THE VALIDITY OF THE DICHOTIC LISTENING TECHNIQUE AS A MEASURE OF HEMISPHERIC SPECIALIZATION IN MALE POOR AND AVERAGE READERS

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A Thesis

in

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Arts at
Concordia University
Montreal, Québec, Canada

May, 1976

ABSTRACT

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The present study investigated the validity of the dichotic listening technique as a measure of hemispheric specialization in male poor and average readers. The reading groups each consisted of 24 predominantly right-handed fourth-grade boys, matched according to median and range of age and memory, and differentiated by reading ability. Subjects were given two presentations of four dichotic tests which differed in amount of material. The findings were that recall performance varied directly with reading ability and presentation, varied inversely with amount of material, and was better for the right than for the left ear. Right ear recall increased with practice, as did the proportion of right ear starts, whereas left ear recall did not change. First ear minus second ear recall scores varied directly with mean recall for the two ears combined. When the two reading groups were artificially matched on mean recall for the two ears combined, the first ear minus second ear recall scores were higher for poor than for average readers. The results of the present investigation were interpreted as indicating that differences in left-right response asymmetries between reading groups on dichotic listening tests do not reflect differential degrees of hemispheric specialization as had been suggested by previous literature. Rather, the differences between reading groups seem to reflect differences in ear of first report, in performance levels, and in short-term memory between the reading groups.

ACKNOWLEDGEMENTS

This research was supported in part by a team research grant from the Province of Quebec (Formation de Chercheurs d'Action Concertée - Dr. D. White).

I would like to thank my supervisor, Dr. Tannis Maag, and the members of my thesis committee -- Drs. Stanley Munoz, Campbell Perry, and Nancy Taylor for their help and advice. Sincere thanks are also extended to Mrs. Pamela Neblett for typing the thesis, Ken Louden for helping to prepare the dichotic tapes, and to Wayne Arnold for his help and encouragement in many phases of the work.

I wish to express my appreciation to the students, teachers, and principals (John Fiorito of Eugenio Pacelli, Raymond Blanchard of Our Lady of Consolata II, Gordon Bacchi of Francesca Cabrini) and Dr. Alice St. James of the Montreal Catholic School Commission, who made this study possible.

I would also like to express sincerest thanks to my parents, Mr. and Mrs. Dayton Searle, for their patience, encouragement and support during the entire time of my graduate studies.

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Children who are equally privileged in those attributes which would seem obviously to affect reading ability (such as intelligence, memory, educational opportunity, and socio-economic background), often in fact differ in their ability to read. It has been hypothesized that this reading difficulty may be caused by a developmental lag in the functional specialization of the hemispheres of the brain (Critchley, 1970; de Hirsh, 1968; Money, 1966). Various researchers have tried to compare poor and average readers in terms of degree of cerebral lateralization, using a technique called dichotic listening (Sparrow, 1968; Taylor, 1962; Zurif & Carson, 1970). Left-right response asymmetries in dichotic listening have been interpreted as reflecting the different roles of the two hemispheres of the brain in mediating linguistic information (Bryden, 1967; Kimura, 1967). In dichotic listening studies involving reading ability, these left-right asymmetries have been used as an index of degree of hemispheric specialization (Sparrow, 1968; Taylor, 1962; Zurif & Carson, 1970). Shankweiler and Liberman (1972), reviewing this literature, have reported that despite the widespread belief that delayed lateralization is a factor in reading disability the various studies of dichotic listening have reported a mixture of positive and negative results, with the majority finding no significant relation between dichotic listening asymmetry and reading disability. The purpose of the present study was to investigate the validity of the dichotic listening method as a measure of degree of cerebral lateralization in good and poor readers.

Clinical literature on the lateralization of brain function, reviewed by Basser (1962), suggests that in the first few years of human life control of speech and verbal information is represented equally in both hemispheres of the brain. Clinical evidence from persons who have suffered brain damage in adulthood indicates that, in later life, speech and verbal information are represented in only one hemisphere. Tests using the sodium amytal technique to inhibit brain function unilaterally (Branch, Milner & Rasmussen, 1964), have demonstrated that nearly all right-handed adults, and slightly less than fifty percent of left handers, have speech function located in the left hemisphere. Specifically, Arnold (1973) reported a personal communication from Milner that, using the sodium amytal technique, 92 percent of her right handed patients (n = 95) were found to be left-hemispheric dominant for speech while 49 percent of her left handers (n = 87) were found to have left hemispheric specialization. (The remaining left-handers had speech function in the right hemisphere). Lenneberg (1967) has argued, primarily on the basis of clinical evidence, that language lateralization begins to develop in the preschool years and becomes complete by the early teens.

The suggestion that children with reading difficulties may be subject to a developmental lag in hemispheric specialization stems primarily from the observation that the hand, eye and foot preferences of children with learning difficulties are not as consistent as those of normal children. For example, Orton (1937) noted uncertain handedness in children with learning problems. Zangwill (1960) reported

that a disproportionately large number of learning-handicapped children are left-handed. Money (1966), de Hirsh (1968) and Critchley (1970) reported that children described as having developmental dyslexia exhibit the same constellation of problems as adults with left-hemispheric brain damage. Silver and Hagin (1960) found evidence of incomplete cerebral dominance and neurological abnormalities in reading-disabled children.

In recent years several studies have used dichotic listening tests in an attempt to measure degree of lateralization. This test consists of presenting simultaneously to the subject two pieces of information, one to each ear. The subject is asked to repeat immediately all the information that he/she can remember, and the procedure is repeated with new signals. These "signals" or stimuli may be verbal information (i.e. spoken digits, letters, syllables, etc.) or nonverbal sounds (e.g. dogs barking, musical tones, etc.). In dichotic tests using verbal stimuli it has been observed that the number of signals presented to the right ear and correctly reported was usually larger than the number of correct left ear reports (Bryden, 1970; Geffner & Hochberg, 1971; Kimura, 1963; 1967; Knox & Kimura, 1970). This phenomenon, which is common to the majority of normal right-handed subjects, has been called the "right ear advantage" (REA) or "right ear effect". The simplest way of measuring the degree of REA is to take the "difference score", that is, the subject's score for his right ear minus the score for his left ear. The difference score may be normalized or corrected for total score in various ways. Any

quantity so obtained is called a "right-ear-advantage index"; some workers have, with questionable justification, referred to these as "laterality indices".

The REA in verbal dichotic tests has been interpreted as resulting from the well-known left-hemispheric specialization in processing of verbal auditory information (Curry, 1967; Kimura, 1961a; 1967). This interpretation is consistent with the evidence demonstrating that the contralateral pathways between the ear and cortex are more efficient than the ipsilateral pathways (Bocca, Calearo, Cassinari & Migliavacco, 1955). It is therefore natural to postulate a close relationship between REA on dichotic tests and language lateralization. Kimura (1961b) gave verbal dichotic tests to patients whose speech representation had been directly measured by the sodium amytal test (Branch, Milner & Rasmussen, 1964), and found that the right-ear advantage for verbal materials is associated with left-hemispheric speech lateralization. Corroborating evidence was obtained by Curry (1967) and Curry and Rutherford (1967) who studied the relationship between handedness of subject and verbal dichotic listening performance. They found that right-handers showed a consistent and significant REA, as one would expect from the fact that their speech function is normally located in the left hemisphere; left handers exhibited results ranging from a strong left-ear advantage to a strong right-ear advantage, as one would expect from the fact that their speech is nearly equally likely to be represented in the left or the right hemisphere.

Some researchers hypothesize further that dichotic tests may be used to measure degree of language lateralization, in particular for purposes of diagnosing potential reading difficulties in children. Verification of this hypothesis has been attempted by two approaches: studies of dichotic performance explicitly involving groups differing in reading ability, and studies tending to confirm the general relationship between degree of REA and degree of speech lateralization.

In the first category are the studies of Taylor (1962), Sparrow (1968), Zurif and Carson (1970) and Arnold (1973). Three of these studies have reported a REA in the majority of subjects but a larger REA in the better readers. This difference in the REA scores was seldom significant, but did appear with some consistency. (The seeming tendency of the better readers to exhibit larger REA scores will be referred to as the "reading ability trend").

The line of reasoning of the second group of studies can be outlined as follows. The reader will recall that the two conspicuous patterns regarding speech lateralization are: 1) that right-handed adults are normally left-hemispherically lateralized for speech; and 2) that the degree of speech lateralization apparently increases with increasing age from the preschool years to the early teens (Lenneberg, 1967). Now the data from dichotic listening tests using verbal information have shown clear differences between right-handed and left-handed subjects (Curry, 1967; Curry & Rutherford, 1967) as described above. Thus if degree of right-ear advantage could be shown to vary appropriately with age, it would be entirely plausible that

it measures degree of speech lateralization.

Research comparing children of different ages has been sparse and the results have been varied. Kimura (1963, 1967), Knox and Kimura (1970), and part of a study by Geffner and Hochberg (1971) found that the right-ear advantage decreased with increasing age, which of course is exactly the opposite of what would have been predicted. Geffner and Hochberg (1971) in another part of their study did find the right-ear advantage increasing with age when lower socio-economic class children were considered. All of these studies used one- to three-digit pairs as their stimuli. Orlando (1971), using one-syllable pairs as his stimuli, found that the REA increases with age. Furthermore, Bryden (1970) using two- and three-digit pairs, found that the percentage of children manifesting a REA increased with age.

To understand these seemingly contradictory results, it must be realized that performance on a dichotic test may be influenced by several factors which were not controlled or corrected for in the studies cited above. Among these factors, two of the most important are the choice of order for reporting information and the difficulty of the task.

Bryden (1963) showed that when information is presented dichotically at a rate of two pairs of signals per second, most subjects prefer to report all the material delivered to one ear before giving any from the other ear. This phenomenon, known as the "ear order of report", has been noted in many other studies (Inglis, 1965; Inglis

and Sykes, 1967; Witelson & Rabinovitch, 1971) and is generally accepted by all workers in the field.

It was further noted (Bartz, Satz & Fennel, 1967; Bryden, 1962; 1967; Witelson & Rabinovitch, 1971) that the majority of right-handed subjects prefer the right ear as the ear of first report. However certain other studies (Inglis & Ankus, 1965; Satz, Achenbach, Pattishall & Fennel, 1965) failed to find any consistent tendency to report the right ear first. Bartz, Satz, Fennel and Lally (1967) have found that the nature of the words employed as stimuli affects the choice of which ear to report first.

For purposes of the following discussion, let R_1 denote the relative frequency of correct report by the right ear if reporting first. It should be noted here that a relative frequency score always refers to

$$\frac{\text{number of signals reported correctly}}{\text{total number of signals presented}}$$

Thus for example R_1 represents

$$\frac{\text{number of letters correctly reported by the right ear as a first reporter}}{\text{number of letters presented to the right ear in items for which the right ear was the ear of first report.}}$$

Similarly let L_1 = the relative frequency of report by left ear if reporting first, R_2 = relative frequency of correct report by right ear if reporting second, and L_2 = relative frequency of correct report by left ear if reporting second.

Inglis and Sykes (1965) found that the ear of first report, whether it was the left or the right ear, always had a higher score

than the ear of second report. That is, they found that $R_1 > L_2$ and $L_1 > R_2$. Since all REA indices which have been used to date are variations of the quantity "right ear score minus left ear score", it is apparent that REA indices on a particular test will be greatly affected by the subject's choice of starting ear.

Bryden (1967) replicated the findings of Inglis and Sykes (1967) that $R_1 > L_2$ and $L_1 > R_2$, but also convincingly showed that $R_1 > L_1$ and $R_2 > L_2$. Therefore, although starting ear certainly has some effect on REA, it is not the only factor in determining REA.

There has been only one study involving age differences or reading ability which has explicitly investigated the influence of reporting sequence on REA. Geffner and Hochberg (1971) found that one group of subjects manifested REA indices increasing with age; in that same group there was an increase with age of the tendency to report the right ear first. In another group of the same study, they found that the subjects manifested REA indices decreasing with increasing age; in this latter group there was a decrease with age of the tendency to report the right ear first.

The above results of Inglis and Sykes (1965), Bryden (1967) and Geffner and Hochberg (1971) make clear the danger of obtaining artificial trends in REA in studies which do not control or correct for the ear of first report.

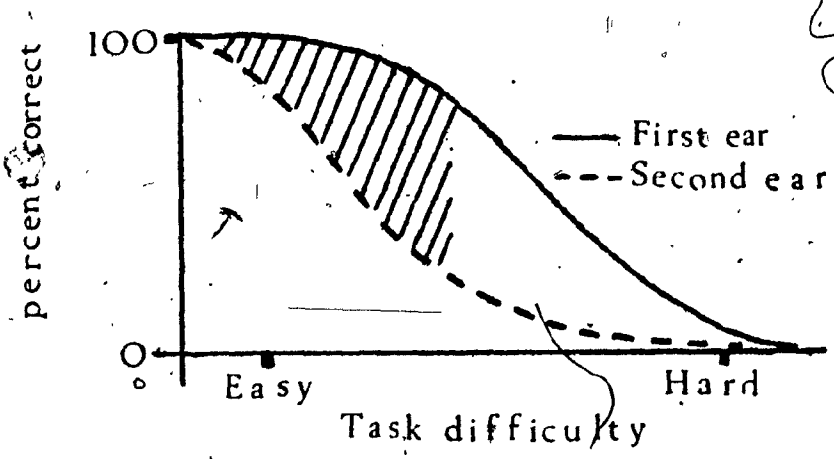
The second and more subtle confounding factor is that of relative task difficulty. In simplest terms the dependence of REA on task difficulty might be described in the following way.

Let us first assume for the sake of simplicity that the right ear is always reported first. If the material is very difficult, then neither ear will be able to report much (in the extreme case, each ear will score zero) and therefore the REA will be very small or zero. If the material is very easy then both ears will score perfectly, giving again a REA of zero. In the intermediate region, the findings of Inglis and Sykes (1965) that $R_1 > L_2$ and $L_1 > R_2$ would place the first-ear curve always above the second-ear curve, thus giving a diagram similar to Figure 1 (a).

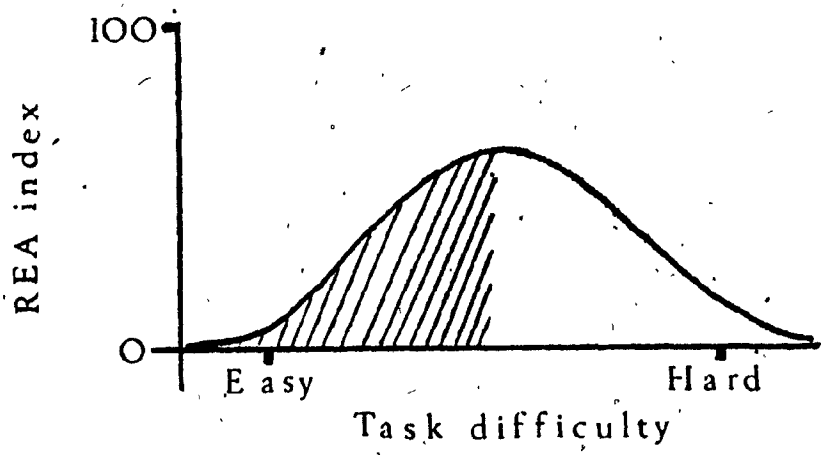
It may be noted that if the difficulty level of a task used in a dichotic listening experiment lay entirely within the shaded region, the data would show REA increasing with difficulty. Similarly if the task difficulty level fell within the non-shaded region of Figure 1 (a) the data would show REA decreasing with increasing difficulty (Figure 1 (b)).

The argument above has been based on the assumption of a right starting ear in all reports. If instead the left ear is always chosen as the ear of first report, then one will obtain a negative REA varying with difficulty as in Figure 1 (c). In the usual case, the subject chooses sometimes the right ear and sometimes the left ear as ear of first report. The trend of REA with difficulty is then a combination of these above simple models; the exact nature of the trend will depend on the relative proportion of right- and left-ear starts.

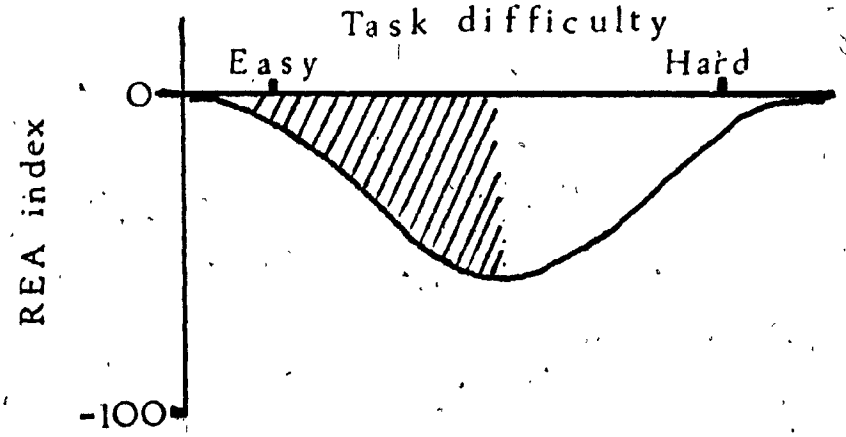
It should be noted that when one varies subjects' age,



(a) First and Second Ear Scores as a Function of Difficulty.



(b) REA as a Function of Difficulty for all Right Ear Starts.



(c) REA as a Function of Difficulty for all Left Ear Starts.

Figure 1. Possible dependence of REA on task difficulty.

reading ability, IQ etc., then the task difficulty relative to the subject will also vary. For example, a given set of stimuli will probably be more difficult for very young children than for older ones, for less intelligent subjects than for more intelligent ones, and so on. Inglis and Sykes (1967) and Bryden (1970) have noted that overall score increases with age and moreover that the second ear reported showed a larger increase with age than the first ear. Bryden pointed out that if one assumed a vast majority of right ear starts the decrease in REA with increasing age found in the Kimura (1963) study could have reflected a larger increase in left ear score than in right ear score with age. Figure 2 presents a hypothetical graph of how the performance of the first and second ear reported might vary with age. The Kimura (1963) study is thus assumed to lie in the shaded region of Figure 2 and the right and left ears are assumed to be the first and second ear reported respectively.

It is suggested that, in studies involving variables which could indirectly change the difficulty of the dichotically presented materials, measures should be introduced to control or examine the effects of these changes on REA. Subject variables that might produce different levels of difficulty include age, reading ability, memory, IQ, sex and socio-economic status. Stimulus variables that might affect difficulty are amount of material per dichotic string, rate of presentation, type of content (digits, letters, words etc.), mode of report (recognition or recall) and practise.

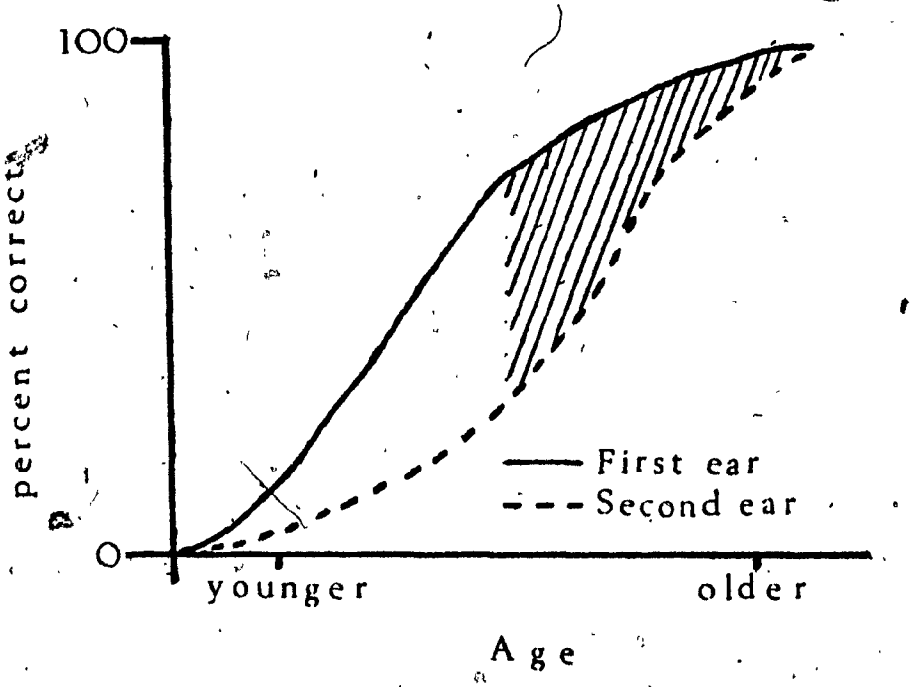


Figure 2. Possible effects of age variation on the performance levels of first and second ears reported (for fixed set of stimuli).

The present investigation was an attempt to study the effects of ear of first report and difficulty of stimuli on the REAs of a group of average and a group of poor readers. In order to provide tasks of differing levels of difficulty within each group, all subjects were presented with two-, three-, four-, and five-letter dichotic pairs. This variation of the amount of material in each item will be referred to simply as "amount" variation. In addition, the tests were each presented twice, in order to examine the effects of practice.

Ear of first report was examined as a function of reading ability, amount, and practice, as were the REA indices $R_1 - L_2$ and $R_2 - L_1$. (The reader will recall that the index $R_1 - L_2$ is simply the REA for those items where the right ear reports first; $R_2 - L_1$ is the REA for those items where the left ear reports first). Total recall scores for each ear were also examined as a function of reading ability, amount and presentation.

In summary, the present study was designed to evaluate two alternative hypotheses. The one hypothesis is that a reading ability trend exists, and that the failure to demonstrate it consistently in past research has been due to the confounding effects of ear of first report and/or of relative task difficulty. The alternative hypothesis is that no true reading ability trend exists, but that in some studies a trend appears to exist due to one or both of these two confounding variables.

Method

Materials and Apparatus

The reading comprehension subtest of the Canadian Test of Basic Skills, the digits-forward subtest of the Wechsler Intelligence Scale for Children, and the ten hand-preference items of the Harris Tests of Lateral Dominance (Harris, 1957) were used to classify subjects as to reading ability, memory span, and handedness respectively.

The Harris Test consisted of ten activities to be acted out. A score of 10 was assigned for activities performed by the right hand, 5 when no preference was demonstrated and 0 for tasks using the left hand. The scores for the ten items were then summed, yielding the subject's total score. A minimum score of 0 indicated strong left-handedness whereas a maximum score of 100 indicated strong right-handedness.

The experimental materials were four sets of dichotic stimuli. Each set contained 10 items. Each item of the "2-set" of stimuli consisted of two pairs of letters. The items of the "3-, 4-, and 5-set" consisted of three, four and five pairs of letters respectively.

The overall test consisted of three dichotic practice items, each made up of three pairs of letters, followed by two presentations of the four sets of stimuli. Each presentation consisted of the ten items of a given set, which were repeated for the two presentations of the set. Preceding each item by one second was a digit presented to both ears which acted as a warning signal. The letters were presented at a rate of 2 per second. Each

item was followed by a blank period to allow the subjects to respond. The blank period was 11, 12, 13, or 14 seconds for the 2-, 3-, 4-, and 5-sets respectively. The increase in the duration of the blank period for the longer sets was based on pilot work which had indicated that subjects needed more time to respond as amount increased.

The consonants, c, h, j, k, l, q, r, s, v, and x were used, this choice being made because of the phonetic distinctness and clarity of the letters. Individual letters were chosen from the letter pool at random without replacement until enough were drawn for one item. The unused letters were then selected at random without replacement for the next item. In the event that the number of unused letters was insufficient to complete an item, the letters necessary to complete the item were selected at random without replacement from a new letter pool composed of all the letters not already used in that item. This procedure ensured that no letter was duplicated in any one item and that all letters appeared with approximately equal frequency in the set of items.

The first half of the letters for each item were then placed on one channel of a dual channel tape recorder, to the beat of a metronome set at two beats per second. Then, simultaneously monitoring the recorded channel and the channel being recorded, the second half of each item was placed on the second channel. This taping procedure was performed by an accomplished musician. Tests on the completed tapes using sensitive recording meters showed that the channels were well matched for onset and offset of the stimuli

as well as for amplitude.

The items thus obtained were then transferred to a master tape and incorporated into the previously described format. The master tape was presented to subjects by means of a dual channel tape recorder (Revox, Type 77A) and stereophonic earphones (Classonic, Model MD-802B).

Subjects

A total of 118 grade-four boys, in three elementary schools in a lower middle class urban area under the Montreal Catholic School Commission, were screened for reading ability using the Canadian Test of Basic Skills. Since testing was done in April the actual grade level of the students at the time of testing was 4.8. During the screening all students who wrote with their left hands were eliminated from further testing.

Two groups of 24 poor and 24 average readers plus alternates were then formed. All subjects were tested individually with the WISC digits-forward test and were either selected or rejected on the basis of their memory scores. A running record of median and range of memory scores was kept for both groups after half the subjects had been tested in each group. Whenever a subject's memory score was not suitable for keeping the range and median of the groups matched, the subject was dismissed from further testing and replaced with an alternate. One average reader with a score of 6 was replaced by an average reader with a score of 5. Five poor readers with scores of 4 and 5 were replaced by subjects with scores of 6 and 7.

When subjects had been assigned by reading and memory scores, they were tested for handedness. No subjects had to be rejected due to handedness. The results of the hand-preference subtest of the Harris Tests of Lateral Dominance indicated that the subjects in this investigation were predominantly right-handed. Thirty-five subjects obtained scores of 100; four, scores of 95; and nine scores of 90. Harris (1957) classified scores of 100 as strong right-handedness and scores of 75-95 as moderate right-handedness.

Table 1 presents the median and range of scores of the average and poor readers on the various measures, and includes the grade level performance equivalent to the median and range standard scores on reading ability. The average and poor readers did not differ significantly with respect to age or memory span. The average readers of course differed from the poor readers in reading ability at a highly significant level. Thus two groups, each consisting of 24 predominantly right-handed fourth grade boys, were obtained, matched according to median and range of age and memory, and differentiated by reading ability.

The subjects in this study had no apparent auditory deficits or uncorrected visual deficiencies, and no subject showed any motor impairments. Since all three schools were located in the same lower middle-class area, it was assumed that the groups were reasonably well matched on academic opportunity.

Design

The basic design was a 2 x 2 x 2 x 4 factorial with the

Table 1

Median and Range Scores on Memory, Age and Reading Ability With the Equivalent Grade Level Performance for the Average and [redacted] Reading Boys

		Average Readers	Poor Readers
Reading Ability*	Median	35	15.5
		(4.7)	(2.65)
	Range	27 - 61	3 - 18
		(4.1) - (6.1)	(1.6) - (3.0)
Age in Months	Median	122	123
	Range	113 - 121	116 - 132
Memory	Median	6	6
	Range	4 - 9	4 - 9

*Actual grade level at time of screening was 4.8

( ) Equivalent grade level performance

first factor, reading ability, being varied between subjects and the latter 3 factors, amount, practise, and ear involving repeated measures. The sequence in which the 4 conditions of amount were presented was counterbalanced across subjects within reading groups but was constant for a given subject for the two presentations. For half the subjects in each reading group channel 1 of the tape was presented to the right ear and channel 2 to the left ear on the first presentation; while for the other half of the subjects the channel-ear relations were switched. On the second presentation all subjects received the opposite channel-ear relation from the one experienced on the first presentation. Porter and Berlin (1975) pointed out, in an article published after the testing for the present study was completed, that the acoustic parameters of dichotic stimuli have an effect on the results of dichotic tests. However, reversing the earphones between subjects and between presentations controlled for any systematic effects due to potential differences in acoustic parameters between the stimuli going to one ear versus those going to the other ear. The use of the various counterbalancing procedures balanced practice, fatigue, ear and channel effects and controlled possible biasing effects of these variables on the results.

Procedure

The subjects were tested individually in one session They were told to report as many of the letters as they could and that guessing was permitted. No dichotic test was administered

until the subject was able to identify correctly some of the letters from each channel of the dichotic practice items. The experimenter recorded the letters precisely as reported by the subjects for later scoring. For each of the dichotic tests the score for each ear was the number of letters identified correctly by that ear regardless of temporal sequence.

Results

Table 2 presents the proportion of right ear starts as a function of amount, presentation and reading ability. The proportions were submitted to an arcsin transformation and a 3-way analysis of variance (Reading Ability x Amount x Presentation) was performed using the method of Murdock and Ogilvie (1968). The only statistically significant effect was the main effect for presentation, $F(1, \infty) = 3.85$, $p < .05$, with a larger proportion of right ear starts on Presentation 2 ($\bar{X} = .605$) than on Presentation 1 ($\bar{X} = .529$).

Table 3 presents the percent recall scores for each ear for the different amount and presentation conditions of the dichotic test battery for average and poor readers. The raw scores were converted to percent scores in order to compare performance in the different amount conditions, and a 4-way analysis of variance (Reading Ability x Amount x Presentation x Ear) was performed. A significant main effect was obtained for reading ability, $F(1, 46) = 8.22$, $p < .05$, with the average readers correctly recalling more information ($\bar{X} = 51.0\%$) than the poor readers ($\bar{X} = 45.3\%$).

The effect for amount was highly significant, $F(3, 138)$

Table 2

Proportion of Right Ear Starts as a Function of Reading Ability, Amount and Presentation

Reading Ability	Amount	Presentation 1	Presentation 2
Poor	2-pair	.454	.625
	3-pair	.508	.592
	4-pair	.542	.629
	5-pair	.529	.550
Average	2-pair	.563	.579
	3-pair	.517	.625
	4-pair	.575	.592
	5-pair	.545	.650

Table 3

Mean Percent Recall[a] For Each Ear as a Function of Reading Ability, Amount and Presentation

Reading Ability	Amount	Presentation 1		Presentation 2		Mean	
		R ear	L ear	R ear	L ear	R ear	L ear
Poor	2-pair	53.8	54.8	64.4	49.6	59.1	52.2
	3-pair	47.8	39.3	51.3	40.8	49.5	40.1
	4-pair	43.6	38.6	49.2	37.1	46.4	37.9
	5-pair	38.1	37.1	43.4	35.8	40.8	36.5
	Mean	45.8	42.5	52.1	40.8	48.9	41.6
Average	2-pair	65.2	53.5	69.6	63.5	67.4	58.5
	3-pair	51.8	45.6	59.6	44.6	55.7	45.1
	4-pair	44.8	42.9	56.0	41.4	50.4	42.1
	5-pair	46.3	39.6	52.6	39.6	49.4	39.6
	Mean	52.0	45.4	59.4	47.3	55.7	46.3

[a]Maximum raw score per ear for each presentation condition with two pairs is 20, with three pairs 30, with four pairs 40 and with five pairs 50.

= 109.01, $p < .001$. A post hoc trend analysis was performed. The linear trend was highly significant, F (1, 138) = 70.81, $p < .001$, with recall decreasing with increasing amount. The quadratic trend was also significant, F (1, 138) = 9.10, $p < .001$, with the rate of decrease in recall becoming less with an increase in amount. Figure 3 gives the mean percent recall scores underlying the linear and quadratic trends.

The effect for presentation was also highly significant, F (1, 46) = 33.62, $p < .001$, with recall lower on Presentation 1 ($\bar{X}$ = 46.4%) than on Presentation 2 ($\bar{X}$ = 49.9%). Finally, the main effect for ear was highly significant, F (1, 46) = 16.46, $p < .001$, with recall by the right ear ($\bar{X}$ = 52.3%) better than recall by the left ear ($\bar{X}$ = 44.0%).

There was one significant two-way interaction, the Presentation x Ear interaction, F (1, 46) = 5.19, $p < .05$. The Tukey Test, (Winer, 1962), applied to means of this interaction, indicated that the right ear recall on Presentation 2 ($\bar{X}$ = 55.7%) was significantly ($p < .01$) better than the right ear recall on Presentation 1 ($\bar{X}$ = 48.9%). Left ear recall did not differ significantly for the two presentations, the means being 43.9% and 44.1% for Presentation 1 and Presentation 2 respectively.

The only other significant interaction was the 4-way interaction, Reading Ability x Amount x Presentation x Ear, F (3, 138) = 3.46, $p < .05$. The nature of this interaction is shown graphically in the eight panels of Figure 4. It appears that the

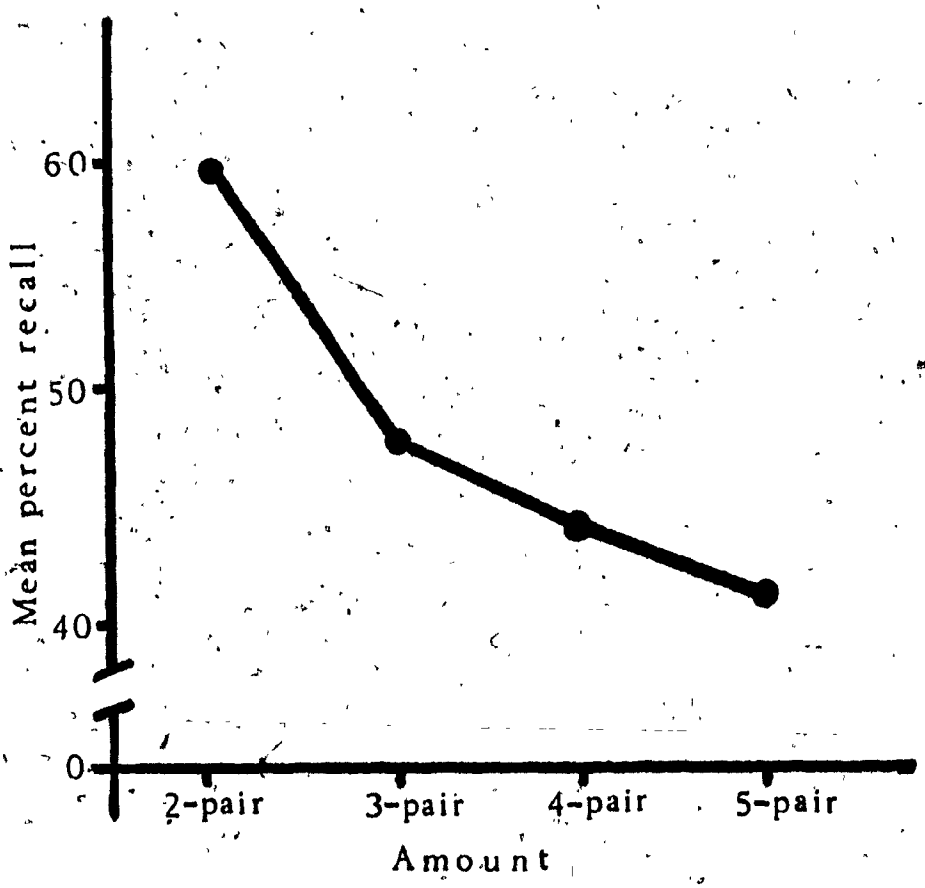


Figure 3. Mean percent recall as a function of amount.

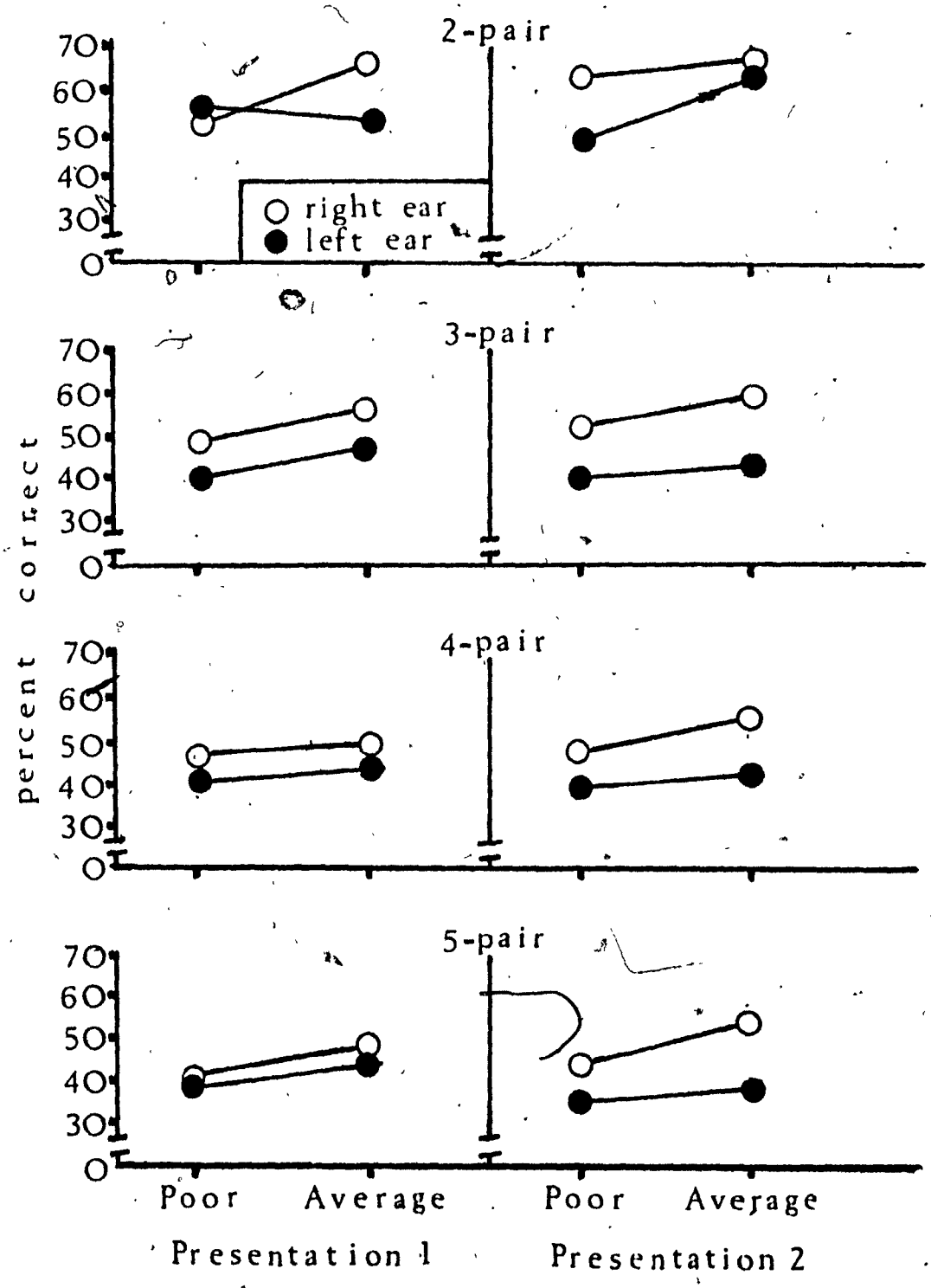


Figure 4. Reading ability x Presentation x Ear interaction as a function of amount.

performance in the 2-pair condition is dissimilar to that for all other conditions of amount, and that furthermore the performance in the 2-pair condition goes in opposite directions on the two presentations. Specifically, in the 2-pair condition on Presentation 1, average readers recall much more information from the right ear than do poor readers, while the poor readers recall slightly more information from the left ear than do average readers. On Presentation 2, the average readers are only slightly better than the poor readers in right ear performance but are considerably better than the poor readers in left ear performance. For all other amount conditions at both presentations, the data reflect simply the overall main effects of ear and reading ability.

Table 4 presents the REA (percent recalled by the right ear minus percent recalled by the left ear) for reports begun with the right ear as a function of reading ability, amount and presentation. The raw scores were converted to percent scores in order to compare performance in the different amount conditions. An analysis of variance (Reading Ability x Amount x Presentation) indicated that the main effect for amount was significant, F (3, 138) = 9.63, $p < .001$. A post hoc trend analysis indicated the linear trend was significant, F (1, 138) = 13.81, $p < .001$, with the REA decreasing with increasing amount ($\bar{X}_2$= 37.0%, $\bar{X}_3$ = 35.0%, $\bar{X}_4$ = 27.8%, $\bar{X}_5$ = 24.8%).

Table 5 presents the REA scores for reports begun with the left ear as a function of reading ability, amount and presentation. It should be noted that REA is positive when produced from the data

Table 4

REA[a] For Right Ear Starts as a Function of Reading Ability, Amount and Presentation

Reading Ability	Amount	Presentation 1	Presentation 2
Poor	2-pair	37.9	42.2
	3-pair	33.8	35.4
	4-pair	28.0	30.7
	5-pair	21.8	27.9
Average	2-pair	37.0	30.8
	3-pair	34.4	36.3
	4-pair	22.2	30.3
	5-pair	22.5	26.9

[a]Percent recalled by right ear minus percent recalled by left ear

Table 5

REA[a] For Left Ear Starts as a Function of Reading Ability, Amount and Presentation

Reading Ability	Amount	Presentation 1	Presentation 2
Poor	2-pair	-35.3	-24.7
	3-pair	-29.6	-33.6
	4-pair	-22.4	-21.4
	5-pair	-20.9	-16.7
Average	2-pair	-29.1	-23.5
	3-pair	-22.5	-24.4
	4-pair	-21.9	- 9.6
	5-pair	-13.3	-15.0

[a]Percent recally by right ear minus percent recalled by left ear

where the right ear was reported first, and negative when coming from the data where the left ear was reported first. This indicates that the ear reported first is vastly superior in accuracy to the ear reported second.

An analysis of variance (Reading Ability x Amount x Presentation) of the REA scores for reports begun by the left ear indicated that the main effect for amount was significant, F (3, 138) = 8.72, $p < .001$. A post hoc trend analysis indicated the linear trend was significant, F (1, 138) = 14.44, $p < .001$, with the REA becoming less negative with increasing amount ($\bar{X}_2 = -28.2\%$, $\bar{X}_3 = -27.6\%$, $\bar{X}_4 = -18.8\%$, $\bar{X}_5 = -16.5\%$).

In summary, the present study investigated the performance of average and poor readers on four dichotic tests, differing in the amount of information to be processed, each test presented twice. The data indicated a direct relationship between reading ability and recall efficiency, and an inverse relationship between amount of material and recall efficiency. The right ear was in general better at recalling information than the left ear. Right ear recall improved from Presentation 1 to Presentation 2, whereas the left ear performance remained at the same level on both presentations except for the average readers at the 2-pair condition of amount where the left ear recall did improve with practice.

It was further shown that the proportion of right ear starts increased from Presentation 1 to Presentation 2. Reading ability and amount had no effect on the proportion of right ear

starts.

The REA index $R_1 - L_2$ that is REA for reports begun with the right ear, was found to decrease with increasing amount, but was not affected by reading ability, practise, or any combination of these three factors. Analogous findings emerged for reports begun with the left ear: that is the index $R_2 - L_1$ increased from more negative to less negative values with increasing amount.

Discussion

The results of this investigation indicate that when consonants are presented dichotically, normal right-handed boys are able to recall significantly more of the information presented to the right ear than that presented to the left ear. Previous studies on groups of normal right-handed children have also demonstrated a right-ear superiority of recall for verbal dichotic stimuli such as digits (Kimura, 1963; Knox & Kimura, 1970; Bryden, 1970) and words (Sommers & Taylor, 1972). Thus the present study replicated the typical right-ear superiority for the dichotic auditory processing of verbal information. The fact that this study did find the REA usually found with verbal dichotic materials indicates that the particular stimulus materials used in this study were for all practical purposes representative of those which have been used in previous research.

The results of the present study fail to indicate the existence of a reading ability trend. Recall of material presented to the right ear significantly exceeded recall of material presented

to the left ear regardless of level of reading ability. The finding of a REA for average readers is, of course, in keeping with the results of the majority of studies. The finding of an REA for poor readers is consistent with a recent study by Yeni-Komshian, Isenberg and Goldberg (1975), but contradicts Taylor (1962), Sparrow (1968) and Zurif and Carson (1970).

This appears to be the only study involving reading ability which closely examined the influence of starting ear on the results. Since this study did not find the reading ability groups differing in ear of first report and furthermore found no reading ability trend, it might be argued that the presence of a reading ability trend is dependent on the presence of a difference in starting ear preferences between reading groups. As already pointed out, although some studies have observed differences in REA between good and poor readers, these differences were seldom significant (Shankweiler & Liberman, 1972). It is possible that the differences that were found were artifacts of a difference in choice of starting ear. This contention is supported by the study of Yeni-Komshian et al (1975). They controlled for ear of first report by instructing subjects as to which ear to report first, and found no difference in REA between their groups. Further support for this notion comes from a study by Witelson (1962). She found a group of children with noticeable language difficulties showing a left ear advantage, while her control group showed a right ear advantage. Her experimental group showed a significantly smaller number of right ear starts.

The present study lends further support to the argument of strong dependence of REA on ear of first report. The REA became larger with practice because the right ear recall improved with practice while the left ear performed at the same level on both presentations. This increase in REA was associated with an increase of right ear starts with practice. It may also be noted that the only experimental condition where a left ear advantage was observed was also the only situation where less than half of the reports were begun with the right ear. This result occurred on the first presentation of the 2-pair amount to the poor readers.

The results of the present investigation indicated that average readers reported a significantly larger percentage of information than did poor readers. Previous studies have also demonstrated superior performance by better readers than poorer readers in identifying dichotic information (Arnold, 1973; Yeni-Komshian et al., 1975; Zurif & Carson, 1970).

It could be argued that the differential abilities of the average and poor readers in recalling auditory information are associated with differences in attention or motivation. However, on the two presentations of the dichotic tasks both the average and the poor readers obtained higher recall scores on Presentation 2 compared to Presentation 1, whereas one would expect that, if attention or motivation were a factor in the poorer performance of the poor readers, there would have been a tendency for their performance to deteriorate rather than improve over what was a relatively

long testing session.

Thus, the finding that the reading groups differed in their ability to recall auditory information would appear to reflect true differences in their capacities to master tasks requiring the recall of letters presented dichotically. In order to explore the implications of these performance differences for REA as a measure of differential lateralization, the relation between total recall and REA was examined more closely.

The present study found that the larger the amount of material the lower the mean percent recall for the two ears combined (recall performance). First ear minus second ear recall scores ($R_1 - L_2$ and $L_1 - R_2$) also decreased with increasing amount, or in other words first ear minus second ear recall decreased with decreasing recall performance. Since the poor readers' recall performance was not as good as that of the average readers on the tasks in this study it would be expected by analogy to the findings with amount that first ear minus second ear recall scores would be smaller for poor than for average readers. The results, however, showed that the groups were statistically equal on this measure. It is possible that the difference in recall performance between the reading groups could have obscured true differences in first ear minus second ear recall scores of the reading groups. Therefore it is conceivable that if recall performance were artificially equated for poor and average readers, the first ear minus second ear recall scores would have been larger for poor than for average readers.

The recall performance of each reading group was computed for each of the amount by presentation conditions. These scores ranged from 37.6% to 57.0% for the poor readers and from 44.0% to 66.6% for the average readers. It can be seen that the ranges of performance scores of the two reading groups overlap betwen 44.0% and 57.0%. By plotting first ear minus second ear recall scores for each reading group against recall performance for each amount by presentation condition it is possible to compare the first ear minus second ear recall scores of the two reading groups at equal levels of recall performance. Figure 5 presents such a graph for right ear starts and Figure 6 is a similar graph for left ear starts.

It can be seen from Figure 5 and 6 that first ear minus second ear recall scores were larger for poor than for average readers at each level of recall performance. With this fact in mind, consider again the hypothesis that poor readers have a developmental lag in hemispheric specialization. Based on this hypothesis and assuming that dichotic tests measure degree of hemispheric specialization, one would expect, for example, that the first ear minus second ear recall scores for average readers would be larger than those for poor readers when recall performance was equal for the two groups and only right ear starts were considered. As Figure 5 shows, however, the results were just the opposite. Therefore, when one equates for recall performance, the data of this study do not support the hypothesis of developmental lag in hemispheric specialization of poor readers. It would seem either that dichotic tests are not sensitive

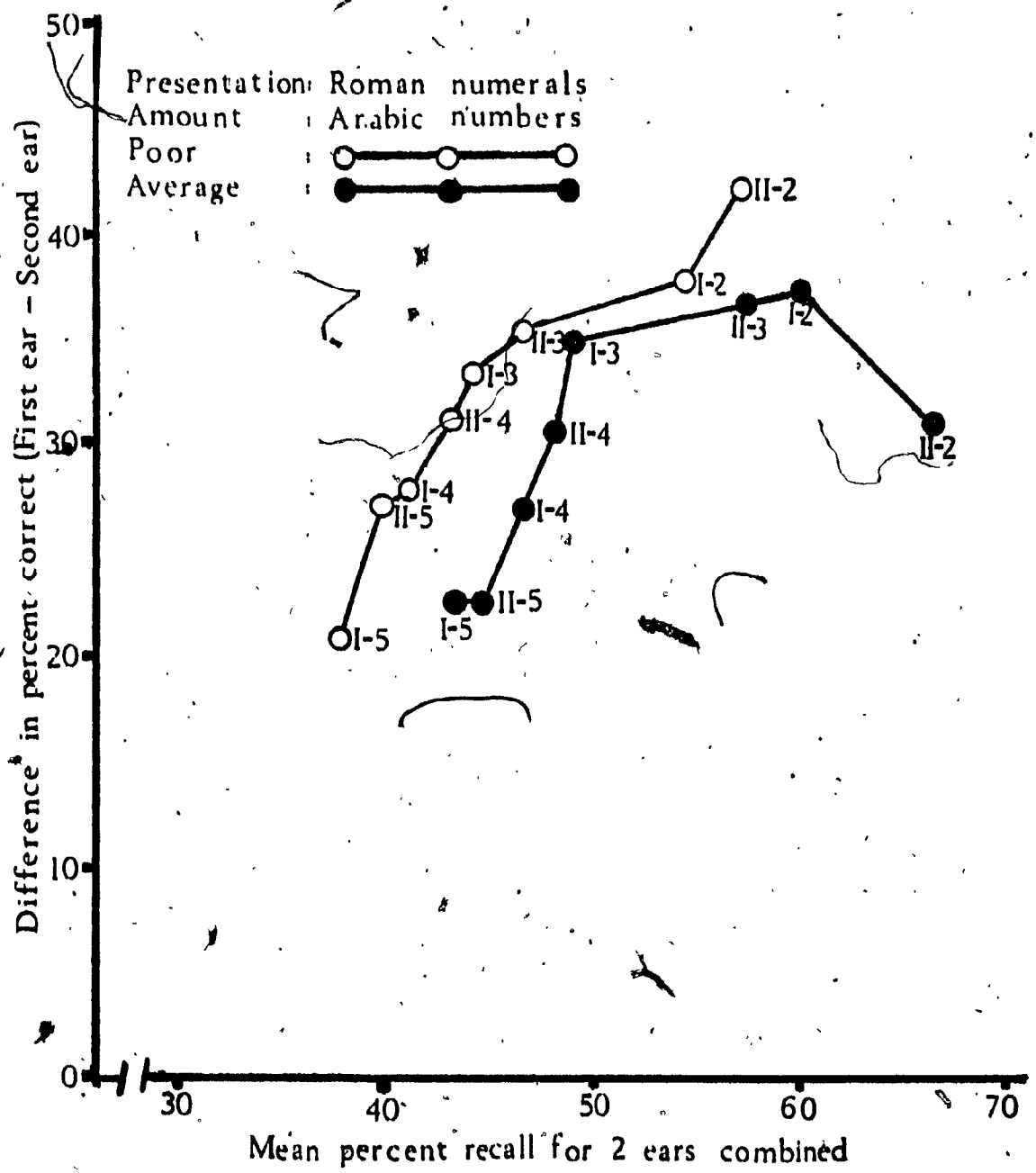


Figure 5. Difference in % correct (first ear - second ear) as a function of mean% recall for 2 ears combined (for right ear starts).

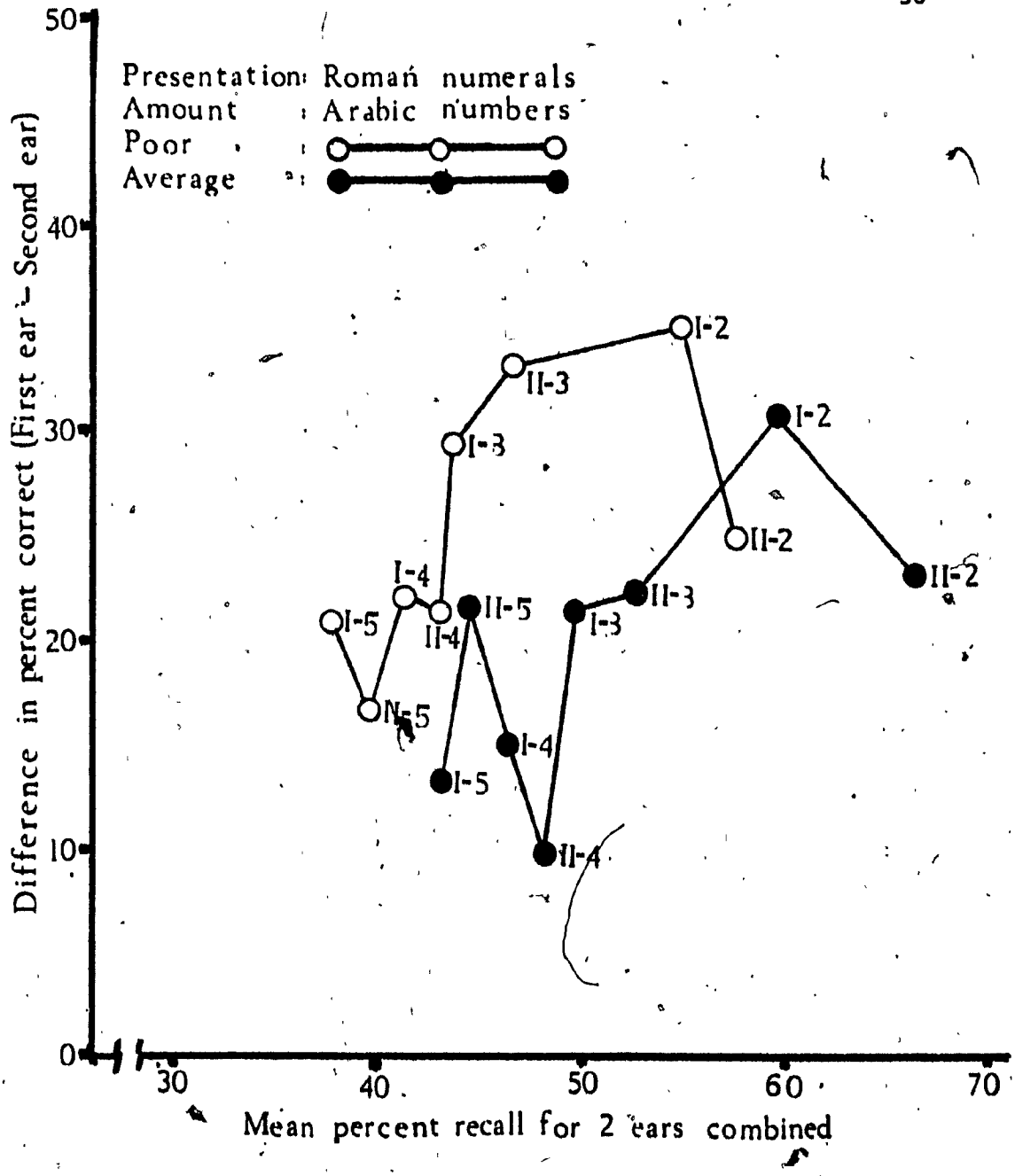


Figure 6. Difference in % correct (first ear - second ear) as a function of mean % recall for 2 ears combined (for left ear starts).

enough to measure degree of lateralization or that reading groups do not differ in degree of lateralization.

Figure 5 and 6 show that first ear minus second ear recall scores were larger for poor readers than for average readers at equal levels of recall performance. When the groups were compared on identical tasks, with recall performance being lower for the poor than for the average readers first ear minus second ear recall scores were equal for the groups. Therefore it is reasonable to conclude that differences in first ear minus second ear recall scores between reading groups tend to vary with differences in recall performance between reading groups. For right ear starts first ear minus second ear recall scores is identical to REA, while for left ear starts REA is obviously second ear minus first ear. In either sense, however, it is clear from Figure 5 and 6 that the magnitude of the relative REA for the two reading groups with starting ear held constant, will depend on their relative recall performance. If the data from the present study are generalizable, it follows that the inconsistent differences in REA between reading groups found in previous studies could have been caused by differences in recall performance between reading groups having varied from study to study.

One can speculate that the poorer overall recall of poor readers and the fact that the first ear minus second ear recall scores were larger for poor than for average readers when equated for level of recall performance reflected a poorer memory for poor readers than for average readers. A dichotic item may be thought

of as a single trial serial list with letters reported by the first ear coming from the beginning of the list and letters reported by the second ear coming from the end of the list. As already pointed out subjects tend to report the signals from one ear before reporting any of the signals from the other ear (Bryden, 1963; Inglis, 1965; Inglis & Sykes, 1967; Witelson & Rabinovitch, 1971). According to a study by Jahnke (1963) on the ordered recall of items after a single trial, differences in memory load, manipulated by varying series length, tend to be reflected more by differences in middle and late list items than in differences in recall of early list items. Thus it is reasonable to conclude that a memory difference between poor and average readers could have accounted for the difference in recall performance between the groups and for the differences in first ear minus second ear recall scores between the reading groups when their scores were compared at equal levels of recall performance.

The difficulty with a memory deficit explanation is that the two reading groups were matched for memory by the WISC digits-forward test. However, it is possible that difficulties in encoding and/or retrieval specifically for letters in poor readers may have caused them to show a memory deficit on the dichotic tests even though they were equated with average readers for memory on the digits-forward task. The rate of presentation of information and the competitiveness of presentation of information were both greater on the dichotic tests than on the digits-forward task, and could have

produced a memory deficit on the former task even though none was found on the latter.

The present study suggests that future research using dichotic listening must take into account the factors of ear of first report and differences in performance levels between any groups under consideration. The finding of a difference between the reading groups in short-term memory as measured by dichotic tasks even though they were matched for memory on the WISC digits-forward test bears further investigation. It is suggested that the difference in rate of presentation, differences in competitiveness of presentation and the differences in stimulus materials between the two memory measures be considered.

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Appendix A

Scores on Reading Ability, Age, and Memory

Reading Ability

Standard Scores on the Comprehension Subtest of the Canadian Test of Basic Skills

Subject	Average Readers	Poor Readers
1	31	14
2	29	18
3	29	17
4	28	14
5	34	14
6	53	18
7	31	17
8	40	11
9	44	17
10	29	18
11	27	14
12	42	14
13	38	18
14	37	16
15	44	17
16	47	3
17	42	17
18	29	10
19	38	13
20	36	15
21	27	14
22	27	16
23	33	14
24	61	18

Age in Months

Subject	Average Readers	Poor Readers
1	121	118
2	124	130
3	131	118
4	120	123
5	129	137
6	124	126
7	119	120
8	122	126
9	113	128
10	129	118
11	130	125
12	122	123
13	117	123
14	124	128
15	125	116
16	124	123
17	121	123
18	123	124
19	120	123
20	117	132
21	119	125
22	119	118
23	119	122
24	124	116

Memory

Digit-Forward Scores on the WISC

Subject	Average Readers	Poor Readers
1	6	6
2	5	4
3	6	6
4	5	5
5	6	5
6	6	6
7	6	7
8	7	5
9	8	5
10	4	4
11	7	9
12	7	8
13	7	7
14	7	6
15	7	7
16	7	7
17	6	6
18	5	6
19	5	6
20	9	6
21	7	7
22	5	5
23	6	7
24	7	7

Appendix B

Instructions

Instructions for Dichotic Tests

I would like you to listen to this tape. On the tape you will hear a number followed by some letters. Listen very carefully to the letters. When they are finished I want you to tell me as many of the letters as you can. You may repeat the letters in any order that you like. You will hear some letters in one ear and some different letters in the other ear. Try to tell me all of the letters. It is OK to guess. (Play 3 practice trials - if some letters are given correctly from each ear on each trial, continue. Repeat trials which did not meet the criterion of at least one correct letter from each ear.)

Appendix C

Raw Data

Performance of Individual Subjects

Poor Readers
2-Pair Amount
Presentation 1

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	4	6	11	12	5	9
2	1	9	12	15	2	15
3	2	7	14	9	4	8
4	2	7	4	11	2	11
5	6	3	10	5	9	3
6	3	7	7	13	3	10
7	2	8	14	17	3	15
8	2	8	10	14	2	13
9	3	7	6	15	4	13
10	4	6	8	8	5	8
11	7	3	12	7	10	4
12	7	3	16	11	13	4
13	4	6	14	13	6	8
14	2	8	5	14	2	12
15	4	6	10	15	7	7
16	3	8	5	10	3	10
17	7	3	10	3	8	3
18	5	5	15	10	9	7
19	2	8	6	10	3	9
20	10	0	19	12	19	0
21	8	2	14	7	13	3
22	7	3	11	7	11	5
23	7	3	13	14	12	4
24	7	3	15	14	12	5

[a]These columns give the number of reports begun with each ear.

[b]These columns give the total number of letters correctly reported by each ear.

[c]These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Poor Readers
3-Pair Amount
Presentation 1

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	5	5	11	16	8	10
2	3	7	11	21	6	17
3	7	3	18	15	15	6
4	0	8	4	13	0	13
5	8	2	21	10	18	3
6	5	4	11	10	10	7
7	1	9	13	23	1	20
8	2	8	6	14	2	14
9	1	9	4	16	2	16
10	5	5	10	7	9	6
11	6	4	15	11	11	6
12	4	5	17	14	9	11
13	6	4	19	17	13	9
14	5	5	14	9	11	8
15	2	8	8	20	4	19
16	5	5	7	10	6	9
17	5	4	12	9	8	6
18	8	2	18	6	17	3
19	6	4	15	12	11	7
20	9	0	25	6	25	0
21	5	5	15	12	11	7
22	10	0	18	4	18	0
23	10	0	23	6	23	0
24	4	6	17	17	10	12

[a]These columns give the number of reports with each ear

[b]These columns give the total number of letters correctly reported by each ear

[c]These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
4-Pair Amount
Presentation 1

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	5	5	18	16	14	16
2	5	5	16	19	10	19
3	4	6	15	22	10	22
4	1	9	8	26	1	26
5	5	5	19	17	12	17
6	3	7	18	20	5	20
7	2	8	14	22	4	22
8	1	9	12	21	2	21
9	3	7	10	22	4	22
10	4	6	11	14	7	14
11	1	9	14	18	2	18
12	3	6	17	17	8	17
13	9	1	20	10	19	10
14	7	3	18	13	14	13
15	6	4	17	15	18	15
16	9	1	23	7	22	7
17	8	2	13	12	12	12
18	9	1	27	4	24	4
19	5	5	14	15	10	15
20	9	1	27	10	27	10
21	9	1	23	13	20	13
22	6	4	17	12	14	12
23	8	2	23	10	21	10
24	8	2	21	17	18	17

[a]These columns give the number of reports with each ear

[b]These columns give the total number of letters correctly reported by each ear

[c]These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
5-Pair Amount
Presentation 1

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	6	4	20	20	19	13
2	4	6	20	23	11	16
3	5	5	19	27	13	17
4	2	8	8	22	3	18
5	7	3	27	16	20	8
6	5	4	13	12	9	7
7	5	4	24	28	15	17
8	1	9	10	29	2	28
9	4	6	15	21	11	17
10	4	6	18	14	8	11
11	7	3	21	18	17	8
12	4	6	19	22	9	16
13	6	4	18	21	14	9
14	7	3	26	18	20	6
15	4	6	21	22	13	16
16	6	4	21	11	16	9
17	4	6	11	14	6	10
18	8	2	22	10	20	3
19	6	4	21	15	14	7
20	8	2	25	14	21	2
21	8	2	25	20	20	5
22	5	5	13	17	11	12
23	4	3	11	8	9	5
24	7	3	25	22	20	8

[a]These columns give the number of reports with each ear

[b]These columns give the total number of letters correctly reported by each ear

[c]These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
2-Pair Amount
Presentation 2

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	6	4	12	9	8	6
2	7	3	13	13	10	6
3	8	2	13	13	13	3
4	7	3	11	6	10	4
5	9	1	14	9	14	1
6	6	4	12	8	8	5
7	7	3	17	11	12	4
8	9	1	17	5	16	1
9	8	1	13	4	12	1
10	8	2	11	6	11	2
11	3	7	6	11	4	10
12	8	2	15	13	12	3
13	7	3	14	13	10	4
14	4	6	8	11	6	10
15	2	8	13	18	4	15
16	4	5	9	7	6	6
17	3	7	10	9	4	8
18	9	1	18	14	17	1
19	5	5	11	7	8	6
20	8	2	18	9	15	3
21	4	6	15	11	7	8
22	4	6	8	10	6	9
23	7	3	17	10	12	4
24	5	5	15	13	9	8

[a] These columns give the number of reports with each ear

[b] These columns give the total number of letters correctly reported by each ear

[c] These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
3-Pair Amount
Presentation 2

Subject	Starting Choice[a]		Score[b]		First Score	
	R ear	L ear	R ear	L ear	R ear	L ear
1	6	4	19	10	13	7
2	5	5	17	16	11	10
3	6	4	18	14	12	7
4	6	4	15	7	11	7
5	6	4	14	14	11	7
6	4	6	15	13	9	11
7	9	1	23	10	21	2
8	10	0	19	4	19	0
9	5	5	13	16	11	12
10	8	2	13	8	13	4
11	4	6	13	15	9	14
12	6	4	15	15	10	3
13	7	3	18	13	16	6
14	5	5	14	12	8	7
15	3	7	7	24	4	19
16	6	4	11	6	10	6
17	4	5	11	12	9	9
18	6	4	14	11	12	7
19	6	4	15	12	12	8
20	7	3	18	12	17	8
21	6	4	20	13	14	7
22	2	8	7	17	4	16
23	7	2	17	9	15	4
24	8	2	21	12	17	4

[a] These columns give the number of reports with each ear

[b] These columns give the total number of letters correctly reported by each ear

[c] These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
4-Pair Amount
Presentation 2

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	4	6	21	14	12	10
2	7	3	23	17	19	8
3	6	4	22	17	16	9
4	8	2	26	7	21	3
5	9	1	27	9	25	1
6	6	4	26	16	15	7
7	10	0	28	13	28	0
8	10	0	26	10	26	0
9	6	4	18	22	13	10
10	9	1	20	11	20	2
11	7	3	17	16	15	7
12	9	1	22	17	21	4
13	5	5	14	14	9	9
14	4	6	14	17	8	15
15	2	8	4	30	3	26
16	5	5	13	14	9	11
17	4	6	14	11	6	9
18	5	5	19	13	16	10
19	6	4	19	14	15	9
20	9	1	28	7	26	1
21	6	4	19	18	14	8
22	2	8	9	16	2	15
23	7	3	22	13	18	8
24	5	5	20	23	11	12

[a]These columns give the number of reports with each ear

[b]These columns give the total number of letters correctly reported by each ear

[c]These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Poor Readers
5-Pair Amount
Presentation 2

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	6	4	27	15	19	15
2	4	6	21	22	13	22
3	5	5	23	25	14	25
4	6	4	21	16	15	16
5	8	2	30	16	23	16
6	4	6	19	23	9	23
7	8	2	29	15	25	15
8	7	3	24	7	20	7
9	5	4	20	15	14	15
10	3	7	13	18	6	18
11	3	7	20	23	9	23
12	6	4	28	23	17	23
13	6	4	18	18	13	18
14	3	7	20	22	9	22
15	3	7	10	33	6	33
16	5	5	17	14	11	14
17	4	6	16	16	10	16
18	6	3	21	11	16	11
19	8	2	23	15	20	15
20	9	1	26	13	26	13
21	5	5	20	[illegible]	11	24
22	4	6	15	21	7	21
23	6	4	29	12	19	12
24	8	2	33	20	30	20

[a] These columns give the number of reports with each ear

[b] These columns give the total number of letters correctly reported by each ear

[c] These columns give the score achieved by each ear as a first reporter

Performance of Individual Subjects

Average Readers
2-Pair Amount
Presentation 1

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	7	2	11	8	10	2
2	7	3	17	3	13	3
3	6	3	7	7	7	4
4	9	1	17	4	16	2
5	4	5	14	9	7	7
6	6	4	15	9	10	7
7	7	3	13	12	10	4
8	7	3	20	15	14	5
9	7	3	13	7	11	4
10	7	3	15	12	11	5
11	3	7	8	10	3	9
12	4	6	17	13	7	8
13	7	1	11	6	11	2
14	4	6	11	14	5	10
15	5	5	11	14	8	8
16	4	6	11	14	5	10
17	3	7	14	14	6	12
18	4	5	10	12	7	7
19	5	5	16	14	8	10
20	6	4	12	11	9	5
21	6	4	13	11	9	6
22	3	7	7	14	5	11
23	6	4	15	13	10	5
24	8	2	14	11	13	3

[a]These columns give the number of reports with each ear.

[b]These columns give the total number of letters correctly reported by each ear.

[c]These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
3-Pair Amount
Presentation 1

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	7	3	19	14	14	5
2	3	7	7	18	6	16
3	6	4	12	9	11	6
4	6	2	21	2	18	2
5	5	5	12	11	9	10
6	6	4	22	8	15	7
7	4	6	18	15	8	11
8	5	5	20	13	10	9
9	3	7	10	13	4	11
10	7	3	18	12	14	5
11	4	6	13	11	6	8
12	4	6	13	21	8	14
13	5	5	20	13	12	10
14	7	3	16	13	13	5
15	4	6	15	14	9	12
16	6	4	9	14	8	8
17	6	4	18	18	14	9
18	4	6	12	11	7	8
19	4	6	20	24	9	14
20	3	7	15	17	6	14
21	6	4	19	13	14	8
22	3	7	9	20	5	16
23	6	4	20	13	13	5
24	8	2	15	9	13	4

[a] These columns give the number of reports with each ear.
[b] These columns give the total number of letters correctly reported by each ear.
[c] These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
4-Pair Amount
Presentation 1

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	5	5	17	17	11	9
2	1	9	8	20	3	19
3	5	5	12	11	9	6
4	4	6	22	11	12	8
5	5	4	18	13	12	8
6	7	3	15	21	14	10
7	1	9	15	21	1	20
8	8	2	27	18	23	5
9	4	6	14	22	5	14
10	6	4	18	17	13	11
11	0	10	9	20	0	20
12	6	4	20	21	17	11
13	9	1	27	5	26	2
14	7	3	22	21	17	8
15	8	2	17	13	16	5
16	7	3	21	23	16	9
17	8	2	24	21	20	6
18	7	3	19	17	14	5
19	6	4	21	14	13	8
20	8	2	27	19	23	7
21	8	2	26	19	22	6
22	6	4	13	13	8	5
23	7	3	21	12	14	6
24	5	5	21	19	11	10

[a] These columns give the number of reports with each ear.

[b] These columns give the total number of letters correctly reported by each ear.

[c] These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
5-Pair Amount
Presentation 1

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	7	3	27	17	22	7
2	5	5	21	13	14	10
3	5	5	18	14	13	10
4	10	0	34	6	34	0
5	4	6	23	22	12	17
6	7	3	21	17	18	6
7	6	4	25	16	15	7
8	6	4	32	15	20	10
9	4	6	24	21	11	14
10	4	5	22	18	13	12
11	4	6	19	17	8	11
12	4	6	22	27	12	20
13	10	0	27	18	27	0
14	5	4	23	26	15	16
15	0	10	14	23	0	23
16	3	7	19	30	9	25
17	4	6	27	29	11	20
18	7	3	20	12	17	6
19	7	3	27	30	20	8
20	6	4	21	22	13	10
21	7	3	28	18	20	5
22	3	7	11	27	4	18
23	6	4	26	21	19	11
24	7	3	24	16	20	6

[a] These columns give the number of reports with each ear.

[b] These columns give the total number of letters correctly reported by each ear.

[c] These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
2-Pair Amount
Presentation 2

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	9	1	13	13	12	1
2	8	2	17	11	15	2
3	6	3	12	5	11	4
4	9	1	16	12	15	2
5	7	3	13	12	10	5
6	6	4	15	14	11	7
7	5	5	13	15	7	10
8	8	2	19	17	16	4
9	4	6	9	13	5	9
10	6	4	13	13	11	6
11	9	1	11	9	12	1
12	6	4	17	18	11	7
13	7	3	18	14	13	4
14	3	7	14	17	5	13
15	4	6	12	12	7	10
16	3	7	11	16	5	13
17	6	4	17	17	11	7
18	8	2	17	6	14	2
19	4	6	16	13	7	10
20	2	8	13	14	3	12
21	5	5	14	11	9	6
22	2	8	4	14	2	13
23	5	5	15	10	8	7
24	7	3	15	9	10	4

[a] These columns give the number of reports with each ear.

[b] These columns give the total number of letters correctly reported by each ear.

[c] These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
3-Pair Amount
Presentation 2

Subject	Starting Choice[a]		Score[b]		First Score[c]	
	R ear	L ear	R ear	L ear	R ear	L ear
1	7	3	18	12	17	6
2	7	3	21	9	14	4
3	7	2	10	6	10	3
4	9	1	26	6	24	1
5	7	3	17	9	15	6
6	5	5	21	13	13	9
7	7	3	16	12	12	6
8	9	1	25	12	24	2
9	6	4	14	17	11	10
10	7	3	17	16	15	7
11	7	3	15	6	13	5
12	6	4	18	17	12	10
13	8	3	22	10	18	5
14	4	6	16	15	10	12
15	3	8	15	20	4	18
16	2	8	14	23	4	21
17	6	4	23	21	14	8
18	7	2	15	8	12	3
19	6	4	16	17	9	8
20	5	5	19	17	10	11
21	6	4	19	14	12	9
22	4	6	9	14	5	10
23	8	2	22	13	20	5
24	8	2	21	14	17	4

[a]These columns give the number of reports with each ear.

[b]These columns give the total number of letters correctly reported by each ear.

[c]These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
4-Pair Amount
Presentation 2

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	8	2	27	13	24	4
2	9	1	24	12	22	2
3	6	4	18	12	14	8
4	10	0	29	13	29	0
5	7	3	27	8	20	5
6	6	4	25	13	16	8
7	8	2	26	9	21	2
8	7	3	30	21	22	7
9	7	3	18	21	13	7
10	8	2	25	12	21	5
11	10	0	25	6	25	0
12	4	6	21	18	11	12
13	6	4	25	14	20	12
14	4	6	19	21	10	13
15	2	8	15	22	3	18
16	3	7	19	23	8	19
17	5	5	25	21	16	14
18	4	6	15	18	7	15
19	5	5	22	20	12	9
20	4	6	21	21	11	13
21	3	7	20	21	8	16
22	3	7	15	21	5	15
23	7	3	23	18	18	6
24	6	4	24	19	15	8

[a] These columns give the number of reports with each ear.

[b] These columns give the total number of letters correctly reported by each ear.

[c] These columns give the score achieved by each ear as a first reporter.

Performance of Individual Subjects

Average Readers
5-Pair Amount
Presentation 2

	Starting Choice[a]		Score[b]		First Score[c]	
Subject	R ear	L ear	R ear	L ear	R ear	L ear
1	4	5	27	17	15	11
2	9	1	30	14	28	4
3	7	3	20	12	18	7
4	10	0	33	13	33	0
5	6	4	24	14	12	7
6	6	4	24	24	16	11
7	4	6	20	20	11	14
8	8	2	37	23	29	6
9	4	6	18	21	12	17
10	4	5	22	19	14	12
11	6	4	21	12	16	7
12	2	8	24	27	6	24
13	8	2	29	21	23	6
14	8	2	30	19	25	6
15	6	4	24	22	17	13
16	6	4	24	28	17	15
17	8	2	37	18	33	9
18	5	5	21	15	15	10
19	8	2	29	17	25	5
20	6	4	31	27	18	10
21	8	2	26	24	20	4
22	7	3	22	25	16	8
23	8	2	33	18	27	6
24	8	2	25	25	22	8

[a]These columns give the number of reports with each ear.

[b]These columns give the total number of letters correctly reported by each ear.

[c]These columns give the score achieved by each ear as a first reporter.

Appendix D

Analyses of Variance Source Tables

Source Table for the Analysis of Variance of the Arcsin Transformation of the Proportion of Right Ear Starts Scores as a Function of Reading Ability, Amount and Presentation

Source	df	MS	F
Within Groups			
Reading Ability (RA)	1	.0776	1.86
Presentation (P)	1	.1607	3.85+
Amount (A)	3	.0333	.80
RA x P	1	.1500	3.60
RA x A	3	.0067	.16
P x A	3	.0667	1.60
RA x P x A	3	.0800	1.92
Error		.0417	

+$p < .05$

Source Table for the Analysis of Variance of the Percent Recall Scores of the Right Ear When Reported First Minus the Percent Recall Scores of the Left Ear When Reported Second as a Function of Reading Ability, Amount and Presentation

Source	df	MS	F
Between Groups			
Reading Ability (RA)	1	.0448	.53
Error	46	.0839	
Within Groups			
Amount (A)	3	.3253	9.63++
A x RA	3	.0231	.68
Error	138	.0338	
Presentation (P)	1	.0736	1.43
P x RA	1	.0072	.13
Error	46	.0534	
A x P	3	.0228	.78
RA x A x P	3	.0272	.93
Error	138	.0292	

+ $p < .001$

Source Table of the Analysis of Variance of the Percent Recall Scores of the Right Ear When Reported Second Minus the Percent Recall Scores of the Left Ear When Reported First as a Function of Reading Ability, Amount and Presentation

Source	df	MS	F
Between Groups			
Reading Ability (RA)	1	.3084	3.06
Error	46	.1006	
Within Groups			
Amount (A)	3	.3434	8.72++
A x RA	3	.0091	.23
Error	138	.0394	
Presentation (P)	1	.1035	2.42
P x RA	1	.0008	.02
Error	46	.0428	
A x P	3	.0619	1.28
RA x A x P	3	.0379	.78
Error	138	.0485	

++ $p < .001$

Source Table for the Analysis of Variance of the Percent Recall Scores as a Function of Reading Ability, Amount, Presentation and Ear

Source	df	MS	F
Between Groups			
Reading Ability (RA)	1	.6332	8.22+
Error	46	.0770	
Within Groups			
Amount (A)	3	1.1754	109.01++
A x RA	3	.0083	.77
Error	138	.0108	
Presentation (P)	1	.2323	32.62++
P x RA	1	.0264	3.70
Error	46	.0264	
Ear (E)	1	1.3361	16.46++
E x RA	1	.0213	.26
Error	46	.0811	
A x P	3	.0051	.86
RA x A x P	3	.0034	.56
Error	138	.0059	
A x E	3	.0075	.80
RA x A x E	3	.0073	.78
Error	138	.0094	
P x E	1	.2164	5.19+
RA x P x E	1	.0063	.15
Error	46	.0417	
A x P x E	3	.0060	.40
RA x A x P x E	3	.0519	3.46+
Error	138	.0150	

+ $p < .05$

++ $p < .001$