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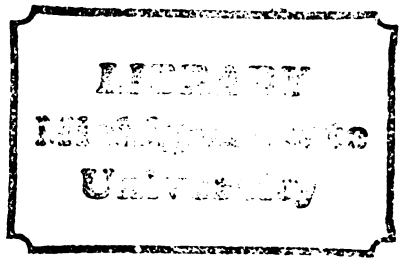


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DEVELOPMENTAL DIFFERENCES IN AUDITORY

MEMORY PHENOMENA: RECENCY AND SUFFIX EFFECTS

presented by

Susan J. Mirowski

has been accepted towards fulfillment
of the requirements for

M.A. degree in Audiology

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# DEVELOPMENTAL DIFFERENCES IN AUDITORY MEMORY PHENOMENA: RECENCY AND SUFFIX EFFECTS.

BY

Susan J. Mirowski

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

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ABSTRACT

The study examined four age groups' spoken immediate serial recall of real speech vowels and real speech CVCs for recency and suffix effects to substantiate any developmental trends in immediate auditory memory. The recall material consisted of three types of lists: (1)Vowel lists; (2)CVC [Consonants Held Constant] lists; (3)CVC [Vowels Held Constant] lists. All recall materials were presented aurally. The four age groups participating in the study were first graders, third graders, fifth graders, and adults. None of the age groups showed conclusive recency effects. However, a significant and conclusive suffix effect was found in the recall of fifth grade subjects for only the vowel lists; these results are different from obtained for the adult group which showed significant suffix effects for the recall of both vowels and CVC (Consonants Held Constant) lists. The recall for the last item of a serial list, the main location of recency and suffix effects, was different between adult subjects and each of the groups of children subjects; on the other hand, there were no significant differences in final serial position mean error scores among the three age groups of children. As an explorative measure, the types of recall errors were grouped and analyzed for the purpose of discerning specific differences in immediate auditory recall. The results of grouping error types is discussed. The study concluded that the observed differences in recency and suffix effects are suspect of being developmental and are influenced by the acoustic distinctiveness of the recall material.

Accepeted by the faculty of the Department of Audiology and Speech Science, College of Communication Arts, Michigan State University, in partial fulfillment of the requirements for the Master of Arts Degree.

Thesis Committee Chairman

Oscar I. Tosi, Ph.D., Sc.D.

To Phillip Mirowski, my brother, whose encouragement enabled me to open the doors of higher learning, with love and admiration.

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# INTRODUCTION

Research on auditory memory phenomena has focused experimentors' attention on specific neuro-physiological processes that may be involved in speech perception. Developmental studies on auditory memory have just recently begun to sharpen that focus on readiness of the higher cortical processes in children and the role of the processes in development of adultlike audition and speech skills. The two auditory memory phenomena which have been extensively studied in adults are recency and suffix effects. Recency, which is the greater probability of correct recall for the last item over the penultimate item in an aurally presented serial recall task is evidenced by a statistical test of significant difference between mean errors. The suffix effect is defined as the reduction of recency when an arbitrary item not to be recalled is added at the end of a serial list. The two memory phenomena emerge as a measure in the auditory serial recall task paradigm. The auditory serial recall task paradigm has not been used extensively with children to study developmental differences in immediate auditory memory.

A general type of serial recall task requires a subject either to view or listen to a series of items (digits, letters, syllables, words, etc.) and to immediately recall the items in correct serial order (Corkin, 1974; Norman, 1969). A serial recall task becomes

increasingly difficult as the number of items in a serial list are increased. The average length of a serial list which subjects are able to recall without too much difficulty is dependant upon two major factors: age of the subject and nature of the material to be recalled, such as whether the items are syllables, meaningful words, or numbers (Simon, 1974).

The serial recall task is a means of investigating three major concerns of developmental differences in auditory memory research: 1) what are the differences in immediate memory for auditory information vs. visual information? (Carterette & Jones, 1967; May & Hutt, 1974); 2) is short term memory capacity constant for all ages, or does short term memory capacity increase with age? (Friedrich, 1974; Simon, 1974); 3) does ability and strategy for obtaining information from short term memory change with age, and if so to what extent? (Corkin, 1974; Friedrich, 1974; Meacham, 1972). The study of recency and suffix effects as a means to determine developmental differences of possible physiological functions have just begun to attract expermentors' attention.

Crowder & Morton (1969) found significantly greater recall in subjects for the first few items and the last few items of a serial list when the subjects listened to the material. If a serial list is presented visually, recall is greatest for the first item in a list and then recall progressively decreases from the first item to the last item. Also observed in the above-mentioned study was a significant decrease in the recency effect when an irrelevant and not-to-be-remembered word is added to the end of the serial lists.

Crowder and Morton (1969) claim that recency and suffix effects are the results of sensory memory, a lingering trace of neural activity. They developed a memory model, Precategorical Acoustic Storage (PAS), which exhibits properties that account for recency and suffix effects. the PAS memory model, a brief storage of the sensory trace present for auditory stimuli only, is characterized by a limited capacity (a limited amount of acoustic information is stored at one time) and rapid decay (time is restricted). Such a model would facilitate the recall of the last items of a serial list; the last items in the list would remain in the sensory trace (recency effect). The model also accounts for decrease in recall of the recency positions when an arbitrary item, not-to-be-recalled, is added at the end of the list. The additional item at the end of the list replaces the last few items in the sensory trace which results in decreasing recency (suffix effect).

Recency is not observed for all aurally presented speech sounds. Crowder (1971) and Cole (1973) reported findings of consonants functioning differently in PAS from vowels or digits. The results showed significantly stronger recency and suffix effects for synthesized vowels and digits than for synthesized consonants.

If indeed a sensory memory exists in adults for auditory information, is there evidence of its presence in children? Foreit (1977) failed to find reliable suffix effects for synthesized vowels and synthesized stop consonants when testing second grade children for a serial recall task, but did find significant suffix effects for

lists of digits. According to Foreit, the failure to find a suffix effect could be an indication of the children's lack of ability to group the acoustic information within each syllable into a single unit. However, when the children's scores were evaluated on a more lenient basis, a suffix effect did emerge. A lenient scoring procedure consists of scoring a syllable in a serial list correct if any part of the CV combination (the consonant, vowel, or both) were recalled in the correct serial position.

In a sub-study of the same experiment, a group of adults failed to show the presence of a suffix effect when given lists of synthesized non-repetitive nonsense syllables to recall, but when scored on a lenient basis, the suffix effect did emerge. The subject was prevented from using familiarity of the syllables as a means to remember the precise speech sounds since each particular syllable occurred once and only once within a list. The lingering trace of acoustic stimuli in immediate auditory memory is very brief (Crowder & Morton, 1969), requiring spontaneous retrieval, which could prove difficult if the stimulus trace is not familiar enough to identify. Therefore, the final item in a list may not be accurately recalled. The study of recency and suffix effects in second grade children's recall (Foreit, 1977) was designed to identify differences in presence of the sensory trace between children and adults.

## Statement of the Problem

Are children and adults equal in neuro-physiological capabilities in terms of processes involved in auditory memory? How does the developing child interact with available auditory memory processes before auditory and speech skills reach an adult level? These two questions are not clearly answered in available literature on auditory memory research. The auditory serial recall task paradigm might be useful in studying the adequacy of auditory memory processes in children, if this paradigm is sensitive to developmental differences. Recency and suffix effects, measures of the serial recall task, need to be more thoroughly investigated in children for a variety of speech classifications. It is of interest to determine whether recency and suffix effects exist for spoken nonsense syllables in normally developing children, what the effects are for different age groups, and how memory strategies for aurally presented serial lists of real speech nonsense syllables and vowels compare between adults and different age groups of children.

## Purpose of the Study

The purpose of the study was to search for differences in recency and suffix effects of serial recall tasks. These tasks consisted of aurally presenting CVC lists and vowel lists to four groups: first graders, third graders, fifth graders, and adults. In addition, an attempt was made to identify the different types of recall errors made by the four experimental groups to determine

whether there are any specific errors associated with a specific age group. Three types of errors are possible for the lists of CVC combinations:

1) incorrect CVC (error in recall for both of the consonants and the vowel);

2) incorrect recall of the consonants only of a CVC combination (recall error for one or both of the consonants);

3) incorrect recall of the vowel only of a CVC combination.

Only one type of error is possible for the vowel lists: replacement of the correct vowel with an incorrect vowel.

The following questions were investigated:

1) is there evidence of recency and suffix effects within each age group tested?;

2) are there specific errors associated with particular age groups?;

3) are there specific errors associated with the first two and/or last two serial positions for a serial recall task?;

4) is there evidence of separate memory functions for consonants and vowels in each age group tested? In other words, are there greater recency and suffix effects for the vowel lists and the CVC lists with consonants held constant as compared to the CVC lists with vowels held constant?

## II. EXPERIMENTAL PROCEDURES

### Subjects

The population employed in this study consisted of normally-developing children, 20 subjects per grade including first, third and fifth grades; all were native speakers of standard American English. These children were selected from two elementary schools in the Madison, Wisconsin school district, and were grouped according to grade level. The groups consisted of an equal number of males and females. A fourth group which was utilized consisted of adults drawn from the resident population of Madison, Wisconsin residents. This group also consisted of 20 subjects, including equal numbers of males and females in the group). Consequently, 80 was the total number of subjects utilized in this study.

An introductory letter (Appendix A), a form of consent (Appendix B), and a questionnaire (Appendix C) were sent to the parents of all first, third, and fifth grade children attending two elementary schools in Madison, Wisconsin. Through means of questionnaires, consent forms, and discussions with parents and teachers, only those children who passed certain criteria were eligible for participation in the study. Criteria were: 1) parent's consent; 2) normal hearing; 3) absence of speech pathologies; 4) absence of learning disabilities; 5) native speaker of standard American English,

bilingual children were not included; 6) age of the child was within aa six-month range away from a target age set for each grade level examined, i.e.: first grade subjects were between the ages of 6 years, two months and 7 years, two months; third grade subjects were between the ages of 8 years, three months and 9 years, three months; the ages of fifth grade subjects fell within the range of 10 years, seven months and 11 years, one month (see Appendix D for means and standard deviations of ages for each of the four groups).

A random sample was drawn from the group of eligible children-subjects. Adults met the same criteria as the children, of course, with the exception of parental consent. The age range for the adults was from seventeen to thirty years.

## Materials

The ability to recall a span of syllables varies with age (Simon, 1974), so the length of lists was different for each of the four age groups. The length of lists for each age group was determined by a pilot study. The group of first graders was required to recall lists consisting of four items. The group of third graders recalled lists which were five items long. Six item lists were presented to both the fifth graders and adults. A total of 54 lists of phonetic materials classified into three different types were presented to the subjects, namely:

1) Vowel Lists: Eighteen different lists were composed of the

three vowels [ɜ˞], [ɛ], [ʊ]. The number of vowels presented in each list depended upon the age group of a subject. These vowels were chosen under two considerations: I) to include one example of a front vowel, a central vowel, and a back vowel; II) the vowel allowed for a great variety of non-meaningful syllables when combined with the consonants chosen for the CVC lists. The number of vowels presented in each list depended upon the age group of a subject. Within lists, phonetic materials were constructed so that vowels were presented at least once but no more than twice. Also, across lists each vowel was presented an equal number of times in each serial position. Nine of the lists are followed by the word "go" which itself was not to be recalled. The remaining nine lists were followed by a 200 Hz pure tone (control). The two different conditions, pure tone and "go", served as a signal to the subject to begin recall (see Appendix E).

2) CVC Lists/Consonants Held Constant: Eighteen different lists were constructed by combining the vowels [ɜ˞], [ɛ], and [ʊ] with the consonant combinations [t_t], [k_p], and [t_p]; consonants were held constant within a list. The length of each list was dependant upon the age group of a subject. Within lists, vowels were presented at least once but no more than twice. Across the lists, the vowels appeared an equal number of times in each serial position, and the above consonant combinations also appeared an equal number of times across

serial position. Half of the lists were followed by the recall condition "go", and the remaining half of the lists were followed by a pure tone, the control recall condition (see Appendix F).

3) CVC Lists/Vowels Held Constant: Eighteen different lists were constructed by combining the same vowels and consonant combinations used for the second type of lists mentioned above; vowels were held constant within a list. The number of syllables presented in each list was dependant upon the age group of the subjects. Within lists, each consonant combination was presented an equal number of times in each serial position, and the three different vowels were presented an equal number of times in random order. Half of the lists ended with the word "go" and the remaining half of the lists ended with a 200 Hz pure tone (see Appendix G).

## Recordings

Each list was spoken by a female speaker who was a native speaker of standard American-English. Lists were recorded in a sound isolated chamber (IAC: Industrial Acoustics Company, Inc.) utilizing an Ampex 2001 microphone (approximately 12 cm away from the speaker's mouth at a 45 angle) and a Sony reel-to-reel tape recorder model #TC 560, at 7 1/2 i.p.s. The level for each list was equated for intensity by monitoring the tape recorder's VU meter. The tape utilized was BASF, 7"x 1200'--1.5 mil. polyester base.

Each syllable was spoken at the rate of 1/second. The syllables were timed by a large laboratory clock with a seconds hand. The recordings of the stimuli consisted of lists of syllables followed by a recall condition--the word "go" or a pure tone. The lists were separated by a silent interval of approximately 15 seconds. The female speaker included the word "go" (same rate as the syllables) at the end of half of the lists. A 200 Hz pure tone was spliced at the end of the remaining lists. The tone was spliced into the tape 500 msec after the last word in the lists. The duration of the tone was 500 msec.

A five minute section of a 200 Hz pure tone was recorded from a CENCO audio oscillator # 80593. The recording of the pure tone was spliced into 500 msec sections and then spliced at the end of half of all syllable lists. The frequency of the pure tone was calibrated by monitoring a TEKTRONIX oscilloscope (model # 5103 N) connected to the output of the pure tone generator.

Testing Procedures

Subjects were tested in a quiet room. A Sears cassette tape recorder (model # 564.21650150) was used for presenting the speech lists in a free field at a comfortable listening level. Another recorder (GE model # 3-5308) was used for recording the subject's recall response after each list.

The subject practiced on pretraining trials for a serial

recall task involving lists of letters of the alphabet. The lists consisted of the letters A, D, and G (see Appendix H). Half of the practice lists were followed by the recall condition "go" to familiarize the subject with the serial recall task including a suffix not to be recalled. Each subject met pretraining criteria before participating in the experimental trials. The pretraining criteria were that five out of eight practice serial lists must be recalled correctly. If the subject did not meet criteria, the subject's participation in the study was terminated and he/she was dismissed. When the criteria were met, the subject was given instructions for the experimental trials. The subject was familiarized with the syllables in each kind of list following the pretraining trials. The experimenter pronounced each syllable one at a time for the subject and asked him/her to repeat the syllables immediately. The experimenter then explained what the subject was required to do.

Testing began after a subject was familiarized with the material and the serial recall task. Each subject was presented with three aural blocks of lists, one block for each type of list mentioned previously. The list types and recall conditions were counter-balanced across subjects. Each block consisted of eighteen trials for a particular type of list. A trial consisted of playing back a tape recorded presentation of a list followed by the subject's spoken recall which was recorded on

tape. Half of the lists in the block contained the word "go" for the recall condition. The remaining lists in the block contained a 200 Hz pure tone for the recall condition. The recall condition was a signal for the subject to respond and was not to be recalled.

The total time for presentation of each block was approximately six minutes. After a block was completed, the subject was given a five minute break. The total testing time including the resting periods was approximately forty-five minutes.

## Analysis

Age was the independent variable between subjects. The independent variables within subjects were list type (vowel lists, CVC lists/consonants held constant, and CVC lists/vowels held constant), recall condition (control tone and the word "go"), and serial position (the first two serial positions and the last two serial positions). There were only four levels for the serial position factor because each age group was required to recall different lengths of lists. Since recency and suffix effects were of interest, the first two and last two serial positions were analyzed. The dependent variable was the total number of errors in the four levels of serial positions.

The statistical test used for the study was one four-way analysis of variance (ANOVA). The statistical design used was

a 4 x 4 x 3 x 2 factorial to determine the effects of age, serial position, list type, and recall condition on the total number of errors in a serial recall task.

The null hypotheses for the 4 x 4 x 3 x 2 design were as follows:

1) There is no difference in the total number of errors for the last two serial positions among the four different age groups.

2) There is no difference in the total number of errors among the different age groups when the syllable lists are followed by the word "go".

3) There is no difference in the total number of errors among the difference in the total number of errors among the different age groups when the syllable lists are followed by a control tone.

4) There is no difference in the total number of errors for the two recall conditions.

5) There is no difference in the total number of errors between age groups for recall of lists of vowels.

6) There is no difference in the total number of errors between age groups for recall of lists of CVCs with vowels held constant.

7) There is no difference in the total number of errors between age groups for recall of lists of CVCs with consonants held constant.

8) There is no difference in total number of errors for a serial recall task between the three different types of lists.

9) There is no difference in overall total number of errors for a serial recall task among the four different age groups.

The criterion set for rejection of each of the null hypotheses was $p<0.05$.

The analysis was accomplished through use of the Statistical Package for The Social Sciences (Nie et al., 1975) on the Univac 1100 at the University of Wisconsin-Madison.

## III RESULTS AND DISCUSSION

The general intention of the study was explorative: the serial recall task paradigm was used as a method for studying developmental differences, if any, in the immediate auditory memory of four age groups for aurally presented nonsense syllables and vowels. Measurements of the dependent variable, recall error, were examined for the effects of four factors: 1)age; 2) serial position; 3) list type; and 4) recall condition. Only the recall errors made in the first two serial positions and the last two serial positions of a list were used for analysis.

Table 1 is a summary of the effects of the four factors of the dependent variable using a four-way analysis of variance (ANOVA). All four main factors independently affected the number of recall errors made for a particular serial recall task (significant at $p = 0.01$). Significant two-way interactions were also found: a significant age x serial position interaction ($p = 0.01$); a significant interaction of age x list type ($p = 0.01$); significant serial position x list type interaction ($p = 0.01$); significant serial position x recall condition ($p = 0.01$); and a significant list type x recall condition ($p = 0.05$). The age x recall condition was the only two-way interaction not significant. No three-way interactions resulted in significance.

Table 1: Summary of analysis of varience of the mean error scores for serial recall tasks involving four age groups: first grade, third grade, fifth grade, and adult subjects.

| Source of Variation | SS | DF | MS | F |
|---|---|---|---|---|
| MAIN EFFECTS | | | | |
| Age (A) | 1707.33 | 3 | 569.11 | 202.824 ** |
| Serial Position (B) | 1148.12 | 3 | 382.71 | 136.392 ** |
| List Type (C) | 1190.46 | 2 | 595.23 | 212.133 ** |
| Recall Condition (D) | 56.14 | 1 | 56.14 | 20.008 ** |
| 2-WAY INTERACTIONS | | | | |
| A X B | 73.97 | 9 | 8.22 | 2.929 ** |
| A X C | 78.55 | 6 | 13.09 | 4.666 ** |
| A X D | 2.92 | 3 | .97 | .347 |
| B X C | 77.59 | 6 | 12.93 | 4.609 ** |
| B X D | 51.17 | 3 | 17.06 | 6.079 ** |
| C X D | 17.89 | 2 | 8.94 | 3.189 * |
| 3-WAY INTERACTIONS | | | | |
| A X B X C | 41.68 | 18 | 2.31 | .825 |
| A X B X D | 19.43 | 9 | 2.16 | .770 |
| A X C X D | 33.87 | 6 | 5.64 | 2.012 |
| B X C X D | 7.67 | 6 | 1.28 | .455 |
| RESIDUAL | 5118.03 | | 2.81 | 2.086 |

* Significant at p = 0.05
** Significant at p = 0.01

Identification of Recall Errors

The recall errors associated with each particular list type were analyzed and compared across age groups with the aim of identifying any reconition differences both within and between age groups.

The first errors examined were those made for the vowel lists. The vowel serial lists were composed of the three vowels [ɜ˞], [ɛ], and [ʊ]. The lists were constructed such that each of the vowels occurred an equal number of times in each serial position across lists. Consequently, if a difference in receptiveness to any particular vowels did not exist, errors should have approximated an even distribution between the three vowels. Also, if age differences in sensitivity to particular phonemes were non-existant, the distributions of percentage of total number of errors made for each particular vowel should have been similarly shaped for all four age groups.

The second errors examined were those made for the two types of CVC lists. The CVC lists were constructed so that specified syllables occured an equal number of times in all serial positions across lists. The CVC recall errors were grouped into the following four types: Type 1.--only the first consonant of the CVC was incorrectly recalled; Type 2.--only the last consonant of the CVC was incorrectly recalled; Type 3.--only the vowel of the CVC was incorrectly recalled; Type 4.--more than one phoneme in the CVC was incorectly recalled. The distributions of percentage of the total number or errors made in each of the above categories were examined.

1) Vowel Lists: Figure 1 illustrates results contrary to the expected outcome of an even distribution of errors between the three vowels. The error distributions for each of the four age groups were plotted in succession for easy comparison. The errors were plotted in percentages of total errors rather than mean scores to determine the clustering of errors between age groups. Follow-up tests were performed on the age x list type interaction. Tukey's HSD test for multiple comparisons was performed on mean error scores of the four age groups for each of the particular vowels (Mendenhal, 1968). A comparison of the mean error scores for the vowel item [ɜ˞] resulted in a significant difference berween the first grade and adult subjects only--HSD(636) = .628, $\alpha$ = .05. It can be seen in Table 2a that the difference between the mean error score of the first grade subjects and the mean error score of the adult subjects exceeded HSD. Table 2b shows that the mean errors for the item [ɛ] differed significantly for the third grade subjects and adult subjects at the level $\alpha$ = .05. Table 2c shows that mean error scores for the first, third, and fifth grade subjects differed significantly from the mean error score of the adults for the item [ʊ] by at least the level $\alpha$ = .05. Although the young subjects' sensitivity to the particular vowel types was different from that of the adults, no significant differences were found among the first grade, third grade, and fifth grade children.

2) CVC Lists (Consonants Held Constant): The next type of serial list examined for errors consisted of strings of nonsense

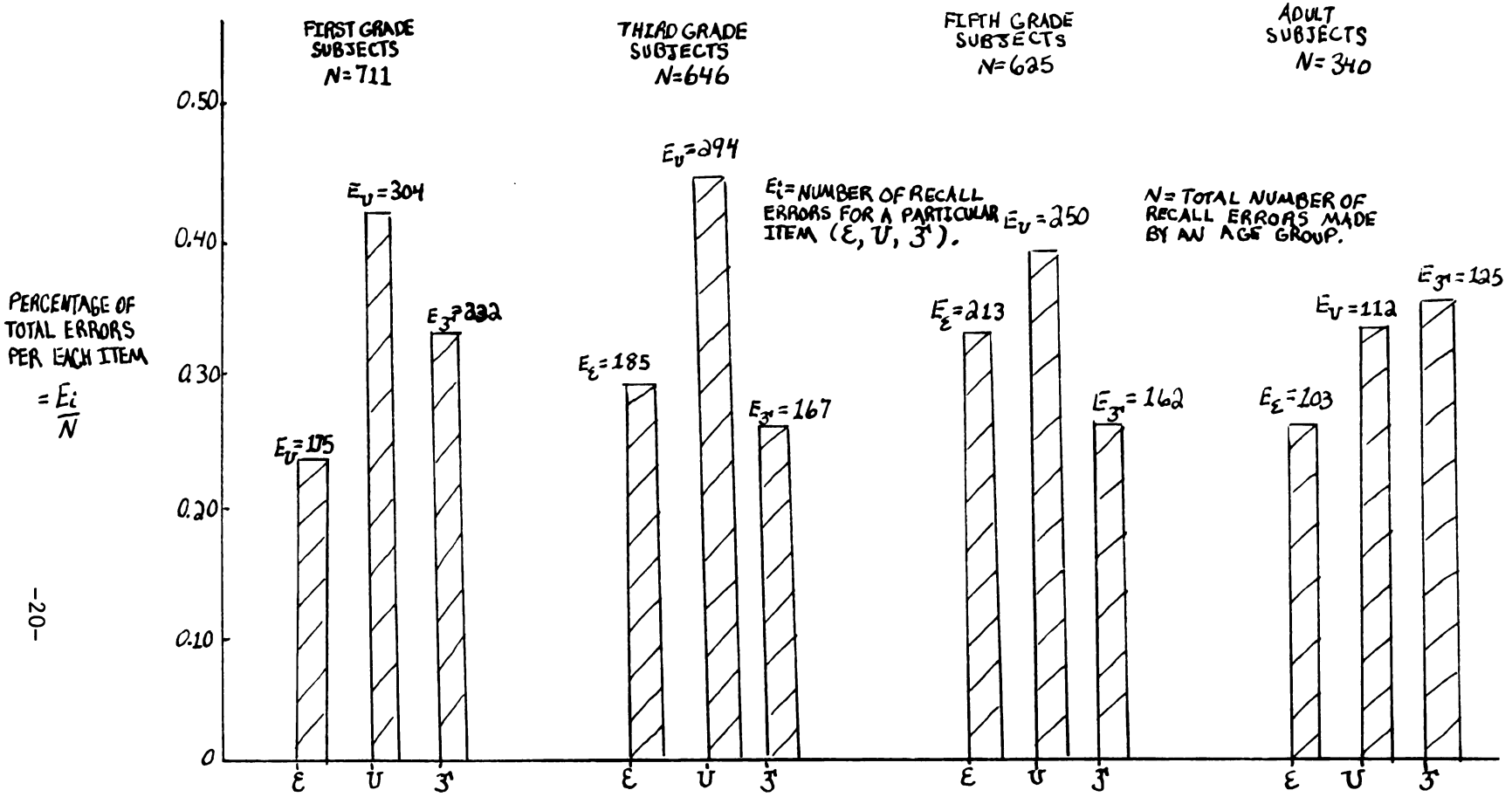


Figure 1. BREAKDOWN OF RECALL ERRORS FOR VOWEL LISTS. The vertical axis represents the number of recall errors made for a particular recall item divided by the total number of recall errors made within an age group. Horizontal axis represents the type of item recalled by the subject.

Tables 2a, 2b, and 2c. Tukey's HSD test for multiple comparisons of means. A matrix showing the mean of each age group for the number of errors made for a particular vowel item. The body of the table shows the differences between pairs of means. For all three tables: df=636; k=4; at $\alpha$=0.05, HSD=0.628 .

2a. AVERAGE NUMBER OF ERRORS FOR THE ITEM ɜ.

| | $X_{1st}$=1.4 | $X_{3rd}$=1.1 | $X_{5th}$=0.89 | $X_{AD}$=0.72 |
|---|---|---|---|---|
| $X_{1st}$=1.4 | -- | .3 | .51 | .68* |
| $X_{3rd}$=1.1 | -- | -- | .21 | .38 |
| $X_{5th}$=0.89 | -- | -- | -- | .17 |
| $X_{AD}$=0.72 | -- | -- | -- | -- |

2b. AVERAGE NUMBER OF ERRORS FOR THE ITEM ɛ.

| | $X_{1st}$=1.1 | $X_{3rd}$=1.17 | $X_{5th}$=1.1 | $X_{AD}$=0.54 |
|---|---|---|---|---|
| $X_{1st}$=1.4 | -- | .07 | 0 | .56 |
| $X_{3rd}$=1.17 | -- | -- | .07 | .63* |
| $X_{5th}$=1.1 | -- | -- | -- | .56 |
| $X_{AD}$=0.54 | -- | -- | -- | -- |

2c. AVERAGE NUMBER OF ERRORS FOR THE ITEM ʊ.

| | $X_{1st}$=1.9 | $X_{3rd}$=1.8 | $X_{5th}$=1.31 | $X_{AD}$=0.68 |
|---|---|---|---|---|
| $X_{1st}$=1.9 | -- | .1 | .59 | 1.22** |
| $X_{3rd}$=1.8 | -- | -- | .49 | 1.12** |
| $X_{5th}$=1.1 | -- | -- | -- | .63* |
| $X_{AD}$=0.54 | -- | -- | -- | -- |

$X_{1st}$ (First Grade Subjects) $X_{3rd}$ (Third Grade Subjects)

$X_{5th}$ (Fifth Grade Subjects) $X_{AD}$ (Adult Subjects)

* significant at $\alpha$=.01 ** significant at $\alpha$=.05

syllables of which only the vowel was varied, such as [tʊp], [tɝp], [tɛp]. Figure 2 is a graph of the percentage of total recall errors vs. error type; a plotting is made for each age group. The greatest percentage of errors were found for error Type 3 in all age groups. Also, there was a tendency towards Type 4 errors for the first, third and fifth grade subjects.

3) CVC Lists (Vowels Held Constant): The third type of list examined for errors consisted of strings of nonsense syllables of which only the consonants were varied within a list, such as [tɛp], [kɛp], [tɛt]. Figure 3 is a graph of the results of classifying the errors for the third kind of CVC list. The greatest percentage of errors were obtained for error Type 4 in all age groups. The remaining percentage of total errors was distributed decreasingly across error Types 2, 1, and 3. Between age groups, an increasing tendency towards a certain error type was found for error Type 4; the first grade subjects made significantly more errors of this type than any other group, and the adult subjects made significantly fewer errors of this type than any other group [HSD(636) = 0.64, $\alpha$ = 0.01; HSD(636) = 0.528, $\alpha$ = 0.05].

The distributions of vowel-errors, with respect to how many errors were made for each particular vowel, show that groups differed in subjects' sensitivity to each of the recall-items. But, distributions of CVC error-types do not show apparent group differences in terms of how subjects erred in recalling the string of phonemes which are contained within each nonsense syllable.

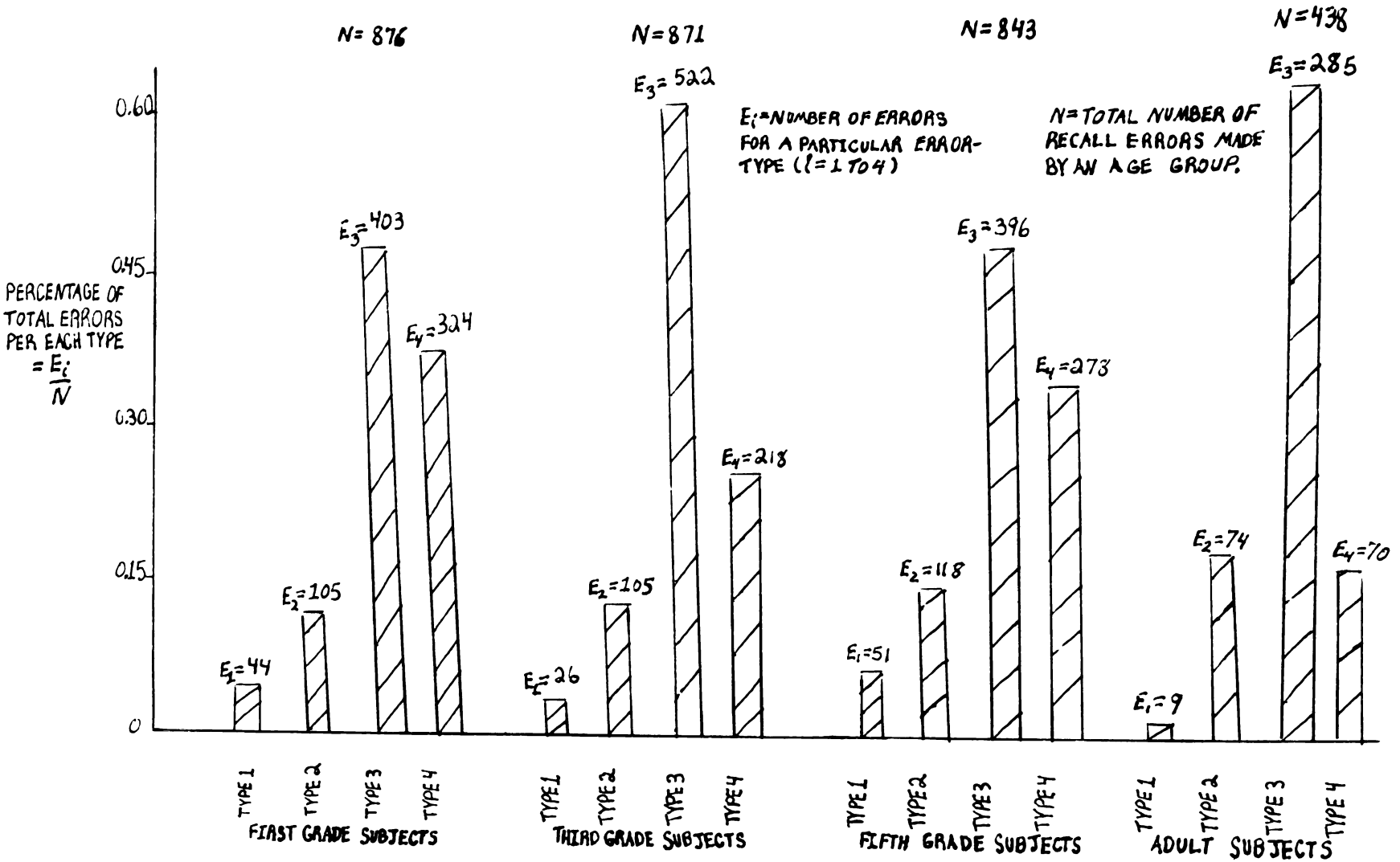


Figure 2. BREAKDOWN OF RECALL ERRORS FOR CVC LISTS (CONSONANTS HELD CONSTANT). The vertical axis represents the number of recall errors made for a particular error type divided by the total number of recall errors made within an age group. Horizontal axis represents the type of errors made by subjects.

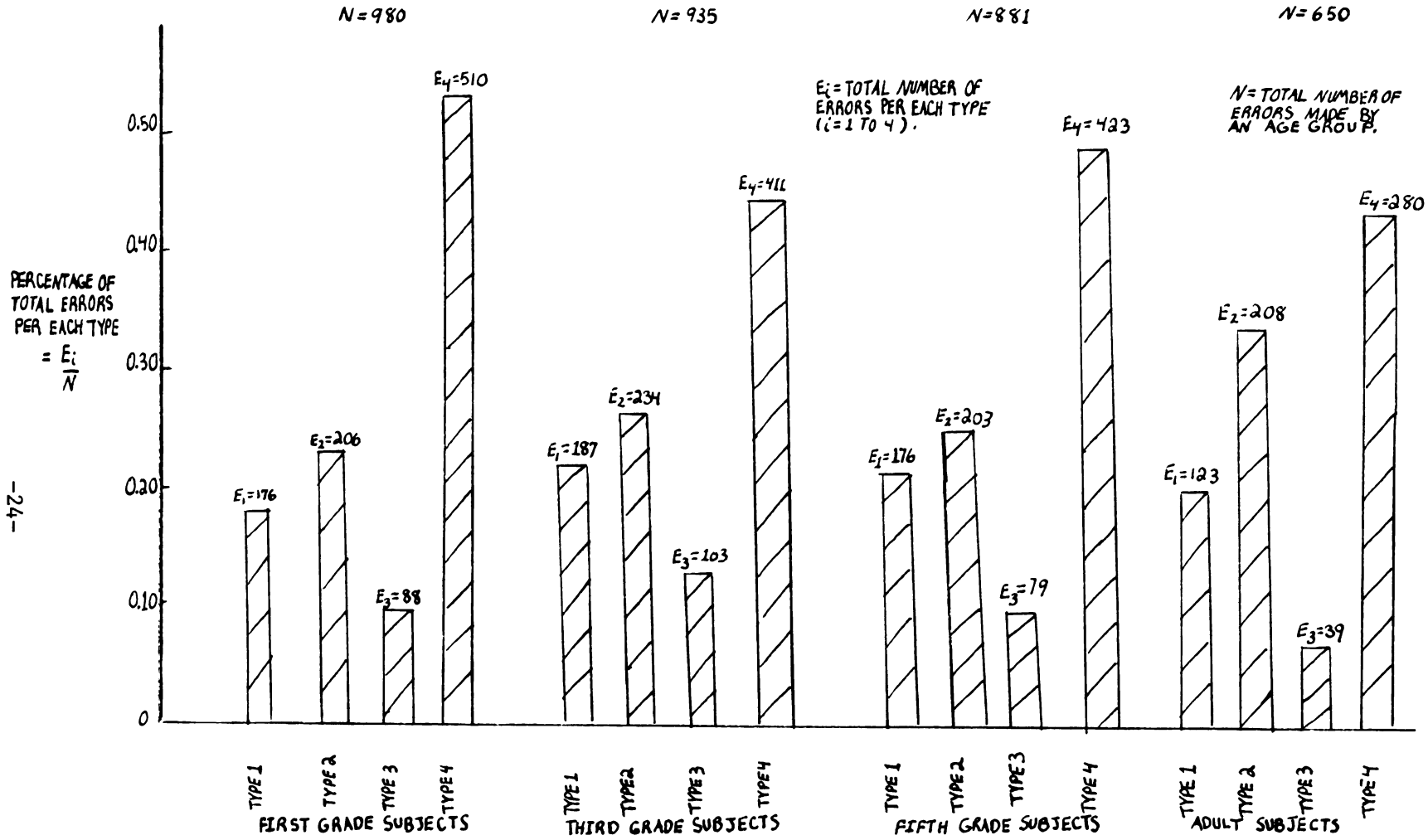


Figure 3. BREAKDOWN OF RECALL ERRORS FOR CVC LISTS (VOWELS HELD CONSTANT). The vertical axis represents the number of recall errors made for a particular error type divided by the total number of recall errors made within an age group. Horizontal axis represents the type of errors made by the subjects.

Recency and Suffix Effects

The main purpose of the study was to compare auditory memory effects of first grade subjects, third grade subjects, fifth grade subjects, and adult subjects. Follow-up t-tests on mean error scores produced results of dubiously significant recency and suffix effects for first grade subjects only; significant results were due to inconsistent retrieval and rehearsal strategies rather than an effect of neuro-physiological traces. The dubious significance of results was evident in both examination of individual error sheets and in the distributions of total error vs. serial position: first grade subjects randomly shifted between rehearsal of the first item in a serial list or the last item in a serial list when the recall-lists were followed by the tone condition; correct recall was random (approaching chance probability) across serial positions when the recall-lists were followed by the suffix condition. With the exception of the first grade subjects, all other significant results were consistent with other studies of auditory memory research.

1) Vowel Lists: Excluding the first grade subjects, no significant recency effects were found when examining the mean error scores of the third and fourth serial position for the lists followed by the tone condition. However, significant suffix effects were found for both the fifth grade and adult subjects when performing follow-up t-tests on the difference in recall between suffix and tone conditions at the last serial position [$t(19) = 3.14$, $p<0.01$; $t(19) = 2.38$, $p<0.05$ respectively]. Figure 4 is a graph of the percentage of total recall errors made in each serial position.

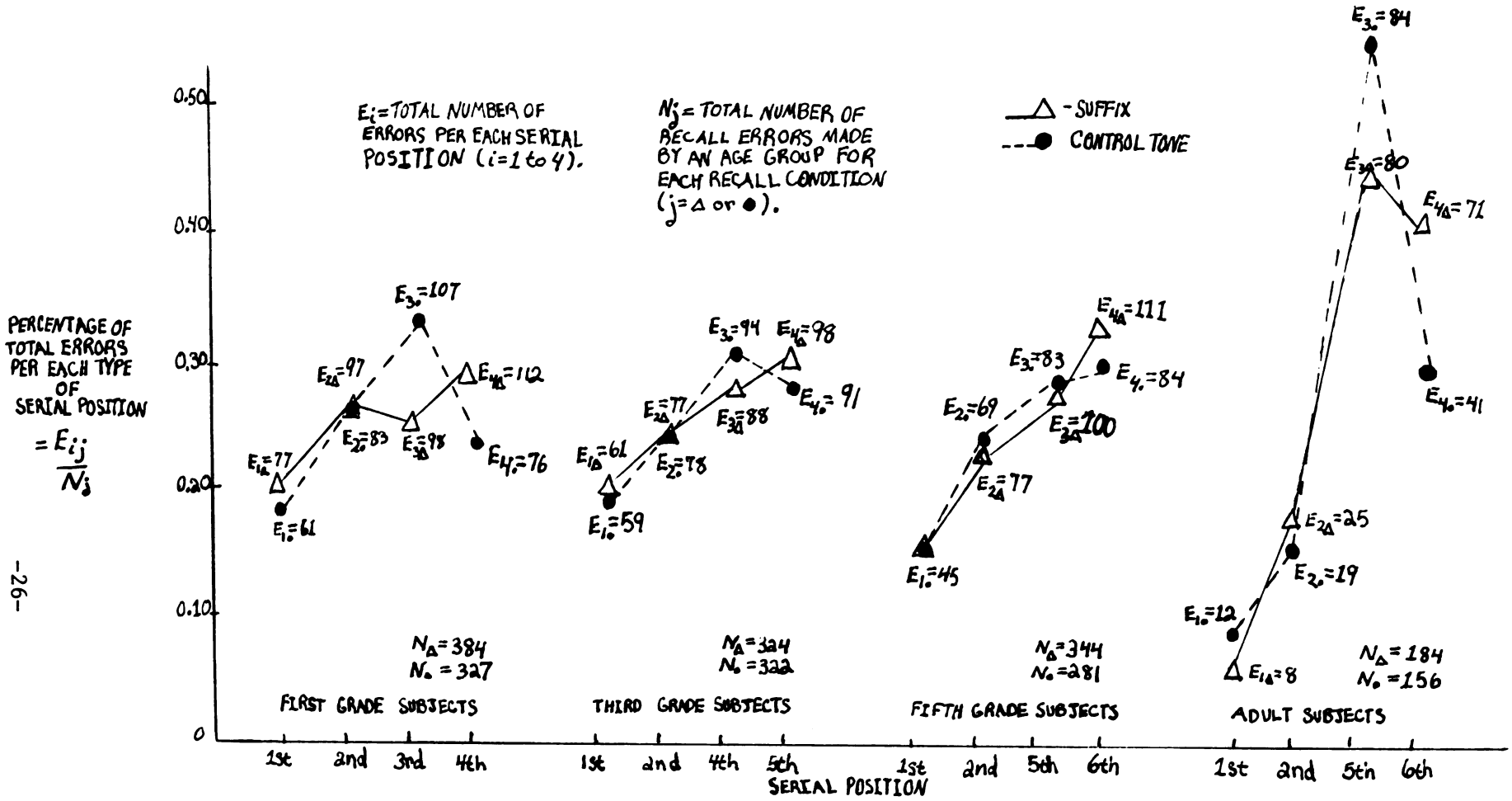


Figure 4. PERCENTAGE OF TOTAL ERRORS BY SERIAL POSITION FOR VOWEL LISTS. Vertical axis represents the number of recall errors made for a particular serial position divided by the total number of recall errors made by an age group. The horizontal axis represents the serial position of the items which subjects had to recall.

2) CVC Lists (Consonants Held Constant): Once again, excluding the first grade subjects, no significant recency effects were found. Significant suffix effects were found for the adult subjects [$t(19) = 2.22$, $p<0.05$]. Figure 5 is a graph of the percentage of total recall errors made according to serial position.

3) CVC Lists (Vowels Held Constant): For this third list type, all age groups failed to show significant recency or suffix effects. The plot of percentage of total errors vs. serial position is presented in Figure 6.

Age Effects

To test for age differences in recall for the last item in a serial list, Tukey's follow-up comparison test was performed. The mean error scores obtained for the fourth serial position under the tone condition were compared for differences in the recency recall advantage (Tables 3a, 3b, 3c). The difference between the adults' mean scores and each of the young subjects groups' mean scores was found to be significant for the vowel lists [$HSD(76) = 1.53$, $\alpha = 0.01$]. The adults recalled the last serial item of the CVC Lists (Consonants Held Constant) more accurately than any other group, the differences exceeding HSD[$HSD(76) = 1.95$, $\alpha = 0.01$]. There were no significant age differences found among groups for the recall of CVC Lists (Vowels Held Constant); for this particular list type, all ages found recall for the last serial item similarly difficult. Although the HSD tests resulted in significant difference in final serial

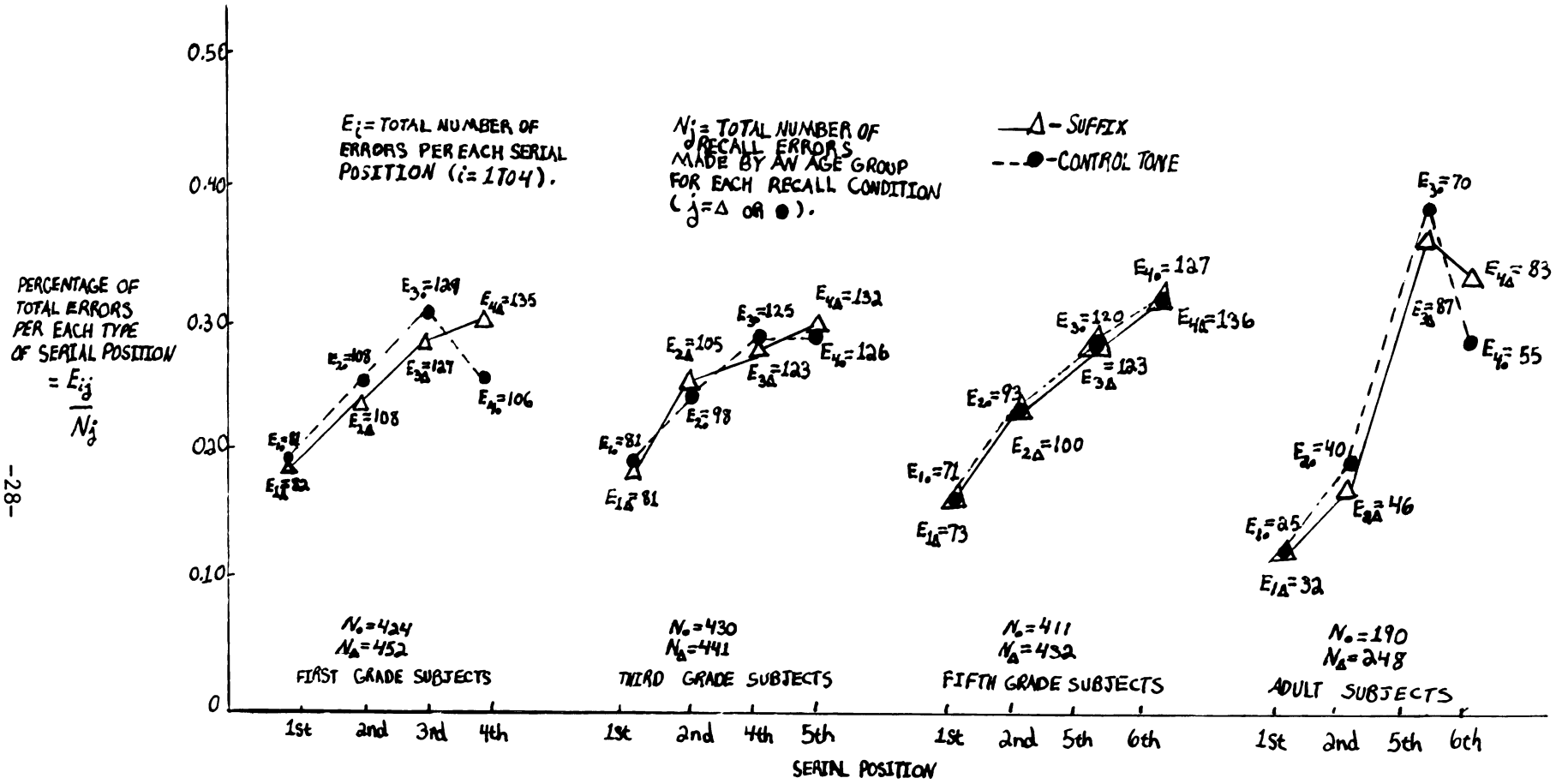


Figure 5. PERCENTAGE OF TOTAL ERRORS BY SERIAL POSITION FOR CVC LISTS (CONSONANTS HELD CONSTANT). Vertical axis represents the number of recall errors made for a particular serial position divided by the total number of recall errors made by an age group. The horizontal axis represents the serial position of the items which subjects had to recall.

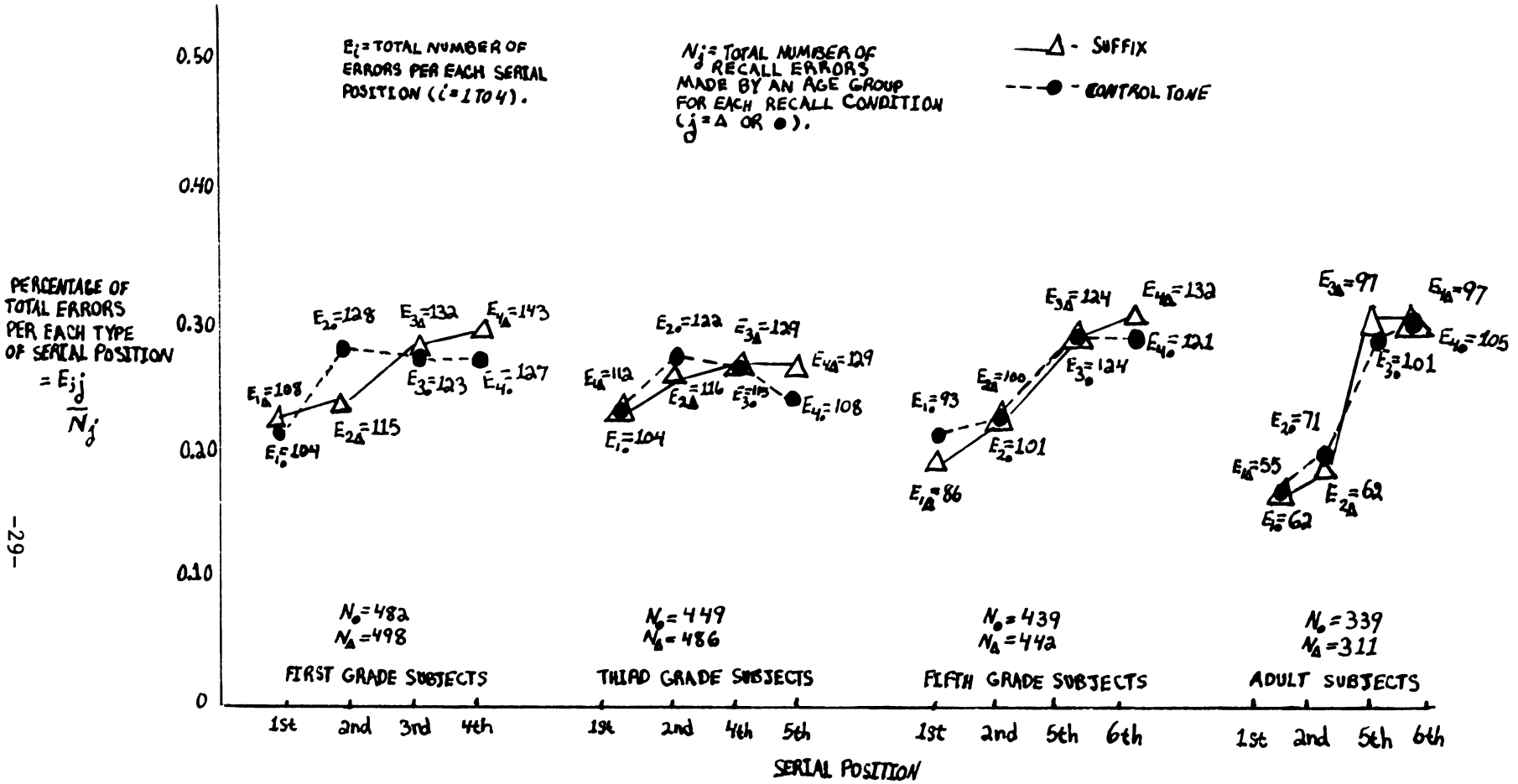


Figure 6. PERCENTAGE OF TOTAL ERRORS BY SERIAL POSITION FOR CVC LISTS (VOWELS HELD CONSTANT). Vertical axis represents the number of recall errors made for a particular serial position divided by the total number of recall errors made by an age group. The horizontal axis represents the serial position of the items which subjects had to recall.

Tables 3a, 3b, and 3c. Matrices showing the mean number of errors made in the final serial position under the control tone condition by each of the four age groups. Tables are divided according to list type, and the bodies of the tables show the differences between pairs of means for multiple comparison tests of significance, Tukey's HSD.

3a. VOWEL LISTS RESULTS,

| | $X_{1st}$=3.8 | $X_{3rd}$=4.55 | $X_{5th}$=4.2 | $X_{AD}$=2.05 |
|---|---|---|---|---|
| $X_{1st}$=3.8 | -- | .7 | .4 | 1.75 * |
| $X_{3rd}$=4.55 | -- | -- | .35 | 2.5 ** |
| $X_{5th}$=4.2 | -- | -- | -- | 2.15 ** |
| $X_{AD}$=2.05 | -- | -- | -- | -- |

df=76; k=4; HSD=1.53

3b. CVC LISTS (CONSONANTS HELD CONSTANT) RESULTS,

| | $X_{1st}$=5.3 | $X_{3rd}$=6.3 | $X_{5th}$=6.35 | $X_{AD}$=2.75 |
|---|---|---|---|---|
| $X_{1st}$=5.3 | -- | 1 | 1.05 | 2.55 ** |
| $X_{3rd}$=6.3 | -- | -- | .05 | 3.55 ** |
| $X_{5th}$=6.35 | -- | -- | -- | 3.6 ** |
| $X_{AD}$=2.75 | -- | -- | -- | -- |

df=76; k=4; HSD=1.59

3c. CVC LISTS (VOWELS HELD CONSTANT) RESULTS,

| | $X_{1st}$=6.35 | $X_{3rd}$=5.4 | $X_{5th}$=6.05 | $X_{AD}$=5.25 |
|---|---|---|---|---|
| $X_{1st}$=6.35 | -- | .95 | .3 | 1.1 |
| $X_{3rd}$=5.4 | -- | -- | .65 | .15 |
| $X_{5th}$=6.05 | -- | -- | -- | .8 |
| $X_{AD}$=5.25 | -- | -- | -- | -- |

df=76; k=4; HSD=1.35

$X_{1st}$ (first grade subjects) $X_{3rd}$ (third grade subjects)
$X_{5th}$ (fifth grade subjects) $X_{AD}$ (adult subjects)
** significant at $\alpha$=.01 * significant at $\alpha$=.05

position mean error scores between adults and each of the groups of children, there were no significant differences in mean error scores between the first grade, third grade, and fifth grade subjects. The results of the HSD tests do not point to any marked progression of either a recall advantage for final position serial items or effects of a suffix.

## Effects of List Type on Auditory Memory

Comparisons were made of the fourth serial position mean error scores for each list type within each age group. Tukey's multiple comparison test was used to determine how immediate auditory recall compared between the three different types of recall material within groups (See Tables 4a, 4b, 4c, and 4d). All age groups found recall of the vowel lists easier than any other list type; mean differences exceeded HSD by at least the probability level $\alpha = 0.05$. The unexpected finding was that all three groups of children found CVC Lists, of which only the vowels varied, more difficult to recall than the Vowel Lists by at least the probability level $\alpha = 0.05$; but the adults found recall for these two kinds of serial lists about the same.

## Summary of Results

The study failed to show conclusive significant recency effects in the recall of any age group tested. However, conclusive significant suffix effects were obtained in both fifth grade subjects' recall of only the vowel lists and adult subjects' recall

Tables 4a, 4b, and 4c. Matrices showing the mean number of errors made in the final serial position for each of the three list types. Tables are divided according to age groups, and the body of the tables shows the differences between pairs of means for multiple comparison tests of significance, Tukey's HSD.

4a. FIRST GRADE SUBJECTS

| | $X_V$=3.8 | $X_{CHC}$=5.3 | $X_{VHC}$=6.35 |
|---|---|---|---|
| $X_V$=3.8 | -- | 1.5* | 2.55** |
| $X_{CHC}$=5.3 | -- | -- | 1.05 |
| $X_{VHC}$=6.35 | -- | -- | -- |

df=117; k=3; HSD=1.36

4b. THIRD GRADE SUBJECTS

| | $X_V$=4.55 | $X_{CHC}$=6.3 | $X_{VHC}$=5.4 |
|---|---|---|---|
| $X_V$=4.55 | -- | 1.75** | .85 |
| $X_{CHC}$=6.3 | -- | -- | .9 |
| $X_{VHC}$=5.4 | -- | -- | -- |

df=117; k=3; HSD=1.20

4c. FIFTH GRADE SUBJECTS

| | $X_V$=4.2 | $X_{CHC}$=6.35 | $X_{VHC}$=6.5 |
|---|---|---|---|
| $X_V$=4.2 | -- | 2.15** | 1.85** |
| $X_{CHC}$=6.35 | -- | -- | .3 |
| $X_{VHC}$=6.5 | -- | -- | -- |

df=117; k=3; HSD=1.1

4d. ADULT SUBJECTS

| | $X_V$=2.05 | $X_{CHC}$=2.75 | $X_{VHC}$=5.4 |
|---|---|---|---|
| $X_V$=4.2 | -- | .7 | 3.2** |
| $X_{CHC}$=2.75 | -- | -- | 2.5** |
| $X_{VHC}$=5.25 | -- | -- | -- |

df=117; k=3; HSD=1.54

$X_V$ (vowel lists) $X_{CHC}$ (lists of CVCs/consonants held constant) $X_{VHC}$ (lists of CVCs/vowels held constant)

** significant at $\alpha$=0.01 ** significant at $\alpha$=0.05

of vowel lists and CVCs (consonants held constant). Further comparisons between the recall of adults and children resulted in significant differences between mean error scores obtained for the last serial position of a particular list type. No significant differences were found between the three groups of children. Significant list type effects were also found which indicate that the vowels were easier for children to recall than both of the two different types of CVC lists; the adults showed a significant difference between the mean errors obtained for the CVC (Vowels Held Constant) Lists and either of the remaining two list types, suggesting a difference in immediate auditory storage of consonants and vowels in adult's recall (Crowder, 1971; Cole, 1973).

Grouping errors obtained in vowel lists according to the proportion of total errors obtained for each particular vowel showed that subjects in all age groups made the most errors for the item [U]. Also age groups differed in receptiveness to the particular vowels; this is seen by the varying shapes of the distributions obtained for error-types across age groups.

## IV. GENERAL DISCUSSION AND CONCLUSIONS

### General Discussion of Results

With the exception of the first grade subjects, the recall of children and adults failed to show significant recency effects under any conditions; the results are not in dissagreement with findings by Darwin and Baddeley (1974), who failed to find recency effects for adult's recall of CVs which differed only in vowels that were similar in first and second formant frequencies. Like their study, the present experiment used recall items which are very acoustically similar. Two of the three vowel items used in the study, [ʊ], and [ɝ], are very similar in first and second formant frequencies; in addition, the vowel [ʊ] is in the formant frequency range between the vowels [ɛ] and [ɝ]. Consequently, the vowel [ʊ] is highly confusable, apparent in the distribution of vowel error-types. In addition, subjects showed varying sensitivity to the vowels between age groups, implicit in the distribution of errors made for vowel items.

The consistenly lower number of recall errors made for vowels than either type of CVC list holds true for all four age groups. This difference in recall accuracy emerged as a significant suffix effect, substantiated by both statistical tests and examination of subjects' individual error sheets, for recall of only the vowel lists by the fifth grade subjects. Unlike the adults, the fifth grade subjects did not show a significant suffix effect for CVCs

(consonants held constant), a difference that might be developmental.

It has been shown by Bennet (1968) that recall of vowels with very similar formant patterns, like those used in the present study, is affected by varying vowel duration which results in confusion errors. This may account for the failure to find suffix effects in the fifth graders' recall of CVCs (consonants held constant), since vowel duration can be influenced by surrounding consonants (Massaro, 1975).

Tukey's HSD test resulted in no significant differences between the first grade, third grade, and fifth grade mean error scores obtained for recall of any list item appearing in the last serial position which is the recall location affected by a suffix. But, the same statistical test did result in a significant difference between the recall of children and adults for mean error scored obtained in the final serial position. Both the absence of conclusive suffix effects in two out of three groups of children and the results of varying sensitivity to vowel-errors between age groups may be implications of group differences in identifying the acoustic representation of the speech sound in the sensory trace.

There is similarity in list type effects across age groups. The mean error scores for vowel lists differed significantly from the mean error scores for at least one of the kinds of CVC lists, if not both; this holds true for all four age groups. This similarity supports the hypothesis that the the immediate auditory storage of

consonants and vowels is a comparable function for both children and adults (Foreit, 1971). However, there is a contrast between children's and adults' recall. There was not a significant difference between mean error scores obtained in the final serial position for vowels and CVCs (consonants held constant) in adults' recall; the reverse is true for the recall of the children. This and the fact that the fifth grade subjects showed a reliable suffix effect implies recall differences are influenced by acoustic distinctiveness of the speech sound.

Implications for Future Research

The unexpected outcome of the study was that although a significant and conclusive suffix effect was found in the recall of one of the groups of children, it emerged only for the vowels; the vowels are more distinctive acoustically than either of the CVC list types. The hypotheses that acoustic confusions are influencing obtained differences in suffix effects between children's and adults' recall needs to be verified. It would be of interest to determine whether suffix effects for children's recall of synthetically produced vowels or CVs would emerge for auditory recall material of which the distinctiveness is varied across list types. One approach to this problem would be to test for the effects of varying the duration of synthetically produced vowels across serial lists of vowels.

An extensive study involving various age groups and strictly

controlled synthetic speech would be informative in determining whether the auditory serial recall task paradigm is truly sensitive to developmental differences. If this research paradigm is sensitive to developmental differences, it would also be of interest to study the effects of different communication disorders on auditory memory phenomena.

One other consideration should be made. The procedure of grouping and analyzing children's recall errors made in the final serial position during a serial recall task may prove a useful tool. Comparing and contrasting errors as an explorative measure may be informative in elucidating the nature of the specific processes, such as neuro-physiological or cognitive, involved in immediate auditory memory.

## Conclusions

The question of what specific or combination of factors determine the emergence of a suffix effect in the immediate auditory recall of children needs to be answered. From the results it seems that the acoustic distinctiveness of the recall material is influencing the differences in suffix effects between the fifth grade subjects and adults. It is concluded that children's auditory serial recall of speech sounds is more susceptible to acoustic confusions than adults' recall of the same task. The more acoustically distinct the sound is, (e.g.,a highly learned word such as a digit), the less likely there will be acoustic confusion; there

would be less interference with identifying a distinct sound over a confusable one in immediate acoustic storage. This assumption is supported by other findings. Eguchi (1976) found differences between children and adults in discriminating formant frequency transitions; and Elliot et al. (1981) demonstrated that children who perform at a 100% level on a clinical test of speech descrimination could not discriminate or label CVs as well as adults. The examination of recency and suffix effects in children's recall may yet prove a useful tool in searching for the nature of the developmental differences mentioned above; the auditory serial recall task appears to be sensitive to developmental differences in immediate auditory processing of speech sounds.

## APPENDIX A

Dear Parents:

During the months of October and November, I am conducting a research study at the University of Wisconsin as a graduate student majoring in Audiology and Speech Sciences. I am beginning the doctoral program at the University of Wisconsin-Madison in the Communication Disorders Department. The research I will be conducting is under the joint supervision of Dr. Oscar Tosi, Michigan State University, East Lansing, Michigan, and Dr. James Abbs, Waisman Center, University of Wisconsin-Madison.

This study is concerned with auditory memory of first, third, and fifth grade children. I request that you kindly consent in allowing your child to participate in the study. Your child is not required to participate in the study. Certainly this study will neither be harmful or beneficial to your child, and you are free to withdraw him/her at any time without penalty. If you consent, your child will be requested to listen to and recall certain syllables during approximately thirty minutes.

Please read the enclosed Consent Form. If you have any questions or concerns please feel free to call me. If you decide to consent, fill out the enclosed forms thoroughly and have your child return the forms to his/her home-room teacher. Thank you.

Sincerely,

Ms. Susan J. Mirowski
505 Conklin Place #16
Madison, WI 53703
Phone (608) 256-2841

APPENDIX B

CONSENT FORM

Ms. Susan J. Mirowski will be conducting a scientific study of auditory memory under the joint supervision of Dr. Oscar Tosi, Professor and Director, Speech and Hearing Sciences Research Laboratory, Michigan State University, East Lansing, Michigan, and Dr. James Abbs, Waisman Center, University of Wisconsin-Madison.

1) I understand the purpose of the study is to determine if differences exist among different age groups of normally developing children for immediate recall of speech sounds.

2) I understand that my child will not be in danger of physical or psychological harm and that he/she will not benefit directly from participating in the study.

3) I understand that I can withdraw my child from participation in the study at any time without penalty and that my child and I will not receive or give payment for participation in the study.

4) I understand that my child is not required to participate in the study.

5) I understand that any data obtained from testing which identifies my child specifically is to remain confidential.

I, _____ voluntarily consent
(SIGNATURE OF PARENT/GUARDIAN)

to allow my child _____ to participate in
(PRINT NAME OF STUDENT)

a scientific study of auditory memory conducted by Ms. Susan J. Mirowski under the above conditions. _____
(DATE)

_____ _____ _____
(GRADE LEVEL OF STUDENT) (DATE OF BIRTH) (AGE)

_____
Address (STREET) (CITY) (STATE) (ZIP CODE)

APPENDIX C

QUESTIONNAIRE--CHILDREN

_____ _____ _____
(PRINT STUDENT'S NAME) (GRADE LEVEL) (DATE OF BIRTH)

_____
Address (STREET) (CITY) (STATE) (ZIP CODE)

_____
(PHONE)

Please answer the following questions (check the appropriate answer.

YES NO

___ ___ My child's hearing has been tested within the last year.

___ ___ If yes, did your child pass the hearing test?

_____ _____
NAME OF INSTITUTION WHICH PROVIDED THE HEARING TEST
NAME OF EXAMINER IF KNOWN

_____
DATE OF HEARING TEST

YES NO

___ ___ If your child did not pass the hearing tests was he/she referred to a hearing clinic or an audiologist?

___ ___ Does your child wear a hearing aid?

___ ___ Does your child have any learning disabilities? If yes, please describe.

_____

YES NO _____

___ ___ Does your child have any speech problems?

___ ___ If yes, please describe. _____

_____

___ ___ Is your child bilingual? If yes, what other languages besides English does your child speak? _____

## APPENDIX D

MEAN AGES AND STANDARD DEVIATIONS FOR EACH OF THE FOUR GROUPS OF SUBJECTS.

| | First Grade Subjects | Third Grade Subjects | Fifth Grade Subjects | Adult Subjects |
|---|---|---|---|---|
| Mean (years) | 6.5 | 8.6 | 10.5 | 23.9 |
| Standard Deviation | .37 | .40 | .25 | 3.8 |

APPENDIX E

Four Item Vowel List A (with suffix)

| | | | | | |
|---|---|---|---|---|---|
| A-1 | ɜ | ʊ | ɛ | ɜ | go |
| A-2 | ɛ | ɛ | ɜ | ʊ | go |
| A-3 | ɜ | ɛ | ɛ | ʊ | go |
| A-4 | ɛ | ɜ | ʊ | ɛ | go |
| A-5 | ɜ | ɛ | ɜ | ʊ | go |
| A-6 | ʊ | ʊ | ɛ | ɜ | go |
| A-7 | ʊ | ɛ | ʊ | ɜ | go |
| A-8 | ɛ | ʊ | ɜ | ɛ | go |
| A-9 | ʊ | ɜ | ɛ | ɛ | go |

Four Item Vowel List B (with control tone)

| | | | | | |
|---|---|---|---|---|---|
| B-1 | ɜ | ʊ | ʊ | ɛ | tone |
| B-2 | ɛ | ʊ | ʊ | ɜ | tone |
| B-3 | ɜ | ɛ | ʊ | ɜ | tone |
| B-4 | ɛ | ɜ | ɜ | ʊ | tone |
| B-5 | ɜ | ɜ | ɛ | ʊ | tone |
| B-6 | ʊ | ɜ | ʊ | ɛ | tone |
| B-7 | ɛ | ɜ | ɛ | ʊ | tone |
| B-8 | ʊ | ɛ | ɜ | ɜ | tone |
| B-9 | ʊ | ʊ | ɜ | ɛ | tone |

APPENDIX E
(continued)

Five Item Vowel List A (with suffix)

| | | | | | | |
|---|---|---|---|---|---|---|
| A-1 | ɜ | ʊ | ɛ | ɛ | ɜ | go |
| A-2 | ɛ | ɛ | ɜ | ɜ | ʊ | go |
| A-3 | ɜ | ɛ | ɜ | ɛ | ʊ | go |
| A-4 | ɛ | ɜ | ʊ | ʊ | ɛ | go |
| A-5 | ɜ | ɛ | ɛ | ɜ | ʊ | go |
| A-6 | ʊ | ʊ | ɛ | ɛ | ɜ | go |
| A-7 | ʊ | ɛ | ɜ | ʊ | ɜ | go |
| A-8 | ɛ | ʊ | ʊ | ɜ | ɛ | go |
| A-9 | ʊ | ɜ | ʊ | ɛ | ɛ | go |

Five Item Vowel List B (with control tone)

| | | | | | | |
|---|---|---|---|---|---|---|
| B-1 | ɜ | ʊ | ɛ | ʊ | ɛ | tone |
| B-2 | ɛ | ʊ | ɜ | ʊ | ɜ | tone |
| B-3 | ɜ | ɛ | ʊ | ʊ | ɜ | tone |
| B-4 | ɛ | ɜ | ʊ | ɜ | ʊ | tone |
| B-5 | ɜ | ɜ | ɛ | ɛ | ʊ | tone |
| B-6 | ʊ | ɜ | ɜ | ʊ | ɛ | tone |
| B-7 | ɛ | ɜ | ʊ | ɛ | ʊ | tone |
| B-8 | ʊ | ɛ | ɛ | ɜ | ɜ | tone |
| B-9 | ʊ | ʊ | ɜ | ɜ | ɛ | tone |

APPENDIX E
(continued)

Six Item Vowel List A (with suffix)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A-1 | ʒ | ʊ | ɛ | ʊ | ɛ | ʒ | go |
| A-2 | ɛ | ɛ | ʒ | ʊ | ʒ | ʊ | go |
| A-3 | ʒ | ɛ | ʒ | ʊ | ɛ | ʊ | go |
| A-4 | ɛ | ʒ | ʊ | ʒ | ʊ | ɛ | go |
| A-5 | ʒ | ɛ | ɛ | ʊ | ʒ | ʊ | go |
| A-6 | ʊ | ʊ | ɛ | ʒ | ɛ | ʒ | go |
| A-7 | ʊ | ɛ | ʒ | ɛ | ʊ | ʒ | go |
| A-8 | ɛ | ʊ | ʊ | ʒ | ʒ | ɛ | go |
| A-9 | ʊ | ʒ | ʊ | ʒ | ɛ | ɛ | go |

Six Item Vowel List B (with control tone)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B-1 | ʒ | ʊ | ɛ | ʒ | ʊ | ɛ | tone |
| B-2 | ɛ | ʊ | ʒ | ɛ | ʊ | ʒ | tone |
| B-3 | ʒ | ɛ | ʊ | ɛ | ʊ | ʒ | tone |
| B-4 | ɛ | ʒ | ʊ | ɛ | ʒ | ʊ | tone |
| B-5 | ʒ | ʒ | ɛ | ʊ | ɛ | ʊ | tone |
| B-6 | ʊ | ʒ | ʒ | ɛ | ʊ | ɛ | tone |
| B-7 | ɛ | ʒ | ʊ | ʒ | ɛ | ʊ | tone |
| B-8 | ʊ | ɛ | ɛ | ʊ | ʒ | ʒ | tone |
| B-9 | ʊ | ʊ | ʒ | ɛ | ʒ | ɛ | tone |

APPENDIX F

Four Item CVC Lists C (with suffix)

| | | | | | |
|---|---|---|---|---|---|
| C-1 | tʊp | tɛp | tʃp | tʊp | go |
| C-2 | tʊt | tʊt | tɛt | tʃt | go |
| C-3 | tɛp | tɛp | tʊp | tʃp | go |
| C-4 | kɛp | kʊp | kʃp | kʊp | go |
| C-5 | kɛp | kʃp | kɛp | kʊp | go |
| C-6 | tʃt | tɛt | tʊt | tʃt | go |
| C-7 | tʃp | tʊp | tɛp | tɛp | go |
| C-8 | tʃt | tʃt | tʊt | tɛt | go |
| C-9 | kʊp | kʃp | kʃp | kɛp | go |

Four Item CVC Lists D (with control tone)

| | | | | | |
|---|---|---|---|---|---|
| D-1 | kʊp | kʊp | kʃp | kɛp | tone |
| D-2 | kɛp | kʃp | kʊp | kʃp | tone |
| D-3 | tʃt | tʃt | tʊt | tɛt | tone |
| D-4 | tɛp | tʊp | tʃp | tʊp | tone |
| D-5 | tʃp | tʊp | tɛp | tʊp | tone |
| D-6 | kʊp | kɛp | kʃp | kɛp | tone |
| D-7 | tɛp | tɛp | tʊp | tʃp | tone |
| D-8 | tʃt | tɛt | tɛt | tʊt | tone |
| D-9 | tʊt | tʃt | tɛt | tʃt | tone |

APPENDIX F

(continued)

Five Item CVC Lists C (with suffix)

| | | | | | | |
|---|---|---|---|---|---|---|
| C-1 | tʊp | tɛp | tɛp | tʃɔp | tʊp | go |
| C-2 | tʊt | tʊt | tʃɔt | tɛt | tʃɔt | go |
| C-3 | tɛp | tɛp | tʊp | tʊp | tʃɔp | go |
| C-4 | kɛp | kʊp | kɛp | kʃɔp | kʊp | go |
| C-5 | kɛp | kʃɔp | kʃɔp | kɛp | kʊp | go |
| C-6 | tʃɔt | tɛt | tɛt | tʊt | tʃɔt | go |
| C-7 | tʃɔp | tʊp | tʃɔp | tɛp | tɛp | go |
| C-8 | tʃɔt | tʃɔt | tʊt | tʊt | tɛt | go |
| C-9 | kʊp | kʃɔp | kʊp | kʃɔp | kɛp | go |

Five Item CVC Lists D (with control tone)

| | | | | | | |
|---|---|---|---|---|---|---|
| D-1 | kʊp | kʊp | kɛp | kʃɔp | kɛp | tone |
| D-2 | kɛp | kʃɔp | kɛp | kʊp | kʃɔp | tone |
| D-3 | tʃɔt | tʃɔt | tʊt | tʊt | tɛt | tone |
| D-4 | tɛp | tʊp | tʃɔp | tʃɔp | tʊp | tone |
| D-5 | tʃɔp | tʊp | tʃɔp | tɛp | tʊp | tone |
| D-6 | kʊp | kɛp | kʊp | kʃɔp | kɛp | tone |
| D-7 | tɛp | tɛp | tʃɔp | tʊp | tʃɔp | tone |
| D-8 | tʃɔt | tɛt | tʊt | tɛt | tʊt | tone |
| D-9 | tʊt | tʃɔt | tɛt | tɛt | tʃɔt | tone |

APPENDIX F

(continued)

Six Item CVC Lists C (with suffix)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C-1 | tʊp | tɛp | tɛp | tʃp | tʃp | tʊp | go |
| C-2 | tʊt | tʊt | tʃt | tɛt | tɛt | tʃt | go |
| C-3 | tɛp | tɛp | tʊp | tʃp | tʊp | tʃp | go |
| C-4 | kɛp | kʊp | kɛp | kʃp | kʃp | kʊp | go |
| C-5 | kɛp | kʃp | kʃp | kʊp | kɛp | kʊp | go |
| C-6 | tʃt | tɛt | tɛt | tʊt | tʊt | tʃt | go |
| C-7 | tʃp | tʊp | tʃp | tʊp | tɛp | tɛp | go |
| C-8 | tʃt | tʃt | tʊt | tɛt | tʊt | tɛt | go |
| C-9 | kʊp | kʃp | kʊp | kɛp | kʃp | kɛp | go |

Six Item CVC Lists D (with control tone)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| D-1 | kʊp | kʊp | kɛp | kʃp | kʃp | kɛp | tone |
| D-2 | kɛp | kʃp | kɛp | kʊp | kʊp | kʃp | tone |
| D-3 | tʃt | tʃt | tʊt | tɛt | tʊt | tɛt | tone |
| D-4 | tɛp | tʊp | tʃp | tɛp | tʃp | tʊp | tone |
| D-5 | tʃp | tʊp | tʃp | tɛp | tɛp | tʊp | tone |
| D-6 | kʊp | kɛp | kʊp | kʃp | kʃp | kɛp | tone |
| D-7 | tɛp | tɛp | tʃp | tʊp | tʊp | tʃp | tone |
| D-8 | tʃt | tɛt | tʊt | tʃt | tɛt | tʊt | tone |
| D-9 | tʊt | tʃt | tɛt | tʊt | tɛt | tʃt | tone |

APPENDIX G

Four Item CVC List E / Vowels Held Constant (with suffix)

| | | | | | |
|---|---|---|---|---|---|
| E-1 | tɛt | tɛp | tɛp | kɛp | go |
| E-2 | tɔ́p | tɔ́t | tɔ́t | kɔ́p | go |
| E-3 | tɛ́p | kɛp | tɛ́t | tɛ́t | go |
| E-4 | kɛp | tɛt | kɛp | tɛp | go |
| E-5 | tʊt | tʊp | tʊp | kʊp | go |
| E-6 | kɔ́p | tɔ́p | tɔ́p | tɔ́t | go |
| E-7 | tʊp | tʊt | kʊp | tʊt | go |
| E-8 | kʊ́p | kʊ́p | tʊ́t | tʊ́p | go |
| E-9 | tɔ́t | kɔ́p | kɔ́p | tɔ́p | go |

Four Item CVC List F / Vowels Held Constant (with tone)

| | | | | | |
|---|---|---|---|---|---|
| F-1 | kɛ́p | tɛp | tɛp | tɛ́t | tone |
| F-2 | tʊt | kʊp | tʊp | kʊp | tone |
| F-3 | tʊ́p | tʊp | kʊ́p | tʊ́t | tone |
| F-4 | tɔ́t | tɔ́p | kɔ́p | tɔ́t | tone |
| F-5 | kʊ́p | tʊ́t | tʊ́t | tʊ́p | tone |
| F-6 | tɛ́p | kɛp | tɛ́t | kɛ́p | tone |
| F-7 | kɔ́p | tɔ́t | tɔ́p | kɔ́p | tone |
| F-8 | tɔ́p | kɔ́p | tɔ́t | tɔ́p | tone |
| F-9 | tɛt | tɛ́t | kɛ́p | tɛp | tone |

APPENDIX G

(continued)

Five Item CVC Lists E / Vowels Held Constant (with suffix)

| | | | | | | |
|---|---|---|---|---|---|---|
| E-1 | tɛt | tɛp | tɛt | tɛp | kɛp | go |
| E-2 | tʃp | tʃt | tʃp | tʃt | kʃp | go |
| E-3 | tɛp | kɛp | kɛp | tɛt | tɛt | go |
| E-4 | kɛp | tɛt | tɛp | kɛp | tɛp | go |
| E-5 | tʊt | tʊp | kʊp | tʊp | kʊp | go |
| E-6 | kʃp | tʃp | tʃt | tʃp | tʃt | go |
| E-7 | tʊp | tʊt | kʊp | kʊp | tʊt | go |
| E-8 | kʊp | kʊp | tʊt | tʊt | tʊp | go |
| E-9 | tʃt | kʃp | tʃp | kʃp | tʃp | go |

Five Item CVC Lists F / Vowles Held Constant (with control tone)

| | | | | | | |
|---|---|---|---|---|---|---|
| F-1 | kɛp | tɛp | tɛt | tɛp | tɛt | tone |
| F-2 | tʊt | kʊp | tʊp | tʊp | kʊp | tone |
| F-3 | tʊp | tʊp | kʊp | kʊp | tʊt | tone |
| F-4 | tʃt | tʃp | kʃp | kʃp | tʃt | tone |
| F-5 | kʊp | tʊt | tʊp | tʊt | tʊp | tone |
| F-6 | tɛp | kɛp | tɛt | tɛt | kɛp | tone |
| F-7 | kʃp | tʃt | tʃp | tʃp | kʃp | tone |
| F-8 | tʃp | kʃp | tʃt | tʃt | tʃp | tone |
| F-9 | tɛt | tɛt | kɛp | kɛp | tɛp | tone |

APPENDIX G

(continued)

Six Item CVC Lists E / Vowels Held Constant (with suffix)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| E-1 | tɛt | tɛp | tɛt | kɛp | tɛp | kɛp | go |
| E-2 | tɜ́p | tɜ́t | tɜ́p | kɜ́p | tɜ́t | kɜ́p | go |
| E-3 | tɛp | kɛp | kɛp | tɛp | tɛt | tɛt | go |
| E-4 | kɛp | tɛt | tɛp | tɛt | kɛp | tɛp | go |
| E-5 | tʊt | tʊp | kʊp | tʊt | tʊp | kʊp | go |
| E-6 | kɜ́p | tɜ́p | tɜ́t | kɜ́p | tɜ́p | tɜ́t | go |
| E-7 | tʊ́p | tʊ́t | kʊ́p | tʊ́p | kʊ́p | tʊ́t | go |
| E-8 | kʊ́p | kʊ́p | tʊ́t | tʊ́p | tʊ́t | tʊ́p | go |
| E-9 | tɜ́t | kɜ́p | tɜ́p | tɜ́t | kɜ́p | tɜ́p | go |

Six Item CVC Lists F / Vowels Held Constant (with control tone)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F-1 | kɛp | tɛp | tɛt | kɛp | tɛp | tɛt | tone |
| F-2 | tʊt | kʊp | tʊp | tʊt | tʊ́p | kʊ́p | tone |
| F-3 | tʊ́p | tʊ́p | kʊ́p | tʊ́t | kʊ́p | tʊ́t | tone |
| F-4 | tɜ́t | tɜ́p | kɜ́p | tɜ́p | kɜ́p | tɜ́t | tone |
| F-5 | kʊ́p | tʊ́t | tʊ́p | kʊ́p | tʊ́t | tʊ́p | tone |
| F-6 | tɛp | kɛp | tɛt | tɛp | tɛt | kɛp | tone |
| F-7 | kɜ́p | tɜ́t | tɜ́p | tɜ́t | tɜ́p | kɜ́p | tone |
| F-8 | tɜ́p | kɜ́p | tɜ́t | kɜ́p | tɜ́t | tɜ́p | tone |
| F-9 | tɛt | tɛt | kɛp | tɛp | kɛp | tɛp | tone |

APPENDIX H

Four Item Practice Lists-Letters

| | | | | |
|---|---|---|---|---|
| 1) | A | G | D | A |
| 2) | D | D | A | G |
| 3) | A | D | D | G |
| 4) | D | A | G | D |
| 5) | A | D | A | G |
| 6) | G | G | D | A |
| 7) | G | D | G | A |
| 8) | D | G | A | D |
| 9) | G | A | D | D |

Five Item Practice Lists-Letters

| | | | | | |
|---|---|---|---|---|---|
| 1) | A | G | G | D | A |
| 2) | D | D | A | A | G |
| 3) | A | D | G | D | G |
| 4) | D | A | G | G | D |
| 5) | A | D | D | A | G |
| 6) | G | G | D | D | A |
| 7) | G | D | A | G | A |
| 8) | D | G | A | A | D |
| 9) | G | A | A | D | D |

Six Item Practice Lists-Letters

| | | | | | | |
|---|---|---|---|---|---|---|
| 1) | A | G | G | D | D | A |
| 2) | D | D | A | G | A | G |
| 3) | A | D | G | A | D | G |
| 4) | D | A | G | A | G | D |
| 5) | A | D | D | G | A | G |
| 6) | G | G | D | A | D | A |
| 7) | G | D | A | D | G | A |
| 8) | D | G | A | G | A | D |
| 9) | G | A | A | G | D | D |

APPENDIX I

University of Wisconsin Madison

**CENTER FOR HEALTH SCIENCES**
Human Subjects Committee

H6/273
Clinical Science Center
600 Highland Avenue
Madison, WI 53792
(608) 263-2362

NOTICE OF APPROVAL

Meeting Date October 5, 1981 Protocol Number 81-840-216

TO: Susan Mirowski
505 Conklin Place #16
Madison, WI

FROM: Ellen Frautschi
Program Coordinator

RE: Protocol entitled, "The Development of Auditory Memory in Children at Different Stages of Normal Language Development"

The Human Subjects Committee has reviewed and approved the research protocol referenced above. Please note the following additional information:

INSTITUTIONAL ENDORSEMENT: If notification of HSC approval is required by a granting agency, the name and address of the agency should be submitted to the Program Coordinator.

ADVERSE REACTIONS: If an unexpected adverse reaction should develop as a result of this study, you must notify the Program Coordinator of the HSC immediately.

AMENDMENTS: If you wish to change any aspect of the study [such as design, procedures, consent form(s), subject population, or principal investigator(s)], please submit your requested changes, using Change of Protocol forms, to the Program Coordinator of the HSC. The new procedure is not to be initiated until HSC approval has been given.

TERMINATION OF RESEARCH PROJECT: Investigators are requested to notify the HSC of the termination of a project.

RENEWAL: You are required to apply for renewal of approval every year. Federal agencies, such as NIH, require reapproval at yearly intervals. Contact the HSC office for renewal forms.

CONSENT FORMS: All subjects should be given a copy of the consent form(s).

The HSC suggests that you keep this memo with your copy of the approved protocol.

10-7-81

EKF:jfs

APPENDIX J

Grouped Means and Standard deviations of total number of recall errors made in each serial position during nine trials.

| | First Grade Subjects | Third Grade Subjects | Fifth Grade Subjects | Adult Subjects |
|---|---|---|---|---|
| MEAN | 5.373 | 5.115 | 4.937 | 2.996 |
| S.D. | 2.033 | 1.856 | 2.031 | 2.211 |

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