult retain written (visual memory) or spoken (auditory memory) sequences of 2 to 9 consonants. For each of the six subtests, both ordered and unordered recall are assessed under 3 recall conditions: immediate recall, short-term recall, and long-term recall. The test attempts to approximate actual classroom learning conditions by accompanying the memory tasks with verbal interference, which is achieved by having the student count out loud or repeat a meaningless sentence before being asked to recall a string of letters. One point is given for each letter recalled in the last string of each recall condition. Scores for each condition may range from 0 to 9. Tables are provided to convert raw scores to standard scores. However, because of the

narrow range of raw scores, the diagnostic-prescriptive usefulness of this test seems to be limited (Harrington, 1985).

The Short Term Auditory Retrieval and Storage (STARS) test (Flowers, 1975), is a pencil and paper task for grades 1 through 6. The STARS tries to simulate a normal, binaural listening condition, in which background noise interferes with the storage and retrieval process, by employing 2 overlapping words being presented almost simultaneously in a free field (no earphones). Fifty-five test items are involved, each item increasing in complexity with the last 10 items using 3 overlapping words. The response is to mark the correct 2 out of 4 pictures per item. Norms are provided in the form of chronological age ranges (6-1 through 12 years), with special reference group norms for learning disability and educable, mentally handicapped classifications. The STARS is still considered an experimental test. Its major thrust is in the identification of elementary school children who are suspected of short-term auditory memory problems, and it is employed heavily in learning disabled settings within a larger battery of central auditory tests (Flowers, 1983).

In a study of the effects of stimulus type on auditory STM span and sequence, Burford (1976) developed the Auditory Memory Test Battery (AMTB). The AMTB examines the ability of an individual to store and retrieve 5 types of auditory stimuli: digits, related words, unrelated words, sentences, and nonsense syllables. Stimuli are presented at a rate of 2 per second. A correct response for span is if the subject

repeats all items in the stimulus in the correct serial order. Correct responses on the first trial are given 2 points each for span and sequence, and correct responses on the second trial are given 1 point each for span and sequence.

Burford (1976) found that span scores on the AMTB differed significantly between all stimulus types, and sequence scores differed significantly for only digits, sentences, and nonsense syllables. No differences were noted between span and sequence scores within each stimulus type by Burford, however Mountain (1980) used a larger sample size and found that span scores were greater than sequence scores for all 3 grade levels (2nd, 3rd, and 4th) on the subtests of digits, related words, and unrelated words (span and sequence scores for sentences and nonsense syllables were identical). Mountain also examined the mean scores for the 2nd, 3rd, and 4th grade levels to determine a possible developmental growth pattern for auditory STM. Results revealed a fairly equivalent performance between 2nd and 3rd grade levels, and significant differences between 4th and 2nd grade levels for related words and unrelated words sequence scores, and nonsense syllables span scores, and between 4th and 3rd grade levels for related and unrelated words span and sequence scores. Mountain concluded that "these results suggest auditory STM follows a developmental growth pattern, but plateaus exist along the developmental ladder" (p. 37).

As these past studies have shown (Burford, 1976; Mountain, 1980), a normal child's auditory STM ability varies

with the type of stimulus, and also may vary between span and sequence measures. These trends may facilitate the identification and diagnosis of children deficient in the area of auditory memory. The AMTB appears to be the only auditory STM test that examines the attributes of span and sequence using 5 different stimulus types. Mountain (1980) has examined the means and standard deviations for the AMTB using a sample of normal 2nd, 3rd, and 4th grade children. The present study sought to provide additional normative data for the AMTB using a sample of normal, 9, 10, 11, 12, and 13 year old children. In addition, performance scores from young adults ages 20 through 30 years were used to further define the developmental pattern of auditory STM.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS

Seventy students from the Portland Public School District and 14 young adults from Portland State University participated as subjects in this study. Subjects ranged in age from 9 through 13 years and 20 through 30 years. Each age group consisted of 7 males and 7 females.

Subjects were randomly selected from a group of children and young adults meeting the following criteria:

1. received permission from parent or guardian to participate in the study (if under 18 years of age) (see Appendix A for copy of Permission Form);
2. received no remedial speech, language, hearing or reading instruction, as reported by the parents and classroom teacher, or by the subject (if over 18 years of age) (See Appendix A);
3. displayed no physical handicap, as reported by classroom teacher or by observation of examiner;
4. negative history of middle ear problems before 2 years of age;
5. had no more than 1 ventilating tube placement, in either one or both ears;

6. passed an audiometric screening at 20 dBHL for each of the frequencies 500, 1000, 2000, and 40000 Hz, bilaterally (American National Standards Institute [ANSI], 1969).

INSTRUMENTATION

A Beltone portable audiometer model 10D was used for hearing screening. A Panasonic tape recorder model RQ-309DS was used to deliver the test stimuli, utilizing the speaker of the recorder in a semi-reverberant room (i.e., no headphones). The test stimuli consisted of the three subtests of the AMTB (see Appendix B): digits, related words, unrelated words, sentences, and nonsense syllables. Each subtest of the AMTB is comprised of 2 sample sequences, 2 monosyllables in length, at the beginning of each subtest and 14 test stimulus sequences ranging from 2 to 8 monosyllables in length. The five subtests of the AMTB were duplicated from a master reel-to-reel tape onto 5 individual cassette tapes used for test administration.

PROCEDURES

To gain rapport, the examiner engaged in casual conversation with the subject before beginning testing. The hearing screening was administered in an audiometrically quiet room in the subject's school. The subject was asked to raise his or her hand in response to a pure tone stimulus at 20 dBHL (ANSI, 1969) presented once at each test frequency

bilaterally. Those subjects passing the hearing screening were then administered the AMTB. The hearing screening and the AMTB were administered in the same room. During testing, the subject sat across a small table from the examiner. The tape recorder, tapes, and response forms were placed to the right of the examiner. Response forms as well as the list of subjects were placed out of the subject's view.

Prior to test administration, the examiner noted the subject's name and assigned the student a subtest randomization number (see Appendix C for Subtest Randomizing List) (Burford, 1976). Randomization of subtests was used to eliminate any possible learning effects.

Serial stimulus sequences were presented at the rate of 2 per second with falling vocal inflection at the end of each sequence. This falling inflection acted as a cue to the subject that the stimulus sequence had terminated. Sentence sequences were presented at the rate of 2 words per second using normal inflection. A 2-second pause followed each stimulus sequence giving the subjects time to respond. Each sequence was comprised of 2 stimulus trials and 2 response trials.

The examiner gave the following verbal instructions to each subject:

I am going to play 5 tapes for you. On each tape a lady will be saying some words or numbers. Please listen very carefully to what the lady says. Whenever she stops talking you say the same thing she just said, exactly as she said it. The lady will say the words or numbers 2 times. She will say them, then you will say them; she will say them again, then you will

say them again. Some of the things she will say will be harder to remember than others, and some won't make sense. Just listen carefully and do the best you can to say exactly what she says (Burford, 1976, p. 20).

The examiner proceeded to play the 2 trial items on the first tape. If the subject failed to respond to at least the second trial of the first sample item, the tape was stopped, the subject reinstructed, and the second sample item was played. The tape was not turned off again unless the subject failed 2 consecutive test items on both trials. The subtest was then discontinued. Following the administration of each subtest, the examiner gave positive reinforcements such as, "You're doing a great job" and the instructions, "Listen carefully, the next tape will be different from the last one." These procedures were followed for all subtests. An additional instruction was given prior to the nonsense words subtest: "These won't make sense."

Administration of the hearing screening and the AMTB was completed in one session. The average duration was 30 minutes.

SCORING

During each subtest the examiner recorded all responses manually on the appropriate response form (see Appendix B). The following procedures were utilized:

1. A totally correct response on either trial was marked by placing a check (✓) beside the corresponding item on the response form.

2. Criteria for correctness were:

- (a) All items in a sequence were named and repeated in correct serial order.
- (b) All responses to digits, related words, and sentences matched the stimulus exactly.
- (c) All words in response to unrelated words and nonsense words items deviated by no more than one distinctive feature of 1 consonant per word (see Appendix D). An example of a deviation of one distinctive feature is the response "card" to the stimulus "cart."

3. An incorrect response on either trial of an item was recorded by transcribing the error directly below the stimulus on the response form. Digit responses were recorded as digits, word responses as words, and nonsense word responses as phonetic symbols using the International Phonetic Alphabet. Unintelligible responses were recorded as such on the response form.

4. If the response to the first trial on any item was correct, the second trial on that item was administered but not scored.

Following administration of the AMTB, items were scored for both span and sequence. The scoring procedure was as follows:

1. Responses completely correct on the first trial received 2 points each for span and sequence.

2. Responses completely correct on the second trial received 1 point each for span and sequence.

3. Responses including all items in a sequence, but not in correct serial order, on the first trial received 2 points for span and none for sequence.

4. Responses including all items in a sequence, but not in correct serial order, on the second trial received 1 point for span and none for sequence.

5. Responses not including all items in a sequence received zero points for both span and sequence.

For any response to 2 trials of a stimulus sequence, the subject was credited with the greater number of points received for span. If, for example, the subject recalled all of the words in a sequence on the first trial, but erred in the serial order, then went on to respond correctly on the second trial, the subject received 2 points for span and 1 point for sequence on that item.

A total span score was determined for each of the five subtests by adding span scores within each subtest. This procedure was also used to determine the total sequence score. Therefore, each subject obtained 10 total scores: a span score and a sequence score for each of five subtests, with a possible 28 points for each subtest for span and sequence.

DATA ANALYSIS

A multiple analysis of variance (MANOVA) was calculated to determine if the main effects and/or the variables were

significant. Post hoc analysis consisted of 2-tailed t-test to analyze age-related differences among the five subtests.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

This study investigated short-term auditory memory for span and for sequence of normal 9 through 13 year old students and young adults ages 20 through 30 years. The study sought to answer two questions posed at the onset of the investigation. The questions and the results of the study follow.

The main experimental question was: What are the means and standard deviations of the AMTB scores from samples of normal children 9 through 13 years of age and normal young adults 20 through 30 years of age? Results determined by the arithmetic average formula and the square root of the variance are illustrated in Table I. Subtest results for 9 and 10 year old subjects proved fairly equal, except for nonsense syllables--span and sequence, and sentences--span and sequence, where the 9 year olds slightly outperformed the 10 year olds. The mean performance of the 11 year olds exceeded that of the 12 and 13 year olds on the following subtests: digit--span and sequence; related words--span and sequence; unrelated words--span and sequence; nonsense syllables--span and sequence; and sentences--span and sequence. In addition, the 11 year olds outperformed the young adults on the related words--sequence subtest.

TABLE I
MEANS AND STANDARD DEVIATIONS FOR
SIX AGE LEVELS ON THE AMTB

MEASURES FOR MEMORY SPAN						
Age Level		Sentences	Digits	Related	Unrelated	Nonsense
9 years	X	27.86	19.71	14.07	11.93	11.43
	S.D.	0.35	3.85	2.20	2.64	2.68
	range	27.51-28.00	15.86-23.56	11.87-16.27	9.29-14.57	8.75-14.11
10 years	X	27.64	19.79	15.14	12.64	11.29
	S.D.	0.81	1.67	1.88	1.39	2.37
	range	26.83-28.00	18.12-21.46	13.26-17.02	11.25-14.03	8.92-13.66
11 years	X	28.00	23.00	18.64	14.50	13.29
	S.D.	0.00	2.32	3.13	3.25	1.68
	range	-	20.68-25.32	15.51-21.77	11.25-17.75	11.61-14.97
12 years	X	27.93	21.79	17.93	14.64	12.43
	S.D.	0.26	3.38	2.46	1.82	1.79
	range	27.67-28.00	18.41-25.17	15.47-20.39	12.82-16.46	10.64-14.22
13 years	X	27.86	20.50	16.57	14.07	12.07
	S.D.	0.52	2.68	2.82	1.98	2.06
	range	27.34-28.00	17.82-23.18	13.75-19.39	12.09-16.05	10.01-14.13
20 - 30 years	X	27.93	24.07	19.71	16.57	13.36
	S.D.	0.26	2.87	3.12	3.74	2.06
	range	27.67-28.00	21.20-26.94	16.59-22.83	12.83-20.31	11.30-15.42

TABLE I--Continued

MEASURES FOR MEMORY FOR SEQUENCE						
Age Level		Sentences	Digits	Related	Unrelated	Nonsense
9 years	X	27.86	17.71	13.36	11.93	11.36
	S.D.	0.35	3.10	1.60	2.64	2.76
	range	27.51-28.00	14.61-20.81	11.76-14.96	9.29-14.57	8.60-14.12
10 years	X	27.64	18.36	14.21	12.14	11.21
	S.D.	0.81	2.37	1.72	1.23	2.33
	range	26.83-28.00	15.99-20.73	12.49-15.93	10.91-13.37	8.88-13.54
11 years	X	28.00	21.57	17.29	14.14	13.07
	S.D.	0.00	2.53	2.49	2.68	1.90
	range	-	19.04-24.10	14.80-19.78	11.46-16.82	11.17-14.97
12 years	X	27.93	19.29	16.17	13.57	12.21
	S.D.	0.26	2.89	1.82	1.65	1.53
	range	27.67-28.00	16.40-22.18	14.25-17.89	11.92-15.22	10.68-13.74
13 years	X	27.86	18.79	15.43	13.43	12.00
	S.D.	0.52	2.26	2.53	1.79	2.08
	range	27.16-28.00	16.53-21.05	12.90-17.96	11.64-15.22	9.92-14.08
20 - 30 years	X	27.93	22.43	16.93	15.64	13.29
	S.D.	0.26	3.06	3.29	3.13	2.09
	range	27.67-28.00	19.37-25.49	13.64-20.22	12.51-18.77	11.20-15.38

An examination of the standard deviations among the age groups revealed wide variances and some overlap for all subtests except sentences, although there was the least overlap between the 9 and 10 year old group and the 11 year old group.

Table II illustrates the means and standard deviations from an earlier study by Mountain (1980) using the AMTB. The same wide variances can be seen in Mountain's study for all subtests except sentences.

Table III shows a comparison of similar age groups between Mountain's study and the present study. Means and standard deviations are similar, except for unrelated words and nonsense syllables. In the present study, the means for unrelated words were slightly less and the means for nonsense syllables were more. This could be due to the small sample size being more sensitive to extreme scores, or perhaps because the comparison was between a grade level and age levels. Raw data from Mountain's study was not available for further comparative analysis.

TABLE II
MEANS AND STANDARD DEVIATIONS FOR THREE
GRADE LEVELS ON THE AMTB

		Memory Sequence				
Grade Level		Digits	Related	Unre- lated	Sentences	Non- sense
2nd	X	16.98	13.40	12.12	27.72	6.80
	S.D.	2.80	2.19	2.38	.54	1.84
3rd	X	17.00	12.96	11.60	27.44	7.56
	S.D.	2.76	2.35	2.39	.86	2.88
4th	X	17.48	14.72	13.24	27.80	8.32
	S.D.	3.09	2.26	2.60	.50	2.60
		Memory Span				
2nd	X	18.92	14.10	12.64	27.72	6.80
	S.D.	3.09	2.26	2.54	.54	1.84
3rd	X	18.44	13.76	12.08	27.44	7.56
	S.D.	2.97	2.72	2.49	.86	2.88
4th	X	19.36	15.40	14.04	27.80	8.32
	S.D.	3.06	2.69	3.04	.50	2.60

TABLE III
COMPARISON OF MEANS AND STANDARD DEVIATIONS BETWEEN
MOUNTAIN 1980 STUDY AND PRESENT STUDY

Memory Sequence						
Level		Digits	Related	Unre- lated	Sentences	Non- sense
4th gr.	X S.D.	17.48 3.09	14.72 2.26	13.24 2.60	27.80 .50	8.32 2.60
9 yrs.	X S.D.	17.71 3.10	13.36 1.60	11.93 2.64	28.00 0.00	11.36 2.76
10 yrs.	X S.D.	18.36 2.37	14.21 1.72	12.14 1.23	28.00 0.00	11.21 2.23
Memory Span						
4th gr.	X S.D.	19.36 3.06	15.40 2.69	14.04 3.04	27.80 .50	8.32 2.60
9 yrs.	X S.D.	19.71 3.85	14.07 2.20	11.93 2.44	28.00 0.00	11.43 2.68
10 yrs.	X S.D.	19.79 1.67	15.14 1.88	12.64 1.39	28.00 0.00	11.29 2.37

The secondary question of this investigation was: Are the differences between the performance scores statistically significant? A multiple analysis of variance (MANOVA) revealed statistically significant age-related differences (at the .05 level) on the following subtests: digits--span and sequence; related words--span and sequence; and unrelated words--span and sequence. No statistically significant differences between age groups were demonstrated on the subtests of sentences--span and sequence, and nonsense syllables--span and sequence. Mountain (1980) found that the sentences and digits subtests failed to differentiate between the 2nd, 3rd, and 4th graders, however the nonsense syllables subtest was significantly different between the 2nd and 4th graders.

The data between each age group was analyzed using a 2-tailed t-test to locate specifically where the age-related differences occurred. Statistical differences (at the .05 level) between age levels are shown in Table IV. The young adult group did differentiate themselves from the 9 year olds on the following subtests: digits--span and sequence; related words--span and sequence; and unrelated words--span and sequence. The 13 year olds outperformed the 9 year olds on related words--span and sequence, and unrelated words--span. The 12 year olds outperformed the 9 year olds on related words--span and sequence, and unrelated words--span. The 11 year olds outperformed the 9 year olds on digits--span and sequence, related words--span and sequence, and unrelated words--span and sequence. Statistically significant differences between the 9 and 10 year old groups were not observed.

TABLE IV
t-TEST VALUES FOR SIX AGE GROUPS ON THE AMTB

Age Level	Memory Span				
	Digits	Related	Unrelated	Sentences	Nonsense
9-10	-0.06	-1.23	-0.95	data not analyzed	
9-11	-3.22*	-5.37*	-2.32*		
9-12	-1.45	-3.71*	-2.75*		
9-13	-0.57	-2.53*	-2.17*		
9-20+	-3.23*	-5.44*	-3.32*		

Age Level	Memory Sequence				
	Digits	Related	Unrelated	Sentences	Nonsense
9-10	-0.57	-1.29	-0.27	data not analyzed	
9-11	-4.14*	-5.75*	-2.28*		
9-12	-1.39	-3.91*	-1.74		
9-13	-1.13	-2.59*	-1.54		
9-20+	-4.22*	-3.55*	-2.94*		

*Significant at the .05 level.

To investigate interjudge reliability of the AMTB, a Pearson Product Moment Correlation Coefficient was calculated between 3 independent scorers on 3 subjects. Results for each subtest ranged from $r = .86$ to $r = 0$ (see Table V). All subtests, both span and sequence, showed a strong positive correlation. The statistical significant of all Pearson r 's was computed at the .01 level of confidence.

TABLE V
INTERJUDGE RELIABILITY

Subtest		Reliability Coefficient
Unrelated words	span	.93
	sequence	.93
Related words	span	0
	sequence	.98
Digits	span	.96
	sequence	0
Nonsense words	span	.97
	sequence	.86
Sentences	span	0
	sequence	0

RANGE: .86 to 0 (strong correlation)

DISCUSSION

The purpose of this study was to provide normative data on the AMTB developed by Burford (1976), and to determine whether there were differences in performance on the AMTB among normal children ages 9 through 13 years and normal

young adults ages 20 through 30 years. The data from this investigation supported the hypothesis for three of the five subtests: digits, related words, and unrelated words.

Generally, the results show an increase in memory span and sequence ability from age 9 years to young adult. But, as noted previously, the performance of the 9 and 10 year olds was not significantly different, suggesting a developmental plateau at these age levels. A similar plateau was noted by Mountain (1980) between 2nd and 3rd grade levels. The results also support providing normative data on auditory memory tests through adolescence, as there appears to be continued maturation of this ability up to young adulthood.

Examination of the data in Table IV (p. 40) reveals a significant difference in performance between the 9-11 year olds on the digits subtests--span and sequence, related words--span and sequence, and unrelated words--span and sequence. There was a significant difference between the 9-12 year olds and the 9-13 year olds on the subtests of related words--span and sequence, and unrelated words--sequence. But there were no statistically significant differences between the 9-12 year olds on digits--span and sequence, and unrelated words--sequence.

The outperformance of the 11 year olds over the 12 and 13 year olds cannot be explained with this study, and deserves further investigation. It would appear that the 11 year old group was a different population. Perhaps the

sample size was not large enough to overcome extreme scores, as reflected in the large standard deviations.

The wide variance of scores within age groups indicates that the AMTB may demonstrate too much variance to be useful in its current form. This wide variance was also seen in Mountain's (1980) data, but was not addressed at that time.

In summary, the hypothesis posed by this study was not supported for all subtests. Although there were no significant differences for the sentences and nonsense syllables subtests, there was an age-related improvement in memory span and memory for sequence ability for the subtests of digits, related words, and unrelated words between the ages of 9 to young adult, with an apparent plateau between the ages of 9 and 11 years. These results appear to be in agreement with Goldman, Fristoe, and Woodcock's (1974-1976) research which noted an increase in memory ability through adolescence for span and sequence.

CHAPTER V

SUMMARY AND IMPLICATIONS

SUMMARY

Auditory memory, the ability to recall a stimulus which has been presented auditorily, is an important part of speech and language ability (Johnson and Myklebust, 1971). Assessing memory is an important aspect when measuring listening skills and auditory perception. Many assessment tools have been developed to measure auditory memory ability, and have used a variety of types of stimuli. Burford (1976) developed the Auditory Memory Test Battery (AMTB) in order to examine the attributes of span and sequence for 5 stimulus types: digits, related words, unrelated words, sentences, and nonsense syllables. Normative data for 2nd, 3rd, and 4th grade children was provided by Mountain (1980). The purpose of this study was to provide further normative data for children 9 through 13 years of age and young adults 20 through 30 years of age.

Fourteen normal subjects from each of the six age groups (7 male and 7 female) were selected from the Portland Public School District and from Portland State University. Each subject passed a hearing screening on the day they took the AMTB. Following the hearing screening, each subject was

administered the AMTB, which consisted of five subtests: digits, related words, unrelated words, sentences, and non-sense syllables. Each subject received a span and a sequence score for each subtest.

The results of the investigation showed a significant difference in the auditory memory performance for span and sequence between the ages of 9 years and young adult for the subtests of digits, related words, and unrelated words. There were no significant differences between age groups for the sentences or nonsense syllables subtests. There were some inconsistencies, however, in the performance of the 11, 12, and 13 year olds, in which the 11 year olds actually outperformed the 12 and 13 year olds on the digits and unrelated words subtests. This may illustrate a lack of homogeneity within a given chronological age.

The wide variances within age groups and the overlap between age groups limits the usefulness of the AMTB in a clinical setting in its present form.

IMPLICATIONS

The normative data generated by this study extends that of Mountain (1980). The common subtests that differentiated between age groups were related words and unrelated words. The digits subtest differentiated between age groups in the present study but not in Mountain's study, and the nonsense syllables subtest differentiated between age groups in Mountain's study, but not in the present study. Burford (1976)

has demonstrated that stimulus type does affect performance on memory span and memory for sequence tasks. However, the possibility of different developmental patterns for different types of stimuli could be explored. A closer examination of the items within each subtest may provide useful information regarding why some subtests differentiated between age groups at some age levels and not at others.

An item analysis may also provide useful information toward solving the problems of wide variance among age groups and overlap between age groups. Investigating test-retest reliability among the same subjects may aid in explaining some of the variance.

A consistent result across a large experimental sample of children could reduce the effects of extreme scores, as was seen in the outperformance of the 11 year olds over the 12 and 13 year olds.

Future investigations could also study the responses of ages 14 to 20 years, as well as separate ages within the 20 to 30 year old range.

To make the AMTB more sensitive to identifying children with learning disabilities, further study into interstimulus intervals and stimulus duration may be helpful. For example, administering the subtests at different rates and evaluating the resulting scores may prove fruitful. In recent studies by Tallal and Stark (1981), learning disabled children required longer interstimulus intervals and longer stimulus

duration to reach criterion level on stop consonant-vowel syllables.

Also helpful would be a study of response patterns. Does the child consistently miss on the first trial, but get it correct on the second trial? This may be an indication that the child needs more time to process or rehearse the auditory information.

The AMBT is convenient in that it has a variety of stimuli within one battery, and therefore could provide a "memory profile." However, the validity of this combination of subtests is in question by these data. The AMTB requires further refinement to establish a clearer, homogeneous pattern before it can become a useful clinical tool.

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APPENDIX A

PERMISSION FORM

Dear Parent or Guardian:

I am a Portland State University graduate student doing research in Speech and Hearing Science. The purpose of the study is to investigate the auditory memory abilities of normal children. This study, hopefully, will help in the diagnosis and management of children with auditory memory problems.

Participation in this study would require about 30 minutes of your child's time during which (s)he will be given a brief hearing screening test and then will listen to tape recorded sequences of words, numbers, and sentences and repeat them back to me. The testing will take place in your child's school.

There are no risks involved in this study. No names will be used in the written results of the study. You are free to withdraw your child from the study at any time.

If you have any questions, you can reach me in the evenings at 281-7150. If you would like your child to participate in the study, please sign below, indicating your approval, and return the form to school with your child tomorrow. Thank you for your cooperation.

Sincerely,

Beth Carter

Graduate Student; Speech and Hearing Sciences
Portland State University

Please answer the following questions:

1. Has your child received remedial help in Speech, Language, Hearing, or Reading? NO _____ YES _____
2. Has your child had more than 2 episodes of middle ear problems that needed medical treatment before 2 years of age? NO _____ YES _____
3. Has your child had more than 1 placement of "tubes" in his/her ears? NO _____ YES _____

Please sign below to indicate your permission for your child's participation in this study:

Parent's signature _____ DATE _____

Child's signature _____ DATE _____

Child's birthdate _____ 19__

APPENDIX B

AMTB RESPONSE FORMS

RESPONSE FORM

#1 DIGITS

* 4-5	** 2-2
_____	_____
_____	_____
9-1	

2-9	

8-1-1	

6-4-9	

2-8-3-3	

6-3-5-1	

4-3-3-9-9	

6-1-4-2-8	

8-4-8-3-5-5	

2-9-6-1-8-3	

3-6-1-9-2-3-9	

5-3-6-9-8-8-2	

3-1-9-2-3-4-8-8	

9-6-3-8-5-1-2-2	

RESPONSE FORM

#2 RELATED WORDS

*dog-cat	**house-barn
_____	_____
_____	_____
car-bus	

shoe-hat	

cow-goat-horse	

see-hear-smell	

chair-lamp-couch-rug	

eye-hand-ear-nose	

train-ship-plane-boat-truck	

rain-hail-ice-snow-sleet	

talk-yell-scream-cry-shout-sigh	

socks-tie-belt-coat-shirt-pants	

bowl-plate-spoon-cup-fork-glass-knife	

tree-branch-leaf-bud-bush-plant-moss	

meat-corn-pie-milk-egg-soup-bread-peach	

blue-green-pink-black-brown-red-grey-white	

RESPONSE FORM

#3 UNRELATED WORDS

*block-moon

**fall-draw

cat-ice

dog-ship

man-horse-song

pen-girl-cow

cart-bird-desk-road

chair-hen-book-vest

head-milk-dress-oats-night

pipe-west-fence-coat-mule

fish-clock-heart-sun-box-frog

stone-blot-freeze-door-cut-white

skirt-plant-friends-east-tub-barn-hair

mud-vase-north-ten-rain-cross-shoe

car-boat-key-pig-south-know-ink-rope

cat-skate-fan-spend-lamp-wool-axe-toad

RESPONSE FORM

#4 SENTENCES

*Boys play.

**Dog barks.

Tom left.

They sleep.

She went out.

Find the glove.

The car is gone.

Four sheep went by.

They went to the zoo.

Bill has lots of fun.

I will read the blue book.

Joe goes home for his lunch.

She is the one I like best.

Mom gave Sue a new pink dress.

Sam likes to play with his big dog.

We went to town to buy some toys.

RESPONSE FORM

#5 NONSENSE WORDS

•/seb-ɔ̃aɪ/	••/gorset-ʌm/
_____	_____
_____	_____
/pid-ɟʒ/	

/ort-nar/	

/pem-krig-brɪn/	

/taf-mʊʃ-sum/	

/tuf-lʌɔ̃-wep-dit/	

/tʃ-ral-ʃaʊ-han/	

/ʒg-lɛf-bog-ʒb-raz/	

/foɔ̃-hɛv-nɪf-ak-fuz/	

/ɪnt-mat-ʃtrop-grub-pʌŋ-ɪg/	

/lan-ta-nip-lɪn-ɔ̃ʃd-ka/	

/zar-sʌd-wɛm-ɪf-twan-bro-drʌt/	

/vo-doʃ-ɪs-zɪk-ʌɪn-job-zup/	

/oʃ-gɛn-bɪg-mʌ-fɪn-ʃʌm-ump-jam/	

/trɛn-zab-nɪʒk-bem-wʌmp-mɪf-tɛg-bup/	

APPENDIX C

SUBTEST RANDOMIZING LIST

54213 age 9 begin here
42531
34125
43251
21435
51243 age 10 begin here
41253
34251
42351
43512
43215 age 11 begin here
14253
25341
41235
13524
41523 age 12 begin here
32145
35124
51423
12345
45132 age 13 begin here
21453
42351
31245
13452
54312 ages 20 - 30 begin here
41532
51324
24153
32145
41253
51432
42531
42153
51342
31524
41352
54312
31452

APPENDIX D

DISTINCTIVE FEATURE GRID
RELEASES SYLLABLE

	p	b	t	d	k	g	m	n	w	j	l
VOWEL							+	+			
NASAL									+	+	+
GLIDE											
FRICATIVE											
STOP	+	+	+	+	+	+					
VOICED		+		+		+	+	+	+	+	+
BILABIAL	+	+					+		+		
LABIO-DENTAL											
LING-DENTAL											
ALVEOLAR			+	+				+			+
POST-ALV										+	
VELAR					+	+					
GLOTTAL											

	r	f	v	θ	ð	s	z	ʃ	ʒ	tʃ	h
VOWEL											
NASAL											
GLIDE	+										
FRICATIVE		+	+	+	+	+	+	+	+	+	+
STOP									+	+	
VOICED	+		+		+		+		+		
BILABIAL											
LABIO-DENTAL		+	+								
LING-DENTAL				+	+						
ALVEOLAR						+	+				
POST-ALV	+							+	+	+	
VELAR											
GLOTTAL											+

+ indicates acoustic or visual features utilized to produce each phoneme.

SOURCE: Burford (1976)

DISTINCTIVE FEATURE GRID
ARRESTS SYLLABLE

	p	b	t	d	k	g	m	n	ɲ	l	ʒ
VOWEL										+	+
NASAL							+	+	+	+	
GLIDE											
FRICATIVE											
STOP	+	+	+	+	+	+					
VOICED		+		+		+	+	+	+	+	+
BILABIAL	+	+					+				
LABIO-DENTAL											
LING-DENTAL											
ALVEOLAR			+	+				+		+	
POST-ALVEOLAR											
VELAR					+	+			+		
GLOTTAL											

	f	v	θ	ð	s	z	ʃ	ʒ	tʃ	dʒ
VOWEL										
NASAL										
GLIDE										
FRICATIVE	+	+	+	+	+	+	+	+	+	+
STOP									+	+
VOICED		+		+		+		+		+
BILABIAL										
LABIO-DENTAL	+	+								
LING-DENTAL			+	+						
ALVEOLAR					+	+				
POST-ALVEOLAR							+	+	+	+
VELAR										
GLOTTAL										

+ indicates acoustic or visual features utilized to produce each phoneme.