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To explore the binaural integration abilities of six educable mentally retarded boys (ages 8 to 13) and six normal boys (ages 7 to 12) to detect possible brain injury, an adaptation of Matzker's (1958) technique involving separating words into high and low frequencies was used. One frequency filter system presented frequencies from 425 to 1275 cycles per second (Hz) in one band and 2550 to 6800 Hz in the other; the second system presented frequencies from 637 to 1275 Hz and from 2550 to 5100 Hz. Subjects were asked to repeat 10 words from Thorndike's 1929 word list presented in each of four conditions: high frequencies only, low frequencies only, high and low frequencies to separate ears (integration), and both frequencies to both ears (normal). The integration and binaural normal conditions were the only two conditions useful for assessing auditory integration. The second system produced higher mean errors under each condition, but no significant differences were found between the retarded and normal groups in mean number of errors. Only one retardate and possibly one normal boy were suspected of even minimal brain injury. Suggestions are made for future research. (RP)

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THE BRAIN AS A MIXER, II. A PILOT STUDY OF CENTRAL AUDITORY INTEGRATION ABILITIES OF NORMAL AND RETARDED CHILDREN[1]

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Matzker's (1958) technique for the study of central auditory integration abilities was modified and piloted with 6 normal and 6 retarded children. 2 frequency filter systems were used: System 1 presented frequencies from 425 to 1275 Hz in one band and 2550 to 6800 Hz in the other; System 2 presented frequencies from 637 to 1275 Hz and from 2550 to 5100 Hz.

Ss were asked to repeat 40 words presented under 4 conditions: high frequency pass only, low frequency pass only, high and low frequency stimuli to separate ears simultaneously (binaural integration condition), and both frequency bands to both ears simultaneously (normal binaural conditioning).

Results are presented and discussed relative to methodological problems with the techniques used. Performance under the 4 presentation conditions is compared for the 2 filter pass systems, the type and age of Ss (normal vs. retarded), and the specific word stimuli used.

The diagnosis and localization of brain injury among exceptional children has been the subject of considerable interest (Strauss & Lehtinen, 1947). Matzker (1958) has developed a promising technique to assess the brain's ability to integrate sounds. The approach involves separating a meaningful auditory stimulus (e.g., a word) into its high and low frequencies. Presentation of either the high or low frequencies alone results in an extremely low probability of stimulus recognition. Simultaneous presentation of the two components requires S to integrate the two frequencies centrally--thus increasing the probability of stimulus recognition. Matzker used two filter passes (500-800 Hz and 1815-2500 Hz) without explaining the rationale or criteria for selecting these passes.

Matzker (1958) presented evidence that patients with brain pathology could not integrate two frequency bands presented simultaneously, one to an ear. However, Ss could recognize words when the two frequency bands were presented simultaneously to both ears.

Binaural integration of the elements of simultaneously presented meaningful stimulus is purported to take place in the brain stem where the two auditory pathways from either side are interconnected (Bocca & Calearo, 1963). The brain stem is apparently the source of many contralateral efferent impulses which activate or inhibit peripheral excitability. Normal auditory integration suggests that the synaptic connections in the brain-stem region are intact and functioning. Poor integration may reflect faulty synaptic function within the brain stem. According to Matzker (1958), faulty integration may result from the loss of ganglionic cells within the primary auditory centers, specifically at the level of the cochlear nuclei and of the medial geniculate bodies. As evidence for his hypothesis, he adduces the results of autopsies performed on adults known to have had poor auditory integration abilities.

Harris (1963) used Matzker's technique with normal and brain-injured Ss. In a pilot study of 25 normal and 25 brain-injured children he found a significant difference, but in an expanded study of 70 brain-injured and 96 normal children he found no significant differences in binaural integration.

The purpose of the pilot research here reported was to explore the relative binaural integration abilities of 12 exceptional and normal children. The study differs in three respects from Harris's (1963). First, two different systems of frequency filtering were piloted. Second, Ss were presented with the same words under four conditions: high frequency only, low frequency only, high and low frequencies to separate ears (integration condition), and both frequencies to both ears (normal binaural condition). Finally, stability of responses was assessed through the presentation of the stimulus list over two trials.

Method

Subjects. Ss were six educable mentally retarded (EMR) boys from Wayne County Child Development Center (IQ range 50-80) and six normal boys attending regular public school classes. The chronological age of the EMR Ss was 8 to 13 years ($\bar{X}$ = 10.0). The normal Ss' CA ranged from 7 to 12 ($\bar{X}$ = 8.0). The Ss had no known hearing difficulties and no major articulation problems.

Filtering system. The two frequency filtering systems used were selected from six different filter systems, including the Matzker system. The first step in their selection was to establish a midpoint cutoff

frequency which would produce about equal distortion of both high and low frequency passed speech material. This midpoint frequency was set at 1700 Hz. Various frequency pass bands symmetrically arranged on either side of the 1700 Hz cutoff point were then evaluated by the investigators and the two systems used in the study were adopted.

Figure 1 illustrates the procedure for assembling the final study tape. Unfiltered speech was first passed through two band-pass filters in series, which determined the high and low frequency limits of the speech material according to the filtering system used. This signal was then split and sent through high and low pass filters on separate channels; the result was a high and low band-pass of the test material on either side of the 1700 Hz point. The two signals were balanced for maximum gain and minimum noise through a series of amplifiers and attenuators before passing through a switching system which alternated and combined the signals on the final tape recorder. The final step was to randomize the filtered test material and present it.

Insert Figure 1 about here

Filter System 1 presented frequencies from 425 to 1275 Hz (1-1/2 octaves) in one band and frequencies from 2550 to 6800 Hz (1-1/2 octaves) in the other band. The frequencies from 1275 to 2550 Hz (1 octave with center on 1700 Hz) were filtered out. Filter System 2 used frequencies from 637 to 1275 Hz and from 2550 to 5100 Hz, with the middle frequencies again omitted.

Procedure. Stimulus materials consisted of 10 words from the Thorndike (1929) list of the first thousand most frequently used words. The words chosen offered maximum distortion in each filter system and in the presentation of either high or low frequencies alone. Each word was presented in each of four conditions: high frequencies only, low frequencies only, high and low frequencies to separate ears (integration), and both frequencies to both ears (normal), so as to make a total list of 40 items separated by 6-sec. interstimulus intervals. The presentation order of conditions was reversed on the second of two trials. The words were presented through earphones at a comfortable level of loudness, though items at only the high or low frequencies suffered a slight loss of volume compared with the other conditions.

Ss were asked to repeat each word after hearing it through earphones. One correct practice trial using different words was required before the test began. After the practice trial and the first test trial, E stopped the tape recorder and said, "You're doing fine; now we'll do some more." E observed the child closely and recorded each attempt at repetition of the word. The final score was the number of stimuli incorrectly repeated under each condition.

Results and Discussion

Figure 2 summarizes the percentage of errors of all Ss for each word under each presentation condition across trials. The suitability of the stimuli is attested by the high percentage of errors for a word heard under either the high or low condition and the corresponding low percentage of errors for the word under the integration or normal condition. Only the word path could not be correctly repeated under the integration condition (IC) or normal binaural condition (NBC).

Insert Figure 2 about here

Comparison of the two filter-band systems indicated that the band-pass with frequencies from 637 to 1272 Hz and from 2550 to 5100 Hz produced higher mean errors under each condition (see Table 1). The stimulus words presented the same pattern of difficulty under both systems. Figure 3 presents the mean percentage of errors under various conditions for the two filter systems used in the pilot study.

Insert Table 1 about here

Insert Figure 3 about here

The mean error scores and standard deviations for each condition and for each trial for the normal and mentally retarded children is shown in Table 2, with accompanying means and standard deviations for errors under each condition for pooled trials. No attempt was made to use parametric statistical analysis on the data because Ss were not randomly selected. However, the data show no apparent significant differences between the two groups in the

mean number of errors for each condition for pooled trials, but a difference trend is suggested in favor of the EMR Ss.

Insert Table 2 about here

Table 3 presents information on the integration condition and normal binaural condition for the same word. In Trial 1 the NBC condition preceded the IC one only twice; in Trial 2 it happened five times. The NBC-IC comparison could produce five different types of responses: (a) a word presented under both the IC and NBC was repeated correctly each time; (b) it was repeated incorrectly each time; (c) it was repeated incorrectly and differently each time; (d) it was correctly repeated under the IC condition and incorrectly under the NBC one; or (e) it was incorrectly repeated under the IC condition and correctly under the NBC one. Outcome (a) indicates no problems with hearing the material or integrating the frequencies. Outcome (b) may indicate Ss' difficulty in hearing the word under both conditions; it more likely reflects minor articulatory or dialectical variations recorded by E as S's response. For example, E heard the word week under both the integration and normal conditions as wink. Further evidence is the unchanging frequency of occurrence of this error over trials. With outcomes (c) and (d), the test is indeterminate. Only with outcome (e) has the test assessed auditory integration. An auditory integration score can be computed for each child in the following way: the number of responses in which the integration condition was incorrect and the normal correct divided by the number of times both were correct plus the number of times both were wrong but the same.

Insert Table 3 about here

For normal Ss the mean integration scores were .28 and .31 for Trials 1 and 2 respectively and for the EMR Ss the scores were .17 and .11. With S G. M.'s scores of 1.00 and 1.33 subtracted, the scores for the normal groups were .13 and .10.

The number of errors in each of the conditions decreased slightly from the first to the second trial. The learning effect appears greater for normal than for retarded Ss.

Table 4 presents the scores for each of the conditions and the integration score components by age groups. The EMRs were older and did better, although

the one older normal boy also did very well. The test may involve some form of perceptual recognition of incomplete stimuli that is developmentally controlled.

Insert Table 4 about here

One child had integration scores high enough to discuss as a case study. G.M. was a nine-year-old with some reading difficulty and some indication of slow emotional development. He succeeded on the practice trial, but on Test Trial 1 he had only 3 out of a possible 40 words correct. On Trial 2 he missed 7 out of 10 words in each of the high and low conditions and had 5 integration and 5 normal words wrong. He gave both the integration and normal words correctly only three times. Twice he gave incorrect responses to both conditions, and once he gave the integration word correctly but the normal word incorrectly; four times he was unable to integrate. His integration ratio was therefore 4/3. Several explanations are possible for his poor performance: hearing difficulties; discomfort in the testing situation; neurological damage; inability to cope with an incomplete stimulus and form an auditory gestalt.

Several other children had equally high errors on the high and low conditions but only two had high errors on the integration and normal conditions. Both of them were mentally retarded, one with "soft neurological signs." Their scores were probably the result of dialect problems or experimenter errors, since both had high scores of the outcome (b) type.

In a pilot study of this sort it is more appropriate to focus on techniques than findings. Some evidence for an habituation or learning effect over trials, particularly in the integration and normal conditions, has already been mentioned. In subsequent investigations, at least two trials would seem to be advisable.

The high and low conditions were important in determining the usefulness of the stimulus words but of little value in assessing integration ability. The two conditions can probably be dropped in subsequent investigations--but only after equating the stimulus properties of the words selected. These two conditions were inadvertently presented at a slightly lower volume than were the integration and normal conditions. In the future all conditions should be presented at the same volume.

If the high and low conditions are eliminated, additional stimulus words can be presented in the integration and normal conditions. Such additional words should be tested under all four conditions with normal children; only those resulting in errors in the high and low condition but not in the integration and normal condition should be selected.

It is important to use the same words under both integration and normal conditions, so as to neutralize the misleading affects of variant articulation or dialect. The normal words should precede the integration words. In that way integration errors could not be attributable to faulty adaptation to the task.

Filter-band System 2 produced a desirably large number of errors under the high and low conditions, but it also produced more errors under the normal condition. Since the control condition should be almost errorless, filter-band system 1 is the one to use for future studies even though the number of integration errors may thereby be reduced.

The interstimulus interval of 6 sec. appeared too long for Ss. An interval of 4 or 5 sec. should be quite adequate.

The test is intended to detect possible brain injury. There is no reason to believe that more than one of the mentally retarded and possibly one of the normal boys had even minimal brain injury. It is imperative that the test now be tried on children with known neurological impairments.

References

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Footnote

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Figure Captions

Fig. 1. Schematic for filter system.

Fig. 2 Errors made on stimulus words as a percentage of total times the word was presented by type of condition.

Fig. 3. Mean percentage of errors for four conditions for the two filter systems.

Table 1

Mean Error Scores and Standard Deviations for Each Condition by Filter System

Condition	Filter System			
	One		Two	
	Mean	Standard Deviation	Mean	Standard Deviation
High	15.3	1.9	16.5	1.6
Low	11.5	4.1	12.8	3.1
Integration (IC)	6.8	3.9	7.2	3.7
Normal (NBC)	6.2	2.5	8.2	3.2

Table 2

Mean Error Scores and Standard Deviations for Each Condition by Type of Child and Number of Trials

Condition	Type of Child and Number of Trials											
	Filter System One				Filter System Two				Filter Systems (Both)			
	EMR		Normal		EMR		Normal		EMR		Normal	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D
High	8.2	1.2	8.8	1.2	7.2	1.2	7.7	0.8	15.3	2.3	16.5	1.0
Low	6.0	2.2	6.2	1.6	5.5	2.4	6.7	1.6	11.5	4.5	12.8	2.4
Integration (IC)	3.8	1.5	4.0	2.5	3.3	2.7	2.8	1.3	7.2	3.9	6.8	3.5
Normal (NBC)	4.0	1.7	5.2	2.5	2.7	2.1	2.5	1.3	6.7	4.2	7.7	1.2

Table 3

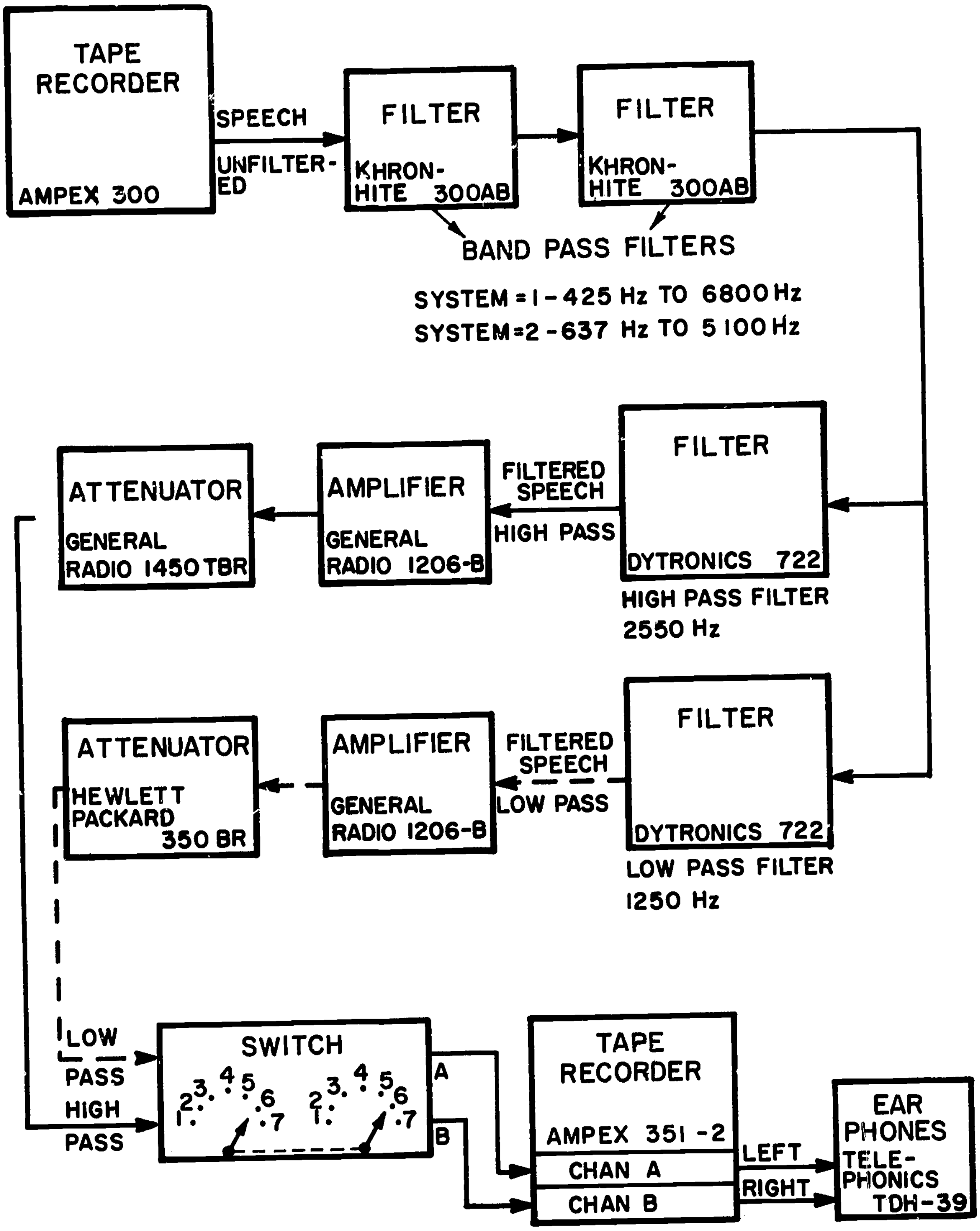
Per Cent Distribution of Error Scores on Integration--
Normal Patterns by Type of Child and Trial

Integration Normal Pattern	Type of Child and Trial					
	Trial One		Trial Two		Total Trials	
	EMR	Normal	EMR	Normal	EMR	Normal
Both Right	50%	40%	65%	65%	57%	52%
Both Wrong Samd Word	12	13	12	7	12	10
Both Wrong Different Words	15	17	10	10	13	14
Integration Right Normal Wrong	13	22	7	5	10	13
Integration Wrong Normal Right	10	8	6	13	8	11
Total	100%	100%	100%	100%	100%	100%

Table 4

Mean Error Scores for Each Age Group by Type of Condition

Age	N	Type	Type of Condition			
			High	Low	Integration	Normal
7	4	N	17	12	5	7
8	2	EMR	16	12	10	8
9	1	N	17	16	14	14
10	1	EMR	14	14	7	7
11	2	EMR	17	12	8	7
12	1	N	15	12	6	5
13	1	EMR	13	7	3	2



SWITCH POS.
1. HIGH TO CHAN. A
2. HIGH TO CHAN. B
3. HIGH TO CHAN. A AND LOW TO CHAN. B
4. LOW TO CHAN. B
5. LOW TO CHAN. A
6. HIGH TO CHAN. B AND LOW TO CHAN. A
7. HIGH & LOW TO CHAN. A AND HIGH & LOW TO CHAN. B

Figure 1

38

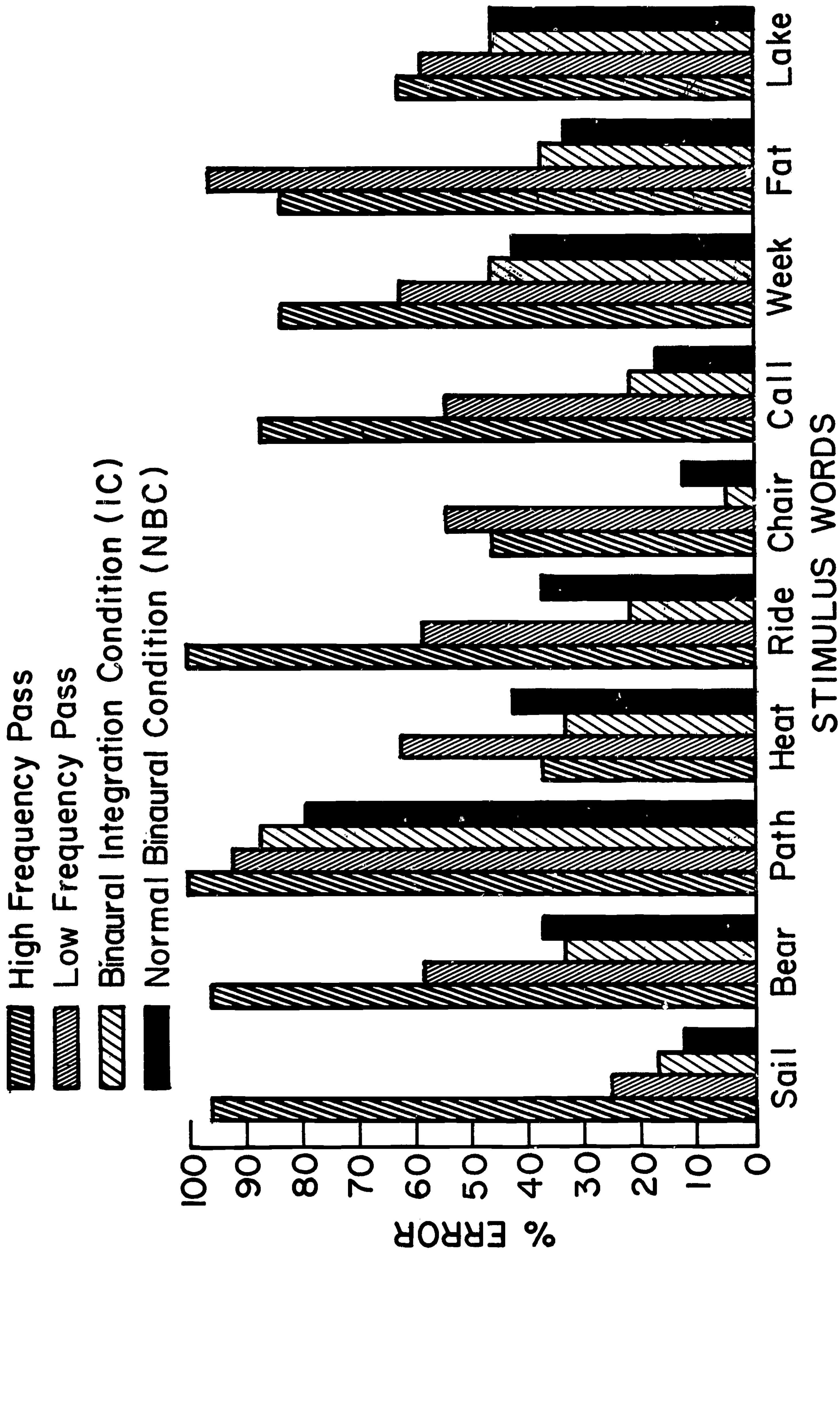

High Frequency Pass
Low Frequency Pass
Binaural Integration Condition (IC)
Normal Binaural Condition (NBC)
% ERROR
100
90
80
70
60
50
40
30
20
10
0
Sail
Bear
Path
Heat
Ride
Chair
Call
Week
Fat
Lake
STIMULUS WORDS

Figure 2

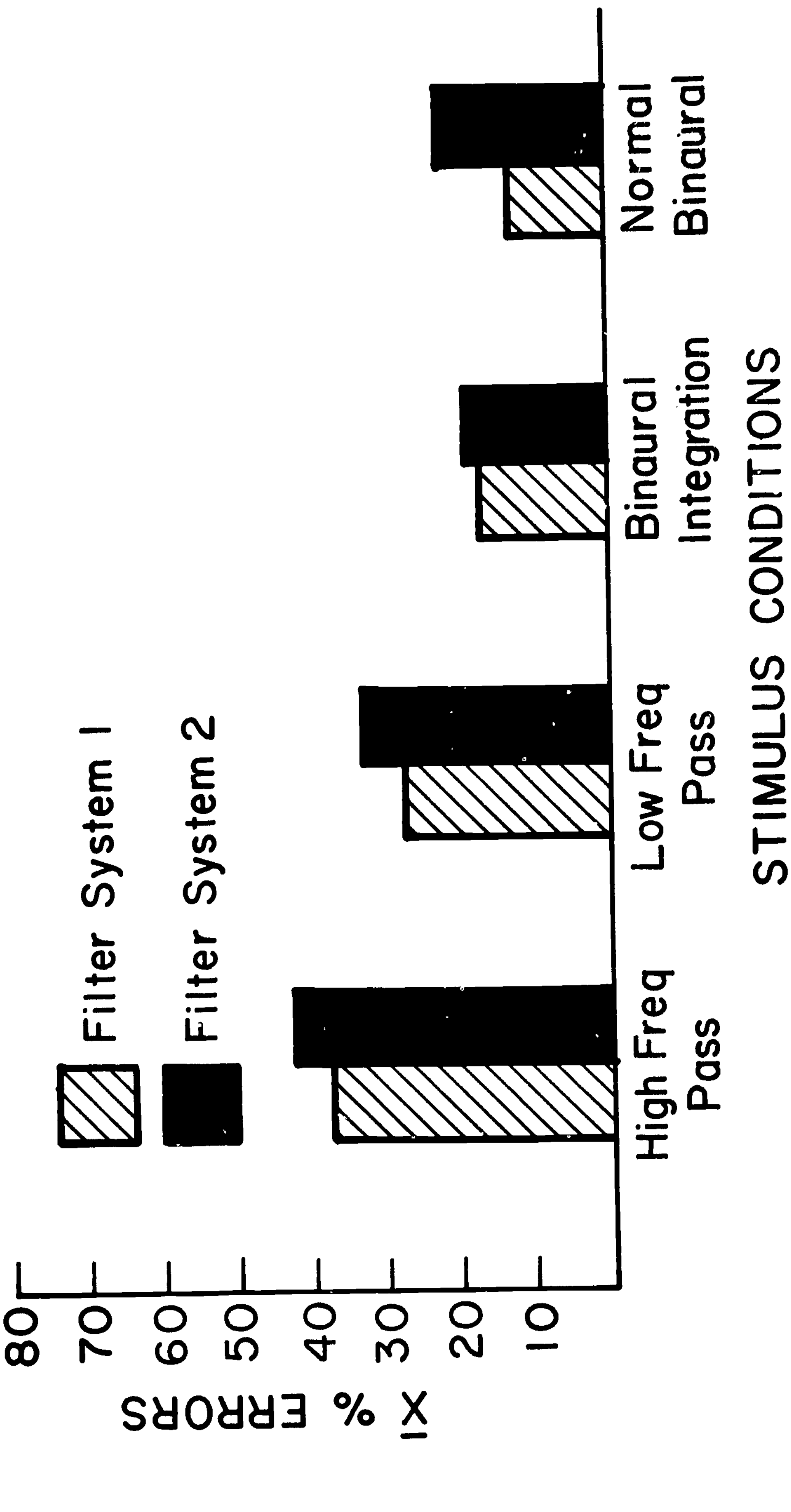

Filter System 1
Filter System 2
$\bar{X}$ % ERRORS
80
70
60
50
40
30
20
10
High Freq Pass
Low Freq Pass
Binaural Integration
Normal Binaural
STIMULUS CONDITIONS

Figure 3