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AN INVESTIGATION OF THE RATE AT WHICH THE AUDITORY DIMENSIONS OF PITCH, LOUDNESS, AND DURATION ARE UTILIZED IN A CONCEPT IDENTIFICATION TASK

A DISSERTATION

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AN INVESTIGATION OF THE RATE AT WHICH THE AUDITORY DIMENSIONS OF PITCH, LOUDNESS, AND DURATION ARE UTILIZED IN A CONCEPT IDENTIFICATION TASK

APPROVED BY

DISSERTATION COMMITTEE

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CHAPTER I

INTRODUCTION

"A concept is said to exist whenever two or more distinguishable objects or events have been grouped together or set apart from other objects on the basis of some common feature or property characteristic of each" (Bourne, 1966).

Much, if not most, of human learning involves dealing with concepts or classes of things rather than with unique objects or events. Organizing the environment in this fashion is apparently dictated by the tremendous amount of information which confronts the individual in his everyday life. In the young particularly, new classes must be formed or learned, while in the more mature organism interaction with the environment usually involves the identification and use of concepts which are already familiar. Traditionally, the behavioral processes associated with these kinds of activities are referred to in the literature as concept formation, concept utilization, and concept identification. It is the last of these processes, concept identification (CI), which is the focus of the present investigation.

The term "concept identification" as found in the literature usually refers to the purpose or goal of a learning task. The learner is directed to sort or categorize objects, events, or other stimuli on the basis of the presence or absence of a given attribute of the stimulus. The term "stimuli or stimulus" is defined by the total signal configuration or pattern that is presented to the learner. A stimulus, therefore, may consist of several dimensions or characteristics. Certain magnitude levels of these dimensions may be used to identify certain response categories. The term "attribute" specifies a single level of a dimension. If frequency, for example, is the dimension, then high and low pitch would be two attributes of that dimension. That characteristic of the stimulus which serves as the basis for a correct identification is called the relevant dimension. Hence, in a stimulus of some specified frequency, intensity, and duration, any one or more of the three dimensions can be defined as the relevant dimension. If a stimulus exemplifies the concept to be identified, that is, the relevant dimension, it is called a positive instance of that concept. If it does not, it is a negative instance of the concept.

In a typical concept identification experiment, the subject is presented with a succession of stimuli and is directed to respond to each one by assigning it to one of two available categories. One of the categories, as designated by the experiment, is made to correspond to a particular attribute of the stimulus. The other category accommodates all other attributes. Information feedback is presented to indicate to the subject the appropriateness of his response. The presentation of the stimulus, the response, and the feedback constitute one trial. Stimuli continue to be presented until the subject attains some criterion level of performance. That level is usually specified as a certain number of successively correct responses.

The stimulus presentations are organized into problems. A given problem is defined by its solution; that is to say, in a duration problem, the subject would be required to ignore all other characteristics of the stimulus and respond only on the basis of its duration. A CI problem may be made to vary not only in the kind but also in the amount of information it contains. The amount of information contained in a problem is commonly described in terms of units called "bits". For example, if, within a given problem, a dimension varies from trial to trial and is necessary for the solution of that problem, that dimension is said to provide one bit of relevant information. If a dimension varies from trial to trial and, on the other hand, is not necessary to the solution of the problem, it is said to provide irrelevant information. The number of bits of relevant and irrelevant information contained in the stimulus defines the complexity of the CI problem.

Concept identification, as a feature of human learning, has been the object of considerable study. It is not surprising to find that the establishment of a new class or category or the assignment of an object or event to an already existing category is, to a great extent, dependent upon the characteristics of the stimulus. It has been demonstrated, for example, that the rate at which concepts are identified is a function of both the kind and amount of information carried by the stimulus (Bulgarella and Archer, 1962; Pishkin and Blanchard, 1964; Pishkin and Shurley, 1965; Pishkin and Rosenbluh, 1966).

The probability that a learner will attend to or will utilize a particular dimension of a stimulus to solve a CI problem is an expression of the saliency of that stimulus. Stimulus saliency may be measured by comparing the rate at which various dimensions of a stimulus are utilized in arriving at the solution of a concept identification problem task. The relative information values of different stimulus attributes within a given modality have been demonstrated to be different. Some dimensions are apparently more readily utilized in the solution of a CI problem than others. Most of the studies reporting the saliency of specific dimensions have used either visual or verbal stimuli. In the case of visual stimuli, concept identification has been shown to be most rapid when color is the relevant attribute and to proceed at essentially the same rate when number, size, position, or shape is the relevant dimension (Bourne and Restle, 1959; Pishkin, 1960).

Only a few of the studies investigating nonverbal auditory concept identification have been concerned with the rate at which specific dimensions are utilized in this kind of task. The results of these studies are not in complete agreement but, in general, they suggest that concept identifications based on pitch are more readily learned than identifications based on loudness or duration (Pishkin and Blanchard, 1964; Pishkin and Shurley, 1965; Pishkin and Rosenbluh, 1966). Although there is no a priori reason to predict such differences, there are several factors in the design of the studies cited above which may have produced differences in the rate at which these dimensions were utilized in the CI task.

None of the above studies controlled for the possibility of variations in hearing sensitivity on the part of experimental subjects. Differences in performance were observed between males and females and between adults and children on certain dimensions. The consistently poorer performance of adult males on these dimensions may have been related to a higher incidence of hearing loss within this group. The observation that pitch information is more readily identified than either loudness or duration information has not been explained. No attempt was made to present signals of different frequencies at comparable loudness levels so as to preclude the possibility that the subject's task was facilitated by redundant information.

Frequency, intensity, and duration cues serve as the basis for the identification of phonemic categories and provide information important to the meaning of inflectional, stress and rhythm patterns of speech. These same cues also provide information which allows the individual to monitor and adjust to his environment. An understanding of how normal-hearing individuals utilize these cues may make it possible to determine the ways in which a hearing impairment affects this part of the communication process.

The purpose of this investigation is to determine, under controlled conditions, the rate at which the dimensions of pitch, loudness, and duration are utilized in a concept identification task. It is hypothesized that stimulus dimension will not be a significant factor in determining the rate at which concept identification problems are solved. A review of the literature pertinent to this investigation is presented in the following chapter.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

The purpose of this investigation is to determine the rate at which the auditory dimensions of pitch, loudness, and duration are utilized in a concept identification task. Most of the information in the area of concept identification has been generated by studies which have used either verbal or visual stimuli. Only a few of those using non-verbal auditory stimuli have dealt specifically with the question of stimulus saliency. This chapter contains a review of the literature on non-verbal auditory concept identification. The first section describes and discusses studies which have employed non-verbal stimuli in a CI task. These studies, for the most part, are concerned with the effects of problem complexity and sensory modality on concept identification. The second section reviews those studies which report the effect of specific auditory dimensions on the rate at which concept identification is attained.

Non-verbal Auditory Concept Identification

Lordahl (1961) compared the performance of adults on a concept identification task with simultaneously presented auditory and visual information. The major variable under consideration was the amount of irrelevant information presented by way of each sensory channel. Previous investigations using visual stimuli have shown that increases in the amount of irrelevant information significantly increase the difficulty of the task (Bourne, 1957; Bourne and Pendelton, 1958; Brown and Archer, 1956). In the Lordahl study, two stimulus dimensions, one from each modality, were relevant to the solution of the problem. Problem complexity was varied by using from zero to three bits of irrelevant information.

Lordahl employed the following auditory stimulus dimensions: pitch of a pure tone (300 Hz or 1800 Hz); loudness of a pure tone (35 dB or 59 dB at 300 Hz and 54 dB or 84 dB at 1800 Hz); presence or absence of two short bursts of white noise; a steady or interrupted tone; and laterality (right or left earphone). The visual stimuli used consisted of a number of geometric forms which varied in size (large or small), number (three or four figures), orientation (horizontal or vertical), location in the visual field (right or left), and the position of a spot in the visual field (above or below the center of the field). Using these stimuli, Lordahl found that performance as measured by error scores was inversely related to the amount of irrelevant visual information. As the amount of irrelevant visual information was increased from zero to three bits, the mean number of errors increased as follows: 19, 22, 29, and 37. This finding is consistent with other studies using visual stimuli (Bourne, 1957; Bourne and Pendelton, 1958; Brown and Archer, 1956). Contrary to expectation, however, the addition of irrelevant auditory information had no significant effect on the same measure.

Apparently, irrelevant auditory information was not as distracting to the subjects as was irrelevant visual information. The number of correctly identified positive instances of the concept (those stimuli which had both of the relevant dimensions present) decreased as a function of an increase in both visual and auditory irrelevant information. This particular index was considered to be a more sensitive measure of the degree of solution than errors because a subject had to take into account both of the relevant dimensions in order to correctly identify a positive instance of the concept. A reduction in errors, on the other hand, could be achieved by simply selecting the negative lever more than the positive lever since 75 per cent of the presentations were negative instances of the concept. As the amount of irrelevant visual information was increased from zero to three bits, the mean number of correct positive responses decreased as follows: 54, 49, 29, and 15. The scores for irrelevant auditory information were 46, 37, 35, and 29. The type of errors made by the subjects suggested that they responded primarily on the basis of visual information. There were more incorrect responses made when visual stimuli were at a positive level and auditory stimuli were at a negative level than when the opposite condition was present. This reflects the fact that the subject had to ignore the auditory information at the negative level in order to respond only to the positive visual stimuli. This finding is interpreted by the author as suggesting a bias toward the use of visual information.

Haygood (1965) studied the effects of redundant auditory and visual information on concept identification. Bourne and Haygood (1959, 1961) had previously suggested that redundant visual information has a facilitating effect on concept identification. Lordahl, on the other hand, suggested the opposite conclusion in reporting that subjects tend to ignore auditory information when both auditory and visual information are presented. Citing these authors, Haygood offered the following query as a rationale for her investigation:

> If redundant relevant information is uniformally helpful, and if the assumptions of human engineers and educators are correct, then the addition of redundant auditory information to visual and vice versa should improve performance. On the other hand, if the conclusions of Lordahl and Bulgarella and Archer "that subjects tend to ignore auditory information when both auditory and visual are present" is correct, then the addition of redundant auditory information to visual would not improve performance over that found when visual presentation is used alone.

In order to test this hypothesis, adult subjects were presented problems which required an auditory solution, a visual solution, and one in which auditory information was presented redundant with visual information so that either could be used for solution. A problem comparable to Lordahl's was also used in which information from both modalities was necessary for the solution of the problem.

Because irrelevant information was not the variable under consideration, the number of irrelevant dimensions was held constant. Each problem had one auditory and one visual irrelevant dimension. The visual stimuli consisted of three binary dimensions which were color (red or blue), form (triangle or square), and size (large or small). The auditory dimensions varied in pitch (high or low), loudness (soft or loud), and continuity (continuous or interrupted). The data were analyzed in terms of the number of errors to criterion. It was found that there were no significant differences in subject performance on problems with one relevant auditory dimension versus those with one relevant visual dimension. There were no differences in performance between these latter two problems and those in which visual information was presented redundant with auditory information.

In her summary, Haygood offered two possible reasons for her failure to show significant effects for redundant information. The first relates to Lordahl's (1961) conclusion that auditory information is ignored when both auditory and visual information is present. This conclusion, however, was not consistently supported by Haygood's study. Haygood showed that as many subjects choose auditory solutions as visual solutions when problems could be solved by either kind of information. According to Haygood, a more tenable explanation for the failure to demonstrate a significant main effect for modality was due to the inflated variance under the auditory condition. This, she attributed to a lesser emphasis on auditory classification in the culture.

The effect of sensory modality and completeness of information on concept identification was investigated by Laughlin and his coworkers (1968). Previous research has suggested that positive instances of a concept may be more facilitative to concept identification than negative instances of a concept and that the relative differences between the two decrease over a series of problems (Friebergs and Tulving, 1961). It was Laughlin's contention that where concepts have two or more relevant attributes the positive and negative instances are really two points on the same continuum. Positive instances are at one end and indicate all of the relevant attributes while negative instances are at the other where all of the relevant attributes are absent. Other instances commonly classified as negative are partially positive, according to Laughlin, because they contain anywhere from one relevant attribute to the total number of relevant attributes minus one.

The effect of differing amounts of information was determined by informing subjects prior to the stimulus presentation whether it was positive, negative, or partially positive. These instructions were considered as providing complete information. Those subjects receiving incomplete information were told only whether the presentation was negative or positive.

One hundred and eighty adult subjects were presented concept identification problems differing with respect to the completeness of information and the sensory modality through which the information was presented. The problems required either an auditory solution, a visual solution, or a conjunctive auditory and visual solution. All problems had three relevant dimensions. The conjunctive auditory and visual problem had one relevant dimension from one modality and two from the other.

The auditory stimuli used in the investigation consisted of piano notes which varied in number (two, three, or four), pitch (high, medium, or low), inflection (steady, rising, or falling), and loudness (soft, medium, or loud). The visual stimuli were figures mounted on cards. They varied in shape (triangle, circle, or square), color (red, yellow, or green), number (one, two, or three), and size (small, medium, or large).

Performance was measured by the number of trials to solution. The main effects of sensory modality and completeness of information were found to be significant. In contrast to the findings of Lordahl (1961) and Haygood (1965), the conjunctive auditory and visual problem was learned more rapidly than either the auditory or visual problem. The auditory problem was learned more rapidly than the visual and the problems preceded by incomplete information required significantly more trials to solution than those preceded by complete information. The reason for the difference in results between this study and the two previous investigations which also used a conjunctive auditory and visual problem is not apparent. Quite possibly, it may have been due to a difference in the difficulty of the dimensions used in the three studies.

Bulgarella and Archer (1962) investigated the effect of simultaneous variation in relevant and irrelevant information on a concept identification task. They used the following five dimensions: pitch (250 Hz or 1800 Hz), loudness (43 phons or 64 phons at 250 Hz and 54 or 64 phons at 1800 Hz), presence or absence of white noise at 55 phons, continuous or interrupted tone, and laterality (right or left earphone).

Performance was measured in terms of the number of errors, trials, and time to criterion. All of these measures were found to be inversely related to the amount of relevant and irrelevant information. The lack of a significant interaction between relevant and irrelevant information suggested that the addition of irrelevant information to an already difficult task does not make it differentially more difficult. It was concluded that the results of this study are consistent with concept identification data obtained using visual stimuli.

The studies cited and discussed above all have used auditory stimuli in a concept identification task. Their purpose, for the most part, has been to determine the effect of problem complexity and the sensory modality through which information is presented on the rate of problem solution. None of these studies has been concerned specifically with stimulus saliency. The term saliency is used here as an expression of the relative rate of problem solution when various stimulus dimensions are manipulated in a concept identification task.

The following section reviews those studies which report the effect of specific auditory dimensions on concept identification learning.

Non-verbal Auditory Stimulus Saliency

The relative information values for the auditory dimensions of duration, number, laterality, pitch, and loudness were reported by Pishkin and Blanchard (1964). In this investigation, the rate at which these five dimensions were learned in a concept identification task was determined in a series of three experiments. The experimental variables were the amount of irrelevant information, the kind of relevant information (dimensions), and sex. The specific dimension characteristics were duration (one second or three seconds), loudness (30 dB or 60 dB), pitch (1000 Hz or 3000 Hz), number (one or two repetitions of the same stimulus pattern), and laterality (right or left earphone).

In the first experiment, each of the above dimensions served as a relevant dimension. Each problem had one bit of relevant information and no irrelevant information. In the second experiment, duration, laterality, and pitch were the relevant dimensions. Laterality, duration, number, and pitch were the irrelevant cues. In the third experiment, laterality was the relevant dimension, coupled with one, two, or three irrelevant dimensions. This experiment was a replication of the laterality portion of experiment two and was done to provide additional information about sex differences on the laterality dimension. Adult subjects were used in all experiments.

Performance was reported in terms of the mean number of errors to criterion for each dimension. In experiment one, subjects solving problems varying only in loudness made significantly more errors than subjects solving problems varying only in pitch, duration, number, or laterality. Problem solution based on pitch resulted in fewer errors than solutions based on loudness or laterality. Male subjects made more errors than female subjects on all dimensions except pitch. Sex differences, however, were not statistically significant.

In experiment two, pitch as a relevant dimension resulted in fewer errors than either duration or laterality. Males made significantly more errors than females when laterality was the relevant dimension. This difference was most pronounced at low levels of complexity; that is, there was a greater difference between the two groups for problems with one irrelevant dimension than for problems with three irrelevant dimensions. This latter finding was more fully explored by Pishkin and Shurley (1965).

Pishkin and Blanchard's earlier study had shown that, under a condition of no irrelevant information, duration and pitch were about equally difficult for males and females. Under the same conditions, it was demonstrated that the laterality dimension tended to produce sex differences. Pishkin and Shurley (1965), therefore, selected these three dimensions to be relevant. The experimental variables were the kind of relevant information (dimensions) and the number of irrelevant dimensions. The auditory stimuli used in this investigation were the same as those previously described by Pishkin and Blanchard. Subjects were adult employees of the Veterans Administration Hospital. All subjects responded until they made sixteen consecutively correct responses or received a total of 192 stimulus presentation.

An analysis of error scores showed a significant main effect for sex, dimensions, and complexity. Males performed more poorly than females. This difference between the two groups was attributed to the males' poorer performance on the laterality dimension. The number of errors for the two groups was comparable for pitch and loudness. An analysis of trials to criterion indicated the same trend with males requiring about twice as many trials as females. An analysis of errors by trials showed the expected decrease in errors between the first block of six trials and the last block of six trials. For males, laterality was the most difficult dimension followed by duration and pitch. For females, duration was the most difficult dimension followed by pitch and laterality. A statistical treatment of these differences was not reported.

The combined group's performance on problems where pitch was the relevant cue was significantly better than for any other dimension. There were no significant differences in the combined group's performance on the laterality and duration dimension. A significant interaction between sex and dimension resulted from a marked increase in problem difficulty for males when laterality was the relevant dimension. An interaction between dimensions and complexity was considered to be due to the combined group's poorer performance when duration rather than pitch or laterality was the relevant dimension. In discussing these findings, the authors suggest that:

> It is quite likely that the characteristics of duration and number dimensions interact. Hence, two signals of 1 sec. each with a .5 sec. break may have been subjectively interpreted by S as belonging in the same duration category as a 3 sec. single signal, even though with the duration dimension relevant these two stimuli called for an X and O response.

Pishkin and Shurley conclude that the reason pitch was superior to other dimensions was due to the duration by number interaction and the males' poorer performance on the laterality dimension. This conclusion suggests the possibility that the difference shown between dimensions may have been a function of either the way in which the various dimensions were combined or some characteristic of the subject sample.

Consider, for example, the effect that variations in subjects' hearing sensitivity might have on the cue value of certain auditory stimulus dimensions. In such a case, loudness information might be inadvertently disturbed by either minimizing loudness differences or, in the case of recruitment, accentuating them. Similarly, sensitivity differences between ears might result in confusing laterality with loudness judgments.

Both of the studies reporting auditory stimulus saliency and cited above have shown that laterality and loudness are not as readily identified as are other stimulus dimensions. Moreover, they report a difference in performance between males and females in utilizing these dimensions in a listening task. If hearing loss were a consideration that was overlooked in these studies, one would expect it to be more prevalent in males than females. This might have accounted for the difference in performance between the two groups.

According to these authors, pitch was the most readily identified dimension. One possible explanation for this observation may be related to the inadvertant presentation of loudness cues redundant with pitch information. When two different frequencies are presented at the same intensity level, they may or may not be experienced as equally loud. In the absence of equal loudness, the subject is presented with a stimulus which varies in both pitch and loudness. The addition of loudness cues redundant with pitch information could produce a spuriously easy task and one which is not comparable to similar tasks involving other dimensions.

In another study, Pishkin and Rosenbluh (1966) investigated the saliency of five auditory dimensions presented to children. The dimensions varied in number (one or two tones with a two second interval between them), loudness (65 or 80 dB at 250 Hz), laterality (right or left earphone), pitch (250 or 1800 Hz), and duration (one second or three seconds). The design consisted of problems containing one bit of relevant and no irrelevant information. Four age groups of subjects were used: Group I (6-8 yrs.), Group II (9-11 yrs.), Group III (12-14 yrs.), and Group IV (15-17 yrs.). Each group had an equal number of males and females.

Significant main effects were observed for age and dimension but not sex. There was a reduction in errors from Group I to Group II and from Group III to Group IV. Very little difference was observed between age groups II and III. This was attributed to the greater number of errors made by Group III on the number and loudness dimensions. In comparison to the results of Pishkin and Shurley where adult males were shown to perform inferiorly to adult females, this study indicated no difference in performance between the two sex groups. An analysis of the rate at which the various dimensions were identified showed that loudness was the most difficult dimension and that laterality was the most salient dimension. Duration, pitch, and number resulted in about the same number of errors.

Pishkin and Rosenbluh's finding that loudness was the most difficult dimension is consistent with the results of Pishkin and Blanchard which were discussed earlier. The finding, however, that laterality was the most salient dimension is somewhat surprising. Both Pishkin and Blanchard and Pishkin and Shurley reported that laterality was the least salient dimension and the one that produced the greatest sex differences. The reason for these inconsistencies is not apparent, although they might be related to a difference in the age of experimental groups used in the three studies or a difference in design. The oldest subjects in the Pishkin and Rosenbluh study were 17 years old while the subjects in the other two studies had a mean age of about 40 years. Further, Pishkin and Rosenbluh reported laterality to be the most salient dimension under a condition with no irrelevant information while Pishkin and Shurley reported laterality to be the least salient dimension under a condition with three bits of irrelevant information.

A review of the literature suggests that not all auditory dimensions are utilized at the same rate in a concept identification task. The saliency of a particular dimension has been shown to be related to the complexity of the problem, the subjects' sex, and the physical characteristics of the signal serving as a stimulus. While there are no a priori reasons to predict differences in the rate at which the various dimensions are identified, there are several factors which may produce such differences. Variations in hearing sensitivity and the presentation of loudness information redundant with pitch cues are factors which must be controlled in any investigation of stimulus saliency.

The purpose of the present investigation is to provide additional information about the rate at which the auditory dimensions of pitch, loudness, and duration are utilized in a concept identification task. The experimental design includes controls for variations in hearing sensitivity within the subject sample and other factors which might inadvertantly affect the rate at which auditory dimensions are identified. A description of the experimental apparatus, subject sample, and procedures utilized in this investigation is presented in the following chapter.

CHAPTER III

SUBJECTS, APPARATUS, AND PROCEDURE

Introduction

This investigation proposed to study auditory stimulus saliency. Specifically, the experiment was designed to determine the rate at which the auditory dimensions of pitch, loudness, and duration, as they are represented in a pure tone, are utilized in a two-alternative forced-choice CI task. All three dimensions of the stimulus were bi-level; that is, either high or low in pitch, loud or soft in loudness, and long or short in duration. One dimension of the stimulus was always identified as relevant to the solution of the CI problem. Its magnitude from one stimulus presentation to the next was made to vary randomly between the two discrete levels. The other two dimensions of the stimulus were presented at a fixed magnitude level. Each CI problem, therefore, displayed a paradigm in which only the magnitude of the relevant dimension varied from stimulus presentation to stimulus presentation. A total of twelve different CI problems were generated; four pitch problems, four loudness problems, and four duration problems.

Twenty-four adult females served as subjects. Their task was to learn that the stimuli comprising a loudness problem, for example, could be sorted on the basis of loudness information; that is, whether it was loud or soft. Similarly, the stimuli comprising the pitch problems could be sorted according to whether the stimuli were high or low in pitch. Likewise, duration problems required the subject to sort stimuli according to their duration, whether long or short. The order in which the twelve problems were presented was completely balanced. The order in which the different relevant dimensions were presented was partially balanced.

The instrumentation used in this investigation consisted of modular programming equipment and apparatus for generating an acoustic sine wave and manipulating the parameters of signal frequency, signal intensity, and signal duration. The data are expressed in terms of the number of errors, the number of trials, and the elapsed time to solution. A detailed description of the subjects, experimental apparatus, and procedures is presented in the subsequent sections of this chapter.

Subjects

Twenty-four adult females served as subjects for this investigation. Each subject was required to pass in both ears a hearing screening test presented at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz at a 10 dB hearing level (ANSI, 1969). Although both ears were tested at this level, only the subject's right ear was used in the experiment. Individuals with previous experience in a concept identification study were not used as subjects.

It has been suggested that the menstrual cycle may have some effect on loudness judgments (Stokinger, 1971, Personal Communication) and for this reason no subject was tested during her menstrual period. All of the subjects participating in this investigation were graduate students studying in the Department of Communication Disorders at the University of Oklahoma Health Sciences Center. The subjects' age ranged from twenty-one to twenty-eight years with a mean age of twenty-four years.

Apparatus

Screening Apparatus

A Beltone 10C Audiometer fitted with two TDH-39 earphones mounted in MX-41/AR cushions was used to screen the hearing of all experimental subjects. The acoustic output of the air conduction system was calibrated using an artificial ear (Allison Model 300). The hearing screening was done is a sound-treated room normally used for this purpose.

Experimental Test Apparatus

A block diagram of the experimental apparatus is shown in Figure 1 and Figure 2, Part A and Part B. The experimental apparatus was instrumented to deliver to the subject's earphone any combination of a 250 or 1800 Hz sine wave at one of two durations and one of two intensities. The apparatus recorded the subject's response and provided him with immediate knowledge of results (feedback). The following is a description of the signal, timing, and recording apparatus used in this investigation.

Signal Apparatus

A simplified block diagram of the signal apparatus is shown in Figure 1. The acoustic signal was either a 250 Hz or 1800 Hz sine wave generated by one or the other of two audio oscillators (Hewlett Packard

Figure 1.--Schematic representation of the signal apparatus.

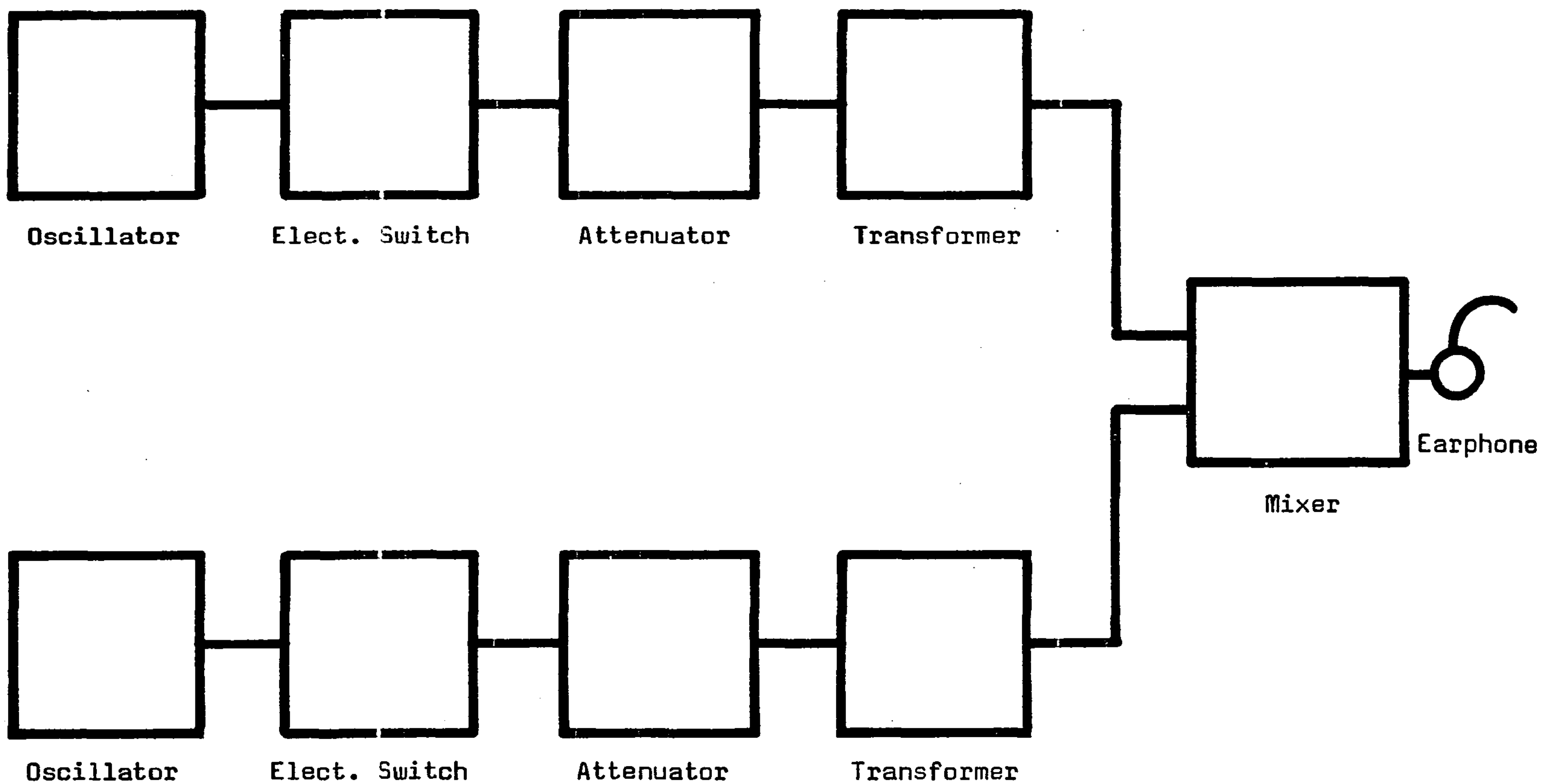

Oscillator
Elect. Switch
Attenuator
Transformer
Mixer
Earphone
Oscillator
Elect. Switch
Attenuator
Transformer

Figure 2.--Part A - Schematic representation of the programming apparatus.

Key to the schematic of the timing apparatus shown in Figure 2 - Part A.

A	To 1213-17
B	To 1213-13
C	To 1213-14
D	To 1213-15
E	To 1213-16
F	To 1213-20
G	To Electronic Switch
H	To Electronic Switch
I	To Counter-Timer (start)
J	To Counter-Timer (stop)
K	To 1213-9
L	To 1213-10
M	To 1213-10
N	To 1213-12
O	To 1211-11
P	To 1213-13
Q	To 1213-15
R	To 1213-14
S	To 1213-16
T	To 1213-11
U	To 1213-9
V	To 1213-12
W	To 1213-10
X	Input from Subject Response Box
Y	Input from Subject Response Box

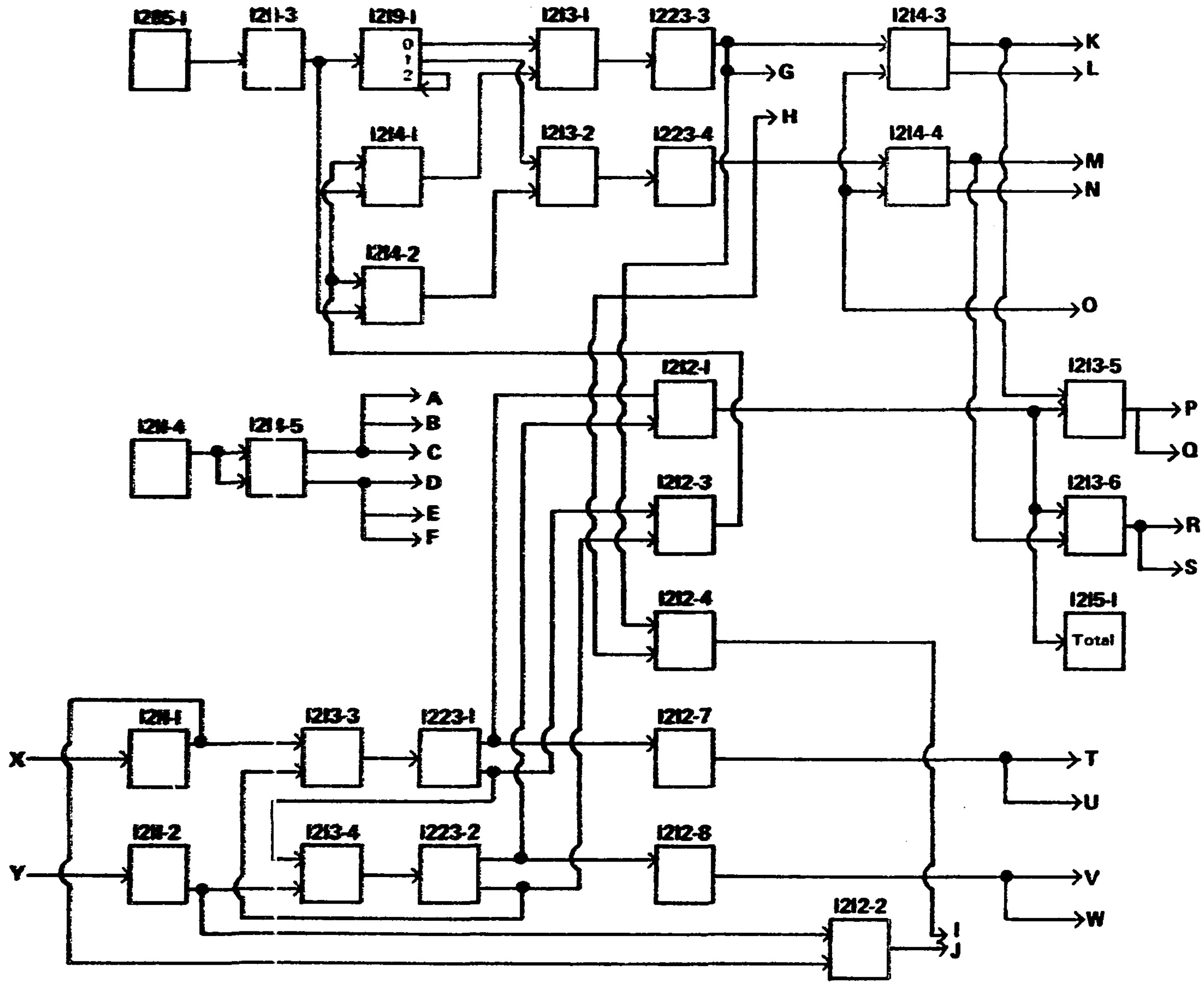
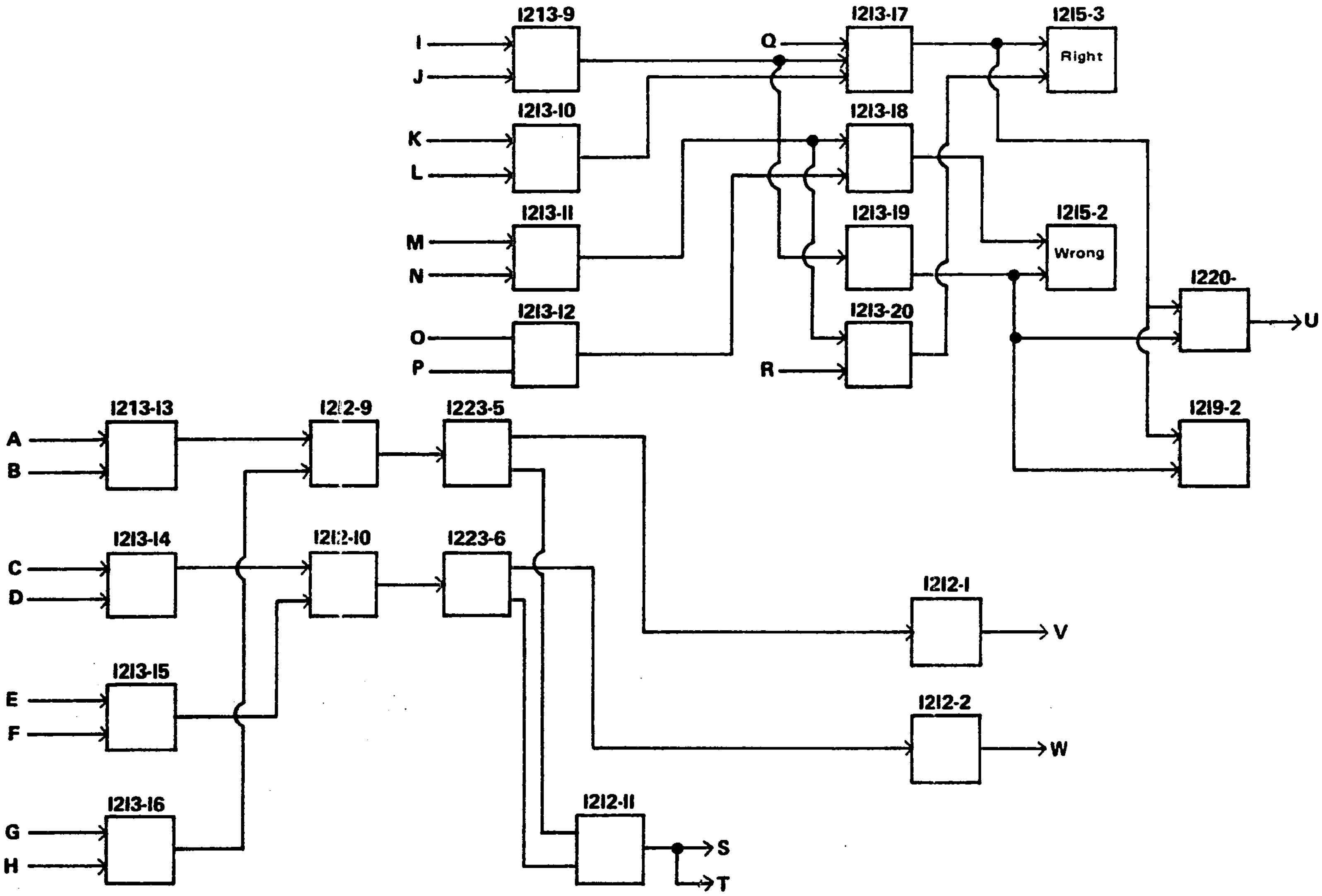

1211-3
1219-1
0
1
2
1213-1
1223-3
1214-3
G
H
K
L
1214-1
1213-2
1223-4
1214-4
M
N
1214-2
O
1212-1
1213-5
P
Q
1211-4
1211-5
A
B
C
D
E
F
1212-3
1213-6
R
S
1212-4
1215-1
Total
X
1211-1
1213-3
1223-1
1212-7
T
U
Y
1211-2
1213-4
1223-2
1212-8
V
W
1212-2
I
J

Figure 2.--Part B - Schematic representation of the programming apparatus.

Key to the schematic of the timing apparatus shown in Figure 2 - Part B.

A	From 1213-5	L	From 1212-8
B	From 1214-5	M	From 1214-3
C	From 1213-6	N	From 1212-7
D	From 1214-5	O	From 1212-8
E	From 1213-5	P	From 1214-4
F	From 1214-5	Q	From 1214-5
G	From 1213-6	R	From 1214-5
H	From 1214-5	S	To 1214-3
I	From 1214-3	T	To 1214-4
J	From 1212-7	U	To Inverter
K	From 1214-4	V	To Feedback Lights
		W	To Feedback Lights


1213-9
1213-10
1213-11
1213-12
1213-13
1213-14
1213-15
1213-16
1213-17
1213-18
1213-19
1213-20
1212-9
1212-10
1212-11
1212-1
1212-2
1223-5
1223-6
1215-3
Right
1215-2
Wrong
1220-
1219-2
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W

Model 200 AB). The output of each oscillator was fed to an electronic switch (Grason Stadler Model 1287) which was controlled by the timing program. The output of each switch was directed to the input of an attenuator (Hewlett Packard Model 350A). From each attenuator, the signal was fed through a transformer (UTC Type LS 33) to a mixer and on to the subject's earphone (TDH-39 fitted in a MX 41-AR cushion). The earphone was mounted on a standard adjustable headband with a dummy earphone mounted on the other side.

Timing Apparatus

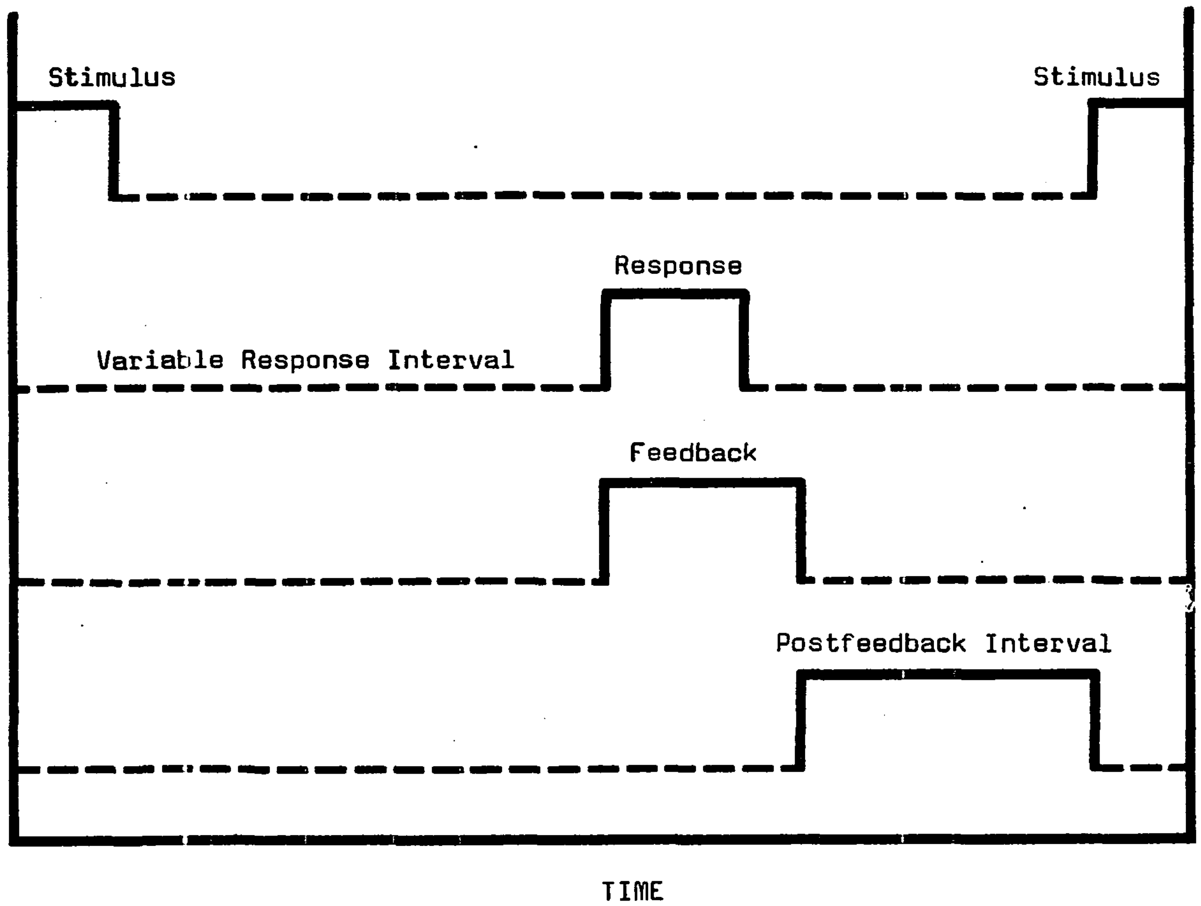
The timing apparatus consisted of an array of functionally related modules of the Grason Stadler 1200 programming system. A simplified block diagram of this apparatus is shown in Figure 2, Part A and Part B. The timing program provided for the random presentation of one of two magnitude levels of either signal frequency, signal intensity, or signal duration and controlled all other events in the test sequence. The random presentation of signal levels was achieved by the use of a random program consisting of a noise generator (Model 1235) whose output was delivered to the sine wave input of an input converter (Model 1211) and on to a sequence counter (Model 1219). The zero and number one outputs of the sequence counter were each fed to separate AND gates (Model 1213). The number two output of the sequence counter (Model 1219) reset the sequence counter to produce a fifty per cent probability schedule. This meant that one or the other AND gate would fire in random order. The output of each AND gate was delivered to a timer (Model 1223) which controlled the on/off state of an electronic switch (Model 1267).

The program-event sequence consisted of a signal, a subject determined variable interval, the subject's response, feedback occurring simultaneously with the response and lasting one second, and a four-second post-feedback interval. This sequence of events is illustrated in Figure 3.

The duration of the feedback and length of the post-feedback interval were controlled by timers (Model 1223). The feedback lasted for one second and was initiated when the subject, upon making his response, closed the contacts of a normally open push button switch. This closure triggered an input converter (Model 1211) which, in turn, activated a timer (Model 1223). The timer was set to deliver an output of one-second duration which was fed to both of two AND gates (Model 1213). Each of these AND gates received one input from a flip-flop (Model 1214) which was put in a set mode by the occurrance of the signal. One of the two AND gates was thereby armed each time a signal was presented. The arming of one or the other AND gate caused the signal from the timer to activate an output converter (Model 1222). A series circuit consisting of the relay contacts of the output converter (Model 1222), a 12-volt DC battery, and the feedback lights was closed when the output converter was activated. This closure illuminated for a period of one second the lights on the subject response box.

The length of the post-feedback interval, that is, the time between the cessation of feedback and the next signal, was controlled by a timer (Model 1223). The input converter (Model 1211) which was associated with that response was triggered when the subject responded. The output of the input converter started a timer (Model 1223) set for five seconds. At the end of this period, the output of the timer armed two

Figure 3.--Schematic representation of events in the program sequence.


Stimulus
Stimulus
Response
Variable Response Interval
Feedback
Postfeedback Interval
TIME

AND gates (Model 1213). At the same time, the output of the sequence counter (Model 1219) was being delivered to one or the other AND gate on a random schedule. That AND gate which was simultaneously receiving a pulse from the sequence counter and a pulse from the timer then fired to trigger another signal five seconds after the subject's response and four seconds after the cessation of feedback.

The initial signal in the test sequence was randomly selected and manually triggered by the experimenter. Thereafter, the program sequence was automatically recycled by the subject's response so that the program continued until ten successive correct responses were recorded, whereupon it was automatically terminated. The termination of the program was achieved by inverting the logic output of a preset counter (Model 1220) and delivering this logic to each AND gate in the system. The presence of inverted logic at the input of each AND gate disarmed them and prevented the continuation of the program.

Recording Apparatus

The subject responded by pressing one of two normally-open push button switches (Switch Craft, Model 101). The switches were symmetrically mounted on a 5" x 4" x 3" standard chasiss box. Above each button was a round one-half inch white light. The light provided the feedback which indicated to the subject which button she should have pressed. The light was illuminated with the onset of the subject's response and remained on for one second.

The closure of each button switch triggered its associated input converter (Model 1211) which, in turn, fired an AND gate (Model 1213). The output from each AND gate was delivered to a timer (Model

1223) which set the interval between the subject's response and the presentation of the next signal. Total correct and incorrect responses, as well as consecutively correct responses, were recorded. The total number of trials to criterion was recorded by directing the output of the two input converters (Model 1211) to a common OR gate (Model 1212). The output from the OR gate was then fed to a digital counter (Model 1215) which was advanced each time the subject responded.

Correct and incorrect responses were recorded independently. The outputs of the two timers (Model 1223) associated with the two response categories, that is, correct and incorrect, were fed to separate OR gates (Model 1212). The output of each OR gate was directed to an AND gate (Model 1213) which was selectively armed by a flip-flop (Model 1214). The flip-flop was triggered by the timer controlling the duration of the signal so that the signal's occurrence was represented at the set mode of one of the two flip-flops. When the subject responded, the input converter associated with that response triggered four AND gates, two of which were correlated with the occurrence of the signal and were active when a signal had been presented. The other two AND gates were correlated with the non-occurrence of the signal. Both groups of AND gates were terminated by counters (Model 1215). Each response fired one of the two pair of AND gates to result in either a correct or an incorrect count as that instance might have dictated.

Ten consecutively correct responses defined problem solution. The probability of obtaining this number of consecutively correct responses for a specified ten trials is 0.00098. This lével was considered to be low enough to warrant the use of ten consecutively correct responses as a measure of problem solution. The program was automatically terminated when ten consecutively correct responses were recorded. One of the AND gates associated with the correct response delivered its output to a sequence counter (Model 1219) and a preset counter (Model 1220). One of the AND gates associated with the incorrect response delivered its output to the reset mode of both the sequence counter and the preset counter. The preset counter was set for ten counts so that when ten successively correct responses had occurred the counter fired to terminate the program by disarming each AND gate in the system.

Experimental Control

Location of Equipment

All data gathering was accomplished in sound treated rooms located in the Speech and Hearing Center of the University of Oklahoma Health Sciences Center. The subject was seated in one room of a two-room suite while the equipment and experimenter were in the other. Communication between the two rooms when the double doors between them were closed was achieved by means of an audio intercom system as well as a window.

Performance of the Apparatus

Calibration measurements were made at regular intervals to monitor the performance characteristics of the equipment used in this investigation. Specifically, these measurements assured the calibration of signal frequency, duration, and intensity as well as the timing of events comprising the program sequence.

Signal Frequency

The signal frequency was either 250 or 1800 Hz. The frequency of the test signal was verified prior to the initial presentation of each problem if that problem required a frequency different from the one preceding it or if it was the first problem of a given test session. Signal frequency was verified by a counter-timer (Darcy Model 361A-R).

Signal Duration

The signal duration was either one second or three seconds. Each duration was controlled by its own timer and each timer triggered its own electronic switch. Signal duration was set with the aid of a counter-timer (Darcy Model 361-A-R).

Signal Intensity

The intensity of the 250 Hz signal was either 70 or 50-dB SPL. The intensity of the 1800 Hz signal was either 63 or 42-dB SPL. The high and low intensity values of each signal frequency represented equal loudness levels. Sound pressure levels re 0.0002 dyne/cm^2 were measured with a calibration unit consisting of a condenser microphone compliment (Western Electric Type 100 D/R) and a microphone housed in a 6 cc. coupler (Western Electric 640 AA microphone and National Bureau of Standards 9-A coupler). The output of the condenser microphone compliment was fed to a vacuum-tube voltmeter (Ballantine Model 643). The output level of the signal was monitored at the beginning of each test session.

Linearity of the Attenuators

The linearity of the attenuators (Hewlett Packard Model 350A) used with this apparatus was measured using a vacum-tube voltmeter. The signal was passed through the attenuator and its output read from the dB scale of the voltmeter (Ballantine Model 643). One attenuator was set for twenty decibels of attenuation when the linearity of the other attenuator was being measured. This was done to mitigate the possibility of one attenuator participating in the performance of the other attenuator due to reflected impedance changes at the transformer which terminated both attenuators. The results of these measurements indicated that both attenuators were linear throughout their operating range. The greatest error in any ten decibel step was less than one decibel while the greatest error within any one decibel step was 0.5 decibel.

Timing Relationships for the Program Sequence

The timing of the events constituting the program sequence was controlled by Grason Stadler ten-second timers (Model 1223). The accuracy of these timers was evaluated by determining the variation between their output as measured on a counter-timer (Darcy 361A-R) and the value specified on the timer dial. The output of the timers evaluated in this way over a series of fifty trials was found to be within the tolerance limits specified by the manufacturer.

Procedure

The present study was designed to investigate auditory stimulus saliency; that is, the rate at which the auditory dimensions of pitch, loudness, and duration are utilized in a concept identification task. Each of the above dimensions when relevant to problem solution represented a separate treatment condition. There were four problems under each of the three conditions. Each problem consisted of a series of stimuli each of which were characterized by the relevant dimension in combination with the other two dimensions. Only the magnitude of the relevant dimension varied from stimulus to stimulus within a given problem. The order in which the problems under each condition were presented was completely balanced. The order in which the treatment conditions were presented was partially balanced. The contingencies for all three conditions are presented in Figure 4.

When pitch was the relevant dimension, the signal was either 250 or 1800 Hz. Whether the signal was high or low in frequency was determined on a random schedule. Within each of the four problems these two frequencies were presented in various orders. Signal loudness, as well as duration, was held at a single magnitude value. The frequencies of 250 and 1800 Hz were selected because they were: (1) widely disparate and, hence, easily discriminable; and (2) used in previous concept identification research and consequently provide a basis for comparison between this study and others (Pishkin and Rosenbluh, 1968).

Care was taken to assure that the two frequencies of 250 and 1800 Hz were presented at equal loudness levels within and among problems. Equal loudness levels for 250 and 1800 Hz were determined by asking eight relatively sophisticated normal-hearing listeners to make a series of monaural equal loudness judgments. The averaged results of these judgments indicated that, at the "loud" level, a 70-dB SPL 250 Hz signal and a 63-dB SPL 1800 Hz signal were judged to be equally loud, while at the "soft" level, a 50-dB SPL 250 Hz signal and 42-dB SPL 1800 Hz signal were judged to be equally loud. Signal frequency and duration were held constant from trial to trial when loudness was the relevant dimension. Only intensity was varied between its loud and soft level. Whether the signal was loud or soft was determined on a random schedule. Similarly, when duration was the relevant dimension, the

Figure 4.—Combination of dimensions for the pitch, loudness, and duration condition.

PROBLEMS

DIMENSIONS	Problem 1	Problem 2	Problem 3	Problem 4
PITCH	Low / High Soft Long	Low / High Loud Short	Low / High Soft Short	Low / High Loud Long
LOUDNESS	Soft / Loud High Short	Soft / Loud High Long	Soft / Loud Low Long	Soft / Loud Low Short
DURATION	Short / Long Low Soft	Short / Long Low Loud	Short / Long High Soft	Short / Long High Loud

duration dimension varied from trial to trial while frequency and loudness levels were held constant. The two duration levels used were one second and three seconds.

The subject was seated in a chair in the test suite and given the response box to hold in her lap while the following instructions were read:

> Because of the nature of this experiment, only limited instructions will be given to you. No further information about what you are expected to do will be provided. After the experiment is completed, I will be happy to answer any questions you may have about the experiment or your performance. The experiment will take about one hour of your time.
>
> You are going to hear a series of tones. After you hear each tone, you are to respond by pressing one of the two buttons on the box in front of you. You will notice that above each button is a light. One of the lights will go on when you respond to each tone by pressing one of the buttons. The light will tell you which button you should have pressed. Listen for each tone. You may take as long as necessary to respond. The experiment will consist of twelve trial runs. I will tell you when each one will start and when it is finished.

After the instructions were read, the test earphone was placed on the subject's right ear with a dummy earphone on the left ear. The experimenter selected from a previously randomized schedule the problem order, starting order, and feedback order for each subject. The starting order schedule determined which of the two magnitude levels of the relevant dimension was to be presented first for each problem. Feedback order determined which push button switch on the subject response box was to be associated with which level of the relevant dimension.

The test session was begun when the experimenter asked the subject if she was ready. The initial signal was then presented. The remainder of the program sequence was controlled by the timing apparatus and was automatically terminated when the subject made ten consecutively correct responses. This procedure was repeated for each of the twelve problems.

Upon completion of the test session each subject was requested to refrain from discussing the details of the experiment with her fellow students. This was done to minimize the possibility that subject performance would be affected by prior knowledge of the experimental task.

Summary

This study was designed to determine the rate at which the auditory dimensions of pitch, loudness, and duration, as they are represented in a pure tone, are utilized in a concept identification task. Twenty-four normal-hearing adult females served as subjects for this investigation. The subjects' task was to learn which of two alternative responses was associated with each level of a relevant dimension.

The data yielded by the subjects using the procedures described above are presented and discussed in the following chapter.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The present investigation was designed to determine the rate at which the auditory dimensions of pitch, loudness, and duration, as they are represented in a pure tone, are utilized in a concept identification task. Twenty-four normal-hearing female adults served as subjects. Each subject was presented CI problems consisting of one bit of relevant information and no irrelevant information. Each one of the three auditory stimulus dimensions served as the relevant cue. Each dimension was combined with each of the other two dimensions generating a total of twelve problems; four for each dimension. Within a given problem, therefore, a subject received stimuli which varied in terms of either pitch (250 Hz or 1800 Hz), loudness (40 Phons or 60 Phons), or duration (one second or three seconds).

The subject's task was to make a two-alternative forced-choice response. Specifically, subjects were to sort or categorize each stimulus into one of two available response categories. Subjects were provided knowledge of results concurrent with their response. Stimulus presentations continued until ten consecutively correct responses were made. Performance was expressed by three response measures; that is, the number of errors, the number of trials, and the time required for the subject to solve the CI problem. Ten consecutively correct responses defined problem solution. These three response measures are the most commonly used in the study of concept learning and the correlations among them are invariably high (Bourne, 1957). Understandably, if the number of errors on a given problem is large, the number of trials and the time required for solution would also be large. It appears that all three measures are affected similarly by the important independent variables of an experiment. Bulgarella and Archer (1962) reported that errors, trials, and time to criterion increased in a parallel fashion with the difficulty of the task.

The data derived from this investigation are reported and discussed below. The initial discussion describes the general characteristics of the data. Subsequent sections discuss subject performance as measured by time to criterion, errors to criterion, and trials to criterion.

General Characteristics of the Data

A summary of the data is presented in Table 1. An examination of the means, standard deviations, and variance indicates a difference in the distribution of scores for the three response variables within and across dimensions. It is noted, for example, that the variance of scores for a given measure differs across dimensions. The variance is smallest for pitch, next smallest for loudness, and largest for duration. An examination of the three response variables indicates that the measures of errors and trials to criterion are not normally distributed. The mean number of trials for pitch is approximately eleven

TABLE 1

MEANS, STANDARD DEVIATIONS, AND VARIANCE OF TRIALS, ERRORS, AND TIME TO CRITERION FOR THE DIMENSIONS OF PITCH, LOUDNESS, AND DURATION

Measure of Performance to Criterion		Dimension: Pitch	Dimension: Loudness	Dimension: Duration
	Mean	11.10	11.82	13.88
Trials	S.D.	1.41	3.70	8.95
	Var.	1.99	13.75	80.14
	Mean	0.83	1.11	2.31
Errors	S.D.	0.76	1.94	5.28
	Var.	0.58	3.76	27.90
	Mean	68.16	73.28	91.80
Time	S.D.	12.67	29.09	51.21
	Var.	160.55	846.37	2622.16

or one more than perfect performance in a task where ten trials represented the minimum number of trials required to reach criterion. The standard deviation for the same condition is slightly greater than one, suggesting that the majority of subjects performed close to this mean value. A similar pattern is seen for errors to criterion, especially for the dimensions of pitch and loudness. The relevance of these observations lies in the choice of the appropriate statistical model employed to treat the data.

Because of the apparent skewedness of values on the measures of errors and trials to criterion, the data reported here were treated using nonparametric statistics. The distribution of values for time to criterion, however, were thought to approximate a normal distribution so that parametric analysis could be employed.

As previously indicated, each subject received four problems for each of the three relevant dimensions and each problem contained the relevant dimension in combination with the other two dimensions. The question might be asked if the way in which the dimensions were combined influenced the rate at which the relevant dimension was identified. To investigate this possibility, subjects' scores for each of the four problems under each dimension were compared. For the measures of errors and trials to criterion, these comparisons were treated using a Wilcoxon Matched-Pairs Sign-Rank Test (Siegel, 1956). For the measure of time to criterion, these comparisons were treated using a paired T test (Li, 1964). For errors and trials to criterion, none of the differences among problems were significant at the 0.05 level. For the measure of time to criterion, two of the loudness problems were found to be significantly different at the 0.05 level. Within this investigation, therefore, it appears that the way in which dimensions are combined does not significantly influence the rate at which the relevant dimension is identified.

A detailed presentation of the data is made in the subsequent sections of this chapter. Time to criterion data are presented first followed by errors and then trials to criterion.

Time to Criterion

Time to criterion is a measure of performance commonly used in the study of conceptual behavior. This measure is defined in the present investigation by that period of time which elapsed between the onset of the initial signal presented to the subject and the onset of the tenth consecutively correct response. For each trial, this period included the signal, the time required for the subject to respond to the signal, and a fixed four-second post-feedback interval. Unlike the measures of errors or trials to criterion where a minimum level of performance could be specified, that is, zero errors or ten trials to criterion, no analagous level could be specified for time. In other words, it was not possible to state precisely the least amount of time any subject should require to attain criterion performance.

The limiting factors in the measurement of time to criterion were the fixed four-second post-feedback interval and the number of one-second and three-second stimulus patterns presented to the subject. Half of the loudness and pitch problems presented to a subject were one second, while the other half were three seconds in duration. When the duration dimension was relevant, the presentation of one or the other stimulus duration was, of course, determined on a random schedule. When loudness or pitch was the relevant dimension, the subject could respond anytime after the onset of the signal, regardless of its duration. When duration was the relevant dimension, however, the subject had to wait a minimum of one-second plus in order to determine whether the signal was to be assigned to the one-second or three-second category. The duration dimension, therefore, might be expected to yield a longer time to criterion than either pitch or loudness. Further, the differences between dimensions shown on this measure may reflect the additional time necessary to make a duration judgment rather than a difference in problem difficulty.

The means, standard deviations, and variance of time to criterion for pitch, loudness, and duration are presented in Table 2. The means of these dimensions for each problem are represented graphically in Figure 5 and indicate a pronounced dimension by problem order interaction. The shape of the function for time to criterion will be shown later to be similar to that seen for trials and errors to criterion. This suggests that the additional time requirement inherent in the duration problems is not sufficient to explain the differences among the three dimensions, at least, not for the first two problems. The apparent difficulty of the duration dimension evident on the first two problems is manifested not only in a longer time to criterion, but also in more errors and, consequently, more trials to criterion.

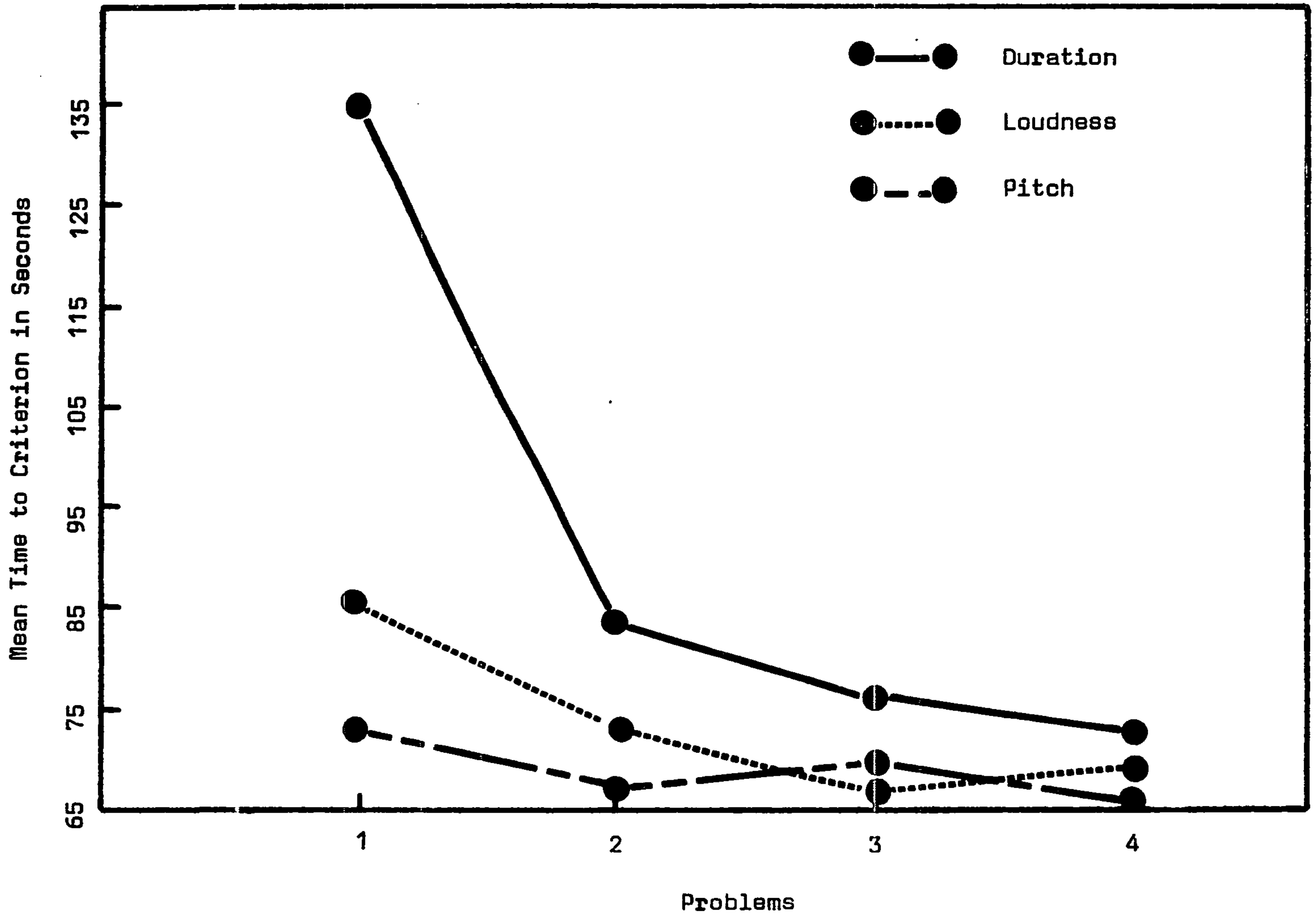
Because of the large magnitude of the differences among dimensions on problem one, differences among dimensions were investigated by summing the scores across problems two, three, and four. These data

TABLE 2

MEANS, STANDARD DEVIATIONS, AND VARIANCE OF TIME
TO CRITERION IN SECONDS FOR PITCH,
LOUDNESS, AND DURATION

		Problem Order				
Stimulus Dimension		1	2	3	4	$G\bar{X}$
	Mean	72.46	66.50	69.62	64.04	
Pitch	S.D.	14.42	11.32	14.37	9.91	62.16
	Var.	207.99	128.17	206.39	98.22	
	Mean	85.33	72.46	66.66	68.67	
Loudness	S.D.	48.04	27.20	11.38	9.95	73.28
	Var.	2307.71	739.65	129.45	98.93	
	Mean	135.17	82.08	77.50	72.46	
Duration	S.D.	87.32	19.57	9.40	8.37	91.80
	Var.	7624.49	383.12	88.35	69.99	
	$G\bar{X}$	97.65	73.68	71.26	68.39	

Figure 5.—Mean values of time to criterion in seconds for pitch, loudness, and duration for problems one, two, three, and four.


Duration
Loudness
Pitch
Mean Time to Criterion in Seconds
135
125
115
105
95
85
75
65
1
2
3
4
Problems

were treated using an analysis of variance (single factor with repeated measures on the same element, Winer, 1962). Each dimension was represented as a treatment and the three problems under each dimension were considered as a duplicate of that treatment. The means of these duplicates were used as the response variable for each subject under each treatment. The results of this analysis are presented in Table 3 and

TABLE 3

SUMMARY OF THE ANALYSIS OF VARIANCE OF TIME TO CRITERION FOR PITCH, LOUDNESS, AND DURATION POOLED OVER PROBLEMS TWO, THREE, AND FOUR

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Subjects	23	8080.89	351.34	1.54
Treatments (Dimensions)	2	4432.58	2216.29	9.74*
Error	46	10466.53	227.53	1.19

* Significant at 0.01 level

indicate a significant difference among dimensions summed over problems two, three, and four.

The F value of 9.74 for treatments (dimensions) is significant at the 0.01 level. The effect of subjects was not significant at the 0.05 level. The means for pitch, loudness, and duration were 66.72, 69.26, and 77.34 seconds, respectively. These values were compared using a Duncan's New Multiple Range Test (Li, 1956). Duration and pitch were found to be significantly different at the 0.05 level. There was no statistical difference between duration and loudness or pitch and loudness at the 0.05 level.

Differences among dimensions within each of the four problems were examined using an analysis of variance (single factor, randomized block, Winer, 1962). The results of this analysis are summarized in Table 4 and indicate a significant difference among dimensions for all problems at the 0.05 level or beyond. Clearly, the measurements used in these tests are not independent of the means of the three problems reported in Table 3. An analysis of these measurements, however, was made to provide additional information about the effect of problem order. An examination of Figure 5 indicates that the duration dimension resulted in a longer time to criterion than either pitch or loudness. A similar comparison of errors and trials to criterion (shown in Figures 6 and 7) indicates differences only for the first two problems. This finding suggests that the longer time for duration on the third and fourth problem could well be accounted for by the additional time required to make duration judgments and, therefore, may not reflect a difference in problem difficulty.

The effect of problem order was investigated by comparing the means for each of the four problems for each dimension. This data was treated using a Duncan's New Multiple Range Test (Li, 1964). For the pitch and loudness dimensions, there was a significant difference only between problems one and four at the 0.05 level. For the duration dimension, there was a significant difference at the 0.01 level between the first problem and all succeeding problems. The time required for problem solution over all dimensions decreased from the first to the last problem. This decrease in time is most apparent between the first

TABLE 4

SUMMARY OF THE ANALYSIS OF VARIANCE OF TIME TO CRITERION FOR PITCH, LOUDNESS, AND DURATION FOR PROBLEMS ONE, TWO, THREE, AND FOUR

	Problem One			
Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Subjects	23	77566.32	3372.45	0.99
Treatments (Dimensions)	2	52651.69	26325.85	7.78*
Error	46	155658.30	3383.88	

* Significant at the 0.01 level

	Problem Two			
Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Subjects	23	9084.99	394.99	0.92
Treatments (Dimensions)	2	2967.86	1483.93	3.47*
Error	46	19686.80	427.97	

* Significant at the 0.05 level

	Problem Three			
Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Subjects	23	3499.32	152.14	1.20
Treatments (Dimensions)	2	1505.03	752.51	5.96*
Error	46	5803.64	126.17	

* Significant at the 0.01 level

	Problem Four			
Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Subjects	23	2719.11	118.22	1.59
Treatments (Dimensions)	2	852.86	426.43	5.72*
Error	46	3425.14	74.46	

* Significant at the 0.01 level

Figure 6.--Mean values of errors to criterion for pitch, loudness, and duration for problems one, two, three, and four.

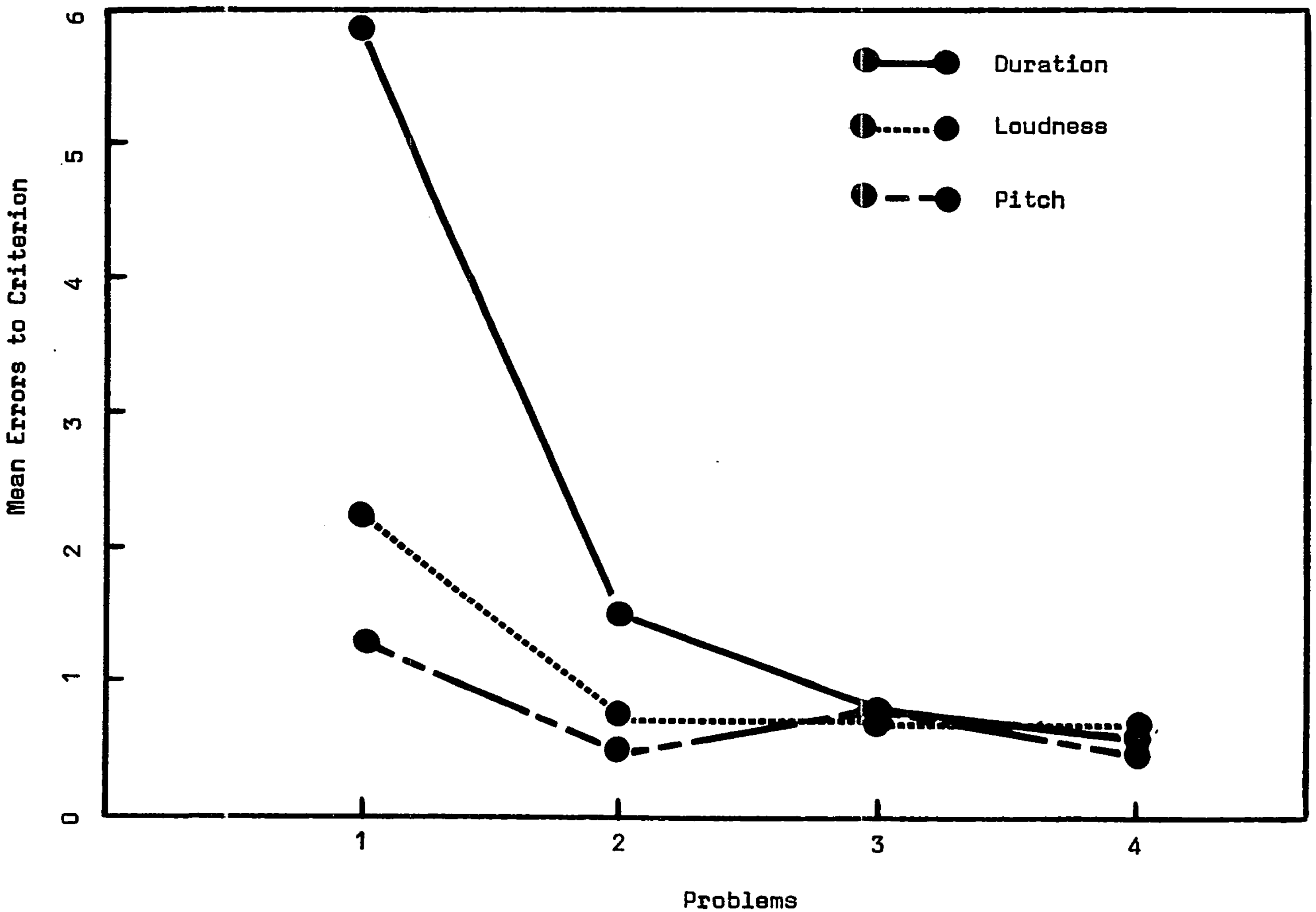
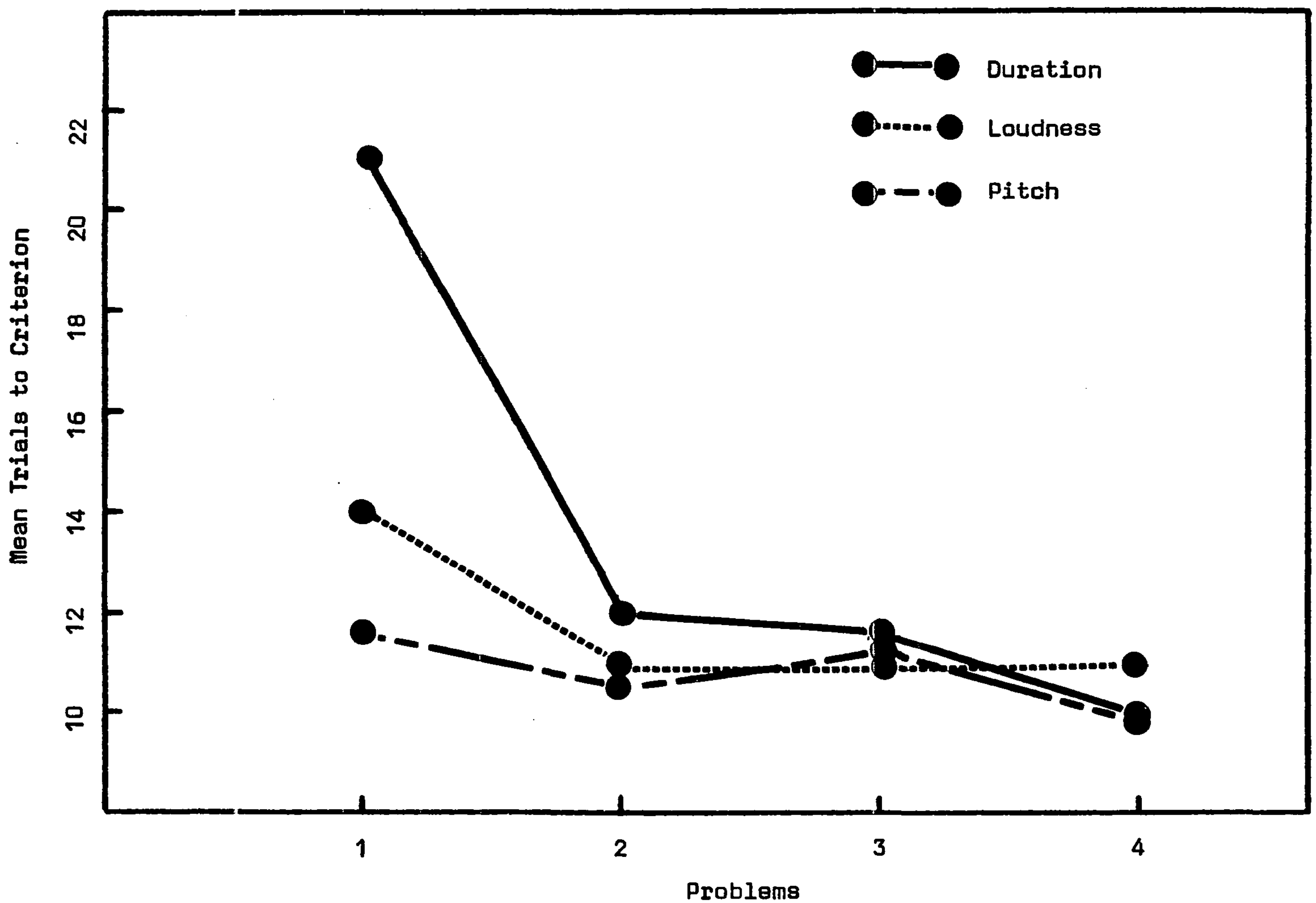

Duration
Loudness
Pitch
Mean Errors to Criterion
0
1
2
3
4
5
6
1
2
3
4
Problems

Figure 7.--Mean values of trials to criterion for pitch, loudness, and duration for problems one, two, three, and four.


Duration
Loudness
Pitch
Mean Trials to Criterion
22
20
18
16
14
12
10
1
2
3
4
Problems

and second problem. This kind of function is not uncommon in learning studies and is thought to reflect a "learning to learn" phenomenon. Learning to learn or the development of a learning set from the subject's point of view involves the application of previously learned strategies to a new problem. The transfer of training from old to new with repeated exposure to most problems becomes more complete and is reflected in improved performance. The effect of this kind of learning is minimized in some experiments by allowing the subject to practice the problem task prior to the collection of data. In the present investigation, however, these effects were ostensibly encouraged by giving subjects only limited instructions and very little information about the nature of the experimental task. If the decrease in time to criterion seen between problems one and two does reflect a kind of learning to learn phenomenon, exposure to duration problems appears to be less facilitative to such transfer of training or the development of a learning set than is either pitch or loudness.

One conclusion which can be drawn from these results is that there is a difference in the time required for the solution of concept identification problems based on pitch, loudness, and duration. Further, these differences are modified by problem order. There is a larger difference among dimensions for the initial exposure to the task than there is for subsequent problems. It is suggested that the greater time to criterion shown on the duration dimension for problems three and four may reflect the additional time required to make a duration judgment rather than a difference in problem difficulty.

Errors to Criterion

The means, standard deviations, and variance of errors to criterion for the three experimental dimensions by problem order are shown in Table 5. A graphic display of the mean number of errors by problems was presented earlier in Figure 6. An examination of these scores indicates an interaction between dimensions and problem order. There is a decrease in errors between the first problem and the last problem for all dimensions. The greatest reduction in errors is seen between problems one and two. This decrease is most pronounced for duration. A comparable improvement in performance over problems was previously noted for time to criterion. Again, it is suggested that this reduction in errors and in time to criterion reflects the subjects' increased familiarity with the task variables.

Differences among dimensions for each problem were tested using a Friedman analysis of variance (Siegel, 1956). Differences among the three dimensions in problems one and two were significant at the 0.025 level. In contrast to the measure of time to criterion, there were no significant differences at the 0.05 level among dimensions in the case of problem three or four. This finding is interpreted to mean that the increased time shown in the case of duration on these problems probably reflects the longer time required for duration judgments rather than an increase or difference in problem difficulty.

A comparison of the errors for pitch and loudness in problems one and two was made using a Wilcoxon Matched-Pairs Sign-Rank Test (Siegel, 1956). The difference between the two dimensions on the first problem was significant at the 0.01 level. The differences as seen in

TABLE 5

MEANS, STANDARD DEVIATIONS, AND VARIANCE OF ERRORS TO CRITERION FOR PITCH, LOUDNESS, AND DURATION

Stimulus Dimension		Problem Order 1	2	3	4	$G\bar{X}$
	Mean	1.33	0.54	0.88	0.58	
Pitch	S.D.	0.96	0.59	0.61	0.58	0.83
	Var.	0.93	0.35	0.38	0.34	
	Mean	2.25	0.71	0.71	0.79	
Loudness	S.D.	3.47	0.81	0.69	0.78	1.12
	Var.	12.02	0.65	0.48	0.61	
	Mean	6.29	1.46	0.88	0.62	
Duration	S.D.	8.67	1.44	0.85	0.77	2.31
	Var.	75.17	2.08	0.72	0.59	
	$G\bar{X}$	3.29	0.90	0.823	0.66	

the second problem were significant at the 0.05 level. In both cases, more errors were made for loudness than pitch. Differences between the duration dimension and the other two dimensions were not tested because of the apparent magnitude of these differences. For both problems one and two, duration resulted in about twice as many errors as did pitch or loudness.

The effect of problem order was investigated by comparing the number of errors made on each of the four problems of each dimension. This data was treated using a Friedman analysis of variance. The results of this analysis indicated a significant effect for problem order within each of the three dimensions. Differences between problems within each of the three dimensions were significant at the 0.01 level.

The relationship between the correct response category and the level of the relevant dimension associated with that category for any given problem was determined on a random schedule. This meant that there was a fifty per cent probability that the subjects's first response would be correct. If it could be assumed that each subject learned the task on the basis of her initial response, then optimal or perfect performance would be represented by an average of 0.5 errors for any given problem. This number of errors assumes that one-half of the subjects correctly identified the first stimulus presentation and one-half of them did not. It also assumes that no errors were made on subsequent identifications. A description of the number of subjects making zero, one, two, and three or more errors in each problem of each dimension is presented in Table 6. This data shows that 58 per cent of the subjects made one error or less on the first pitch problem. In other words, more

TABLE 6

NUMBER OF SUBJECTS MAKING 0, 1, 2, 3, OR MORE ERRORS
ON PROBLEMS ONE, TWO, THREE, AND FOUR

Problems	Errors for Pitch 0	1	2	3 or more	% of S's with 1 or less errors
1	5	9	7	3	58
2	12	11	1	0	96
3	6	15	3	0	88
4	11	12	1	0	96

Problems	Errors for Loudness 0	1	2	3 or more	% of S's with 1 or less errors
1	3	7	10	4	42
2	11	10	2	1	88
3	10	11	3	0	88
4	10	9	5	0	79

Problems	Errors for Duration 0	1	2	3 or more	% of S's with 1 or less errors
1	2	5	3	14	29
2	4	12	5	3	67
3	9	10	4	1	79
4	13	7	4	0	83

than half of the subjects were functioning at a near optimal performance level in their first exposure to the problem task. More than eighty-seven per cent of the subjects were functioning at a near optimal level of performance on problems two, three, and four. An approximation of this level of performance is seen in the case of the other two dimensions. The percentage of subjects operating at this level is generally less for all duration problems in contrast to loudness and pitch problems. The observation that substantially more than one-half of the subjects were performing at a near optimal level after one exposure to the experimental task suggests that the task was quite easy for the college-educated adult female subjects used in this investigation.

Trials to Criterion

The measure of trials to criterion can be expected to provide essentially the same information about subject performance as does the measure of errors to criterion. It is possible, however, for the two measures to differ because of the fact that the number of trials a given subject requires to solve a problem is dependent not only upon how many errors are made but when they are made. Two subjects, for example, could have the same error score and yet require a grossly different number of trials to reach criterion, depending upon when in the trial sequence the errors are made. If one subject made an error on each of the first two trials, the total number of trials to criterion would be twelve. If, on the other hand, another subject made an error on the first and on the ninth trial, the total number of trials would be nineteen. The data of the present investigation indicate that most of the errors were made early in the trial sequence. Consequently, the two measures of performance agree well.

The means, standard deviations, and variance of trials to criterion is presented in Table 7. A graphic display of the mean values across problems was presented earlier in Figure 7. The shape of this function is comparable to that seen for the measures of time and errors to criterion and indicates a dimension by problem order interaction. The greatest improvement in performance is seen between problems one and two for all dimensions.

Differences among dimensions within a given problem were evaluated using a Friedman analysis of variance (Siegel, 1956). The differences among dimensions on problems one and two were significant at the 0.01 level. The same analysis of problems three and four showed no differences among the three dimensions at the 0.05 level. The difference between the dimensions of pitch and loudness on problems one and two was tested using a Wilcoxon Matched-Pairs Sign-Rank Test (Siegel, 1956). Although these measurements were not independent of those used in the Friedman analysis of variance reported above, they were evaluated to provide more specific information about differences among dimensions within problems. The difference between the two dimensions in problem one was significant at the 0.01 level. The same difference in problem two was significant at the 0.02 level. In both cases, there were more errors for loudness than pitch. The difference between the duration dimension and the other two dimensions was not tested because of the apparent magnitude of the difference on the first two problems. With the exception of problem four, duration required more trials to criterion than did either loudness or pitch.

TABLE 7

MEANS, STANDARD DEVIATIONS, AND VARIANCE OF TRIALS TO CRITERION FOR PITCH, LOUDNESS, AND DURATION

Stimulus Dimension		Problem Order 1	2	3	4	$G\overline{X}$
	Mean	11.83	10.71	11.29	10.58	
Pitch	S.D.	1.63	0.95	1.80	0.58	11.10
	Var.	2.67	0.91	3.26	0.34	
	Mean	13.96	11.46	10.83	11.04	
Loudness	S.D.	6.40	2.65	1.00	1.12	11.82
	Var.	40.91	7.04	1.01	1.26	
	Mean	21.08	12.33	11.46	10.67	
Duration	S.D.	15.63	3.14	1.61	0.87	13.88
	Var.	244.25	9.88	2.61	0.75	
	$G\overline{X}$	15.62	11.50	11.19	10.76	

The effect of problem order was investigated by comparing the number of trials required to solve each problem of each dimension. These data were treated using a Friedman analysis of variance (Siegel, 1956). The results of this analysis indicated that the effect of problem order for each of the three dimensions was significant at or beyond the 0.05 level.

The number of subjects requiring ten, eleven, twelve, thirteen, or more trials for each of the four problems is presented in Table 8. This data indicates that, after the first problem, fifty per cent of the subjects solved all subsequent problems in eleven trials or less. This represents a near optimal level of performance and suggests the relative simplicity of the experimental task for the adult female subjects who participated in this investigation.

In summary, duration, in contrast to loudness and pitch, was the most difficult concept to learn in the context of this experiment. Pitch was the least difficult. After repeated exposure to the CI problems, however, there was little, if any, difference in the rate at which the dimensions of pitch, loudness, and duration were utilized in the experimental task. CI problems with one bit of relevant information and no irrelevant information, as used in this investigation, represented a relatively simple task for the adult female subjects participating in the study.

Discussion

It was originally hypothesized that there would be no difference in the rate at which the dimensions of pitch, loudness, and duration are utilized in a concept identification task. The results of this

TABLE 8

NUMBER OF SUBJECTS REQUIRING TEN, ELEVEN, TWELVE, THIRTEEN, OR MORE TRIALS FOR PROBLEMS ONE, TWO, THREE, AND FOUR

Problems	Trials for Pitch 10	11	12	13 or more	% of S's with 11 or less trials
1	5	7	6	6	50
2	12	9	2	1	88
3	6	13	3	2	79
4	11	12	1	0	96

Problems	Trials for Loudness 10	11	12	13 or more	% of S's with 11 or less trials
1	3	5	3	13	33
2	11	7	3	3	75
3	10	11	1	2	88
4	10	6	6	2	67

Problems	Trials for Duration 10	11	12	13 or more	% of S's with 11 or less trials
1	2	2	2	18	17
2	4	8	7	5	50
3	9	7	1	7	67
4	13	7	3	1	83

study have not supported that hypothesis. Significant differences were found in the rate at which the three dimensions were identified for the subjects' first and second exposure to the problem task. For problems one and two, the duration dimension produced more errors, more trials, and a longer time to criterion than did either pitch or loudness. Loudness problems produced more errors, more trials, and a longer time to criterion than did pitch.

A majority of the subjects were functioning at or near an optimal level of performance after having solved two CI problems. This finding suggests that the experimental task used in this investigation may not have been sufficiently difficult to differentiate between dimensions as factors in concept identification.

There was a significant effect for problem order for all three dimensions. Subjects made more errors and required a longer time to criterion on their first exposure to a CI problem than on subsequent problems. There was an interaction between dimensions and problem order. Between problems one and two, there was a greater improvement shown on the duration dimension than on the dimensions of pitch and loudness.

It was anticipated that an analysis of the three response variables, i.e., errors to criterion, trials to criterion, and time to criterion, would result in similar conclusions regarding subject performance. The two measures of errors and trials to criterion, however, yielded a different profile of performance than did the measure of time to criterion. An analysis of time to criterion indicated a significant difference among the three dimensions for all four problems. An analysis of errors and trials, on the other hand, indicated differences among the three dimensions for the first two problems only. This difference in results among the three measures was attributed to the additional time required for duration judgments as compared to the identification of pitch and loudness. It is suggested that the measures of errors and trials to criterion more accurately reflect the relative difficulty of the three dimensions because of the additional time "built into" the duration problems.

There is nothing in the auditory CI literature which would lead one to expect the magnitude of differences shown among the three dimensions on the first two problems. Pishkin and Shurley (1965) reported that female subjects made more errors on the duration dimension than on the dimensions of pitch and laterality. This result, however, was obtained for a condition with varying amounts of irrelevant information and was attributed to an interaction between the relevant and irrelevant dimensions. When duration was the relevant dimension and number was the irrelevant dimension, subjects apparently placed a three-second stimulus in the same category as two one-second stimuli which were separated by a one-half second interval. The absence of irrelevant information in the present investigation precludes a similar explanation for the results shown.

The reason why duration initially was found to be a more difficult dimension to identify than either pitch or loudness is not readily apparent. It may have been that duration was not immediately perceived by subjects as a separate response category or class of stimuli. Hence, one and three-second signals were interpreted by subjects to be an extension of the dimensions of pitch and loudness. A three-second stimulus may have been considered as simply "more of the same" loudness or pitch as a one-second stimulus.

All three of the previous investigations of auditory stimulus saliency have shown differences in the rate at which dimensions are utilized in a concept identification task. All of these studies have used either errors or trials to criterion as a measure of subject performance. Two of the three studies used subjects, dimensions, and levels of problem complexity which were comparable to those employed in the present investigation (Pishkin and Blanchard, 1964 and Pishkin and Rosenbluh, 1965). Both of these studies reported loudness to be the least salient dimension. In the first of these studies, the mean number of errors made by female subjects were: one for frequency, one for duration, and ten for loudness. Pishkin and Rosenbluh used young adult subjects and reported four errors for duration, five for frequency, and twenty errors for loudness. The younger subjects in Pishking and Rosenbluh's study produced about twice as many errors as did Pishkin and Blanchard's older subjects. The mean age of the younger group was about sixteen years while the mean age of the older group was 39 years. The difference in results between the two studies may have been related to this difference in the age of the subjects. Both studies, however, showed roughly the same proportion of errors across comparable dimensions.

The reason for the difference in the results between these two studies and the present investigation may have been due to several factors. Pishkin and Blanchard used a 1000 Hz or 3000 Hz pure tone presented at 30 or 60 dB. No reference intensity was given for these values. Pishkin and Rosenbluh used a 250 Hz pure tone presented at 65 or 80 dB SPL. The present investigation employed either a 250 Hz or 1800 Hz pure-tone signal presented at a loudness level either of 40 or 60 Phons. Although the previous studies did not report any attempt to equate loudness levels at the two frequencies, the intensity differences in their signals were similar to the levels used in the present investigation. It would, therefore, appear unlikely that the differences in subject performance on the loudness dimension are related to a difference in the loudness levels presented to the subjects in the three experiments.

The observation that subjects in all three experiments were presented with comparable loudness differences and yet performed differently suggests that such differences were not equally apparent to all of the subjects. The reason for this may relate to the characteristics of the experimental population used in these investigations. Neither Pishkin and Blanchard or Pishkin and Rosenbluh controlled for the possibility of variations in hearing sensitivity in their subject sample. It previously has been suggested that the effect of such variations may be to minimize the value of loudness cues in eliciting a differential response. This possibility was controlled in the present study by testing the subjects' hearing prior to their inclusion in the subject sample.

Another possible reason for the differences across studies observed on the loudness dimension may relate to the homogeneity of the subject sample with respect to their educational level and previous musical training. A large majority of the subjects in this experiment reported having had at least three years of formal musical training.

Further, all of the subjects used in the experiment were graduate students in either Audiology, Speech Pathology, or Deaf Education at The University of Oklahoma Health Sciences Center. It may be that the kind of training received in these areas of professional preparation tends to produce a relatively sophisticated subject for an auditory concept identification task.

A summary of the entire investigation reported here, along with a few concluding remarks, is presented in the next and final chapter.

CHAPTER V

SUMMARY

Introduction

Auditory communication among human beings is dependent upon the organism's ability to perceive, discriminate, and utilize information contained in the auditory signal. This signal can be defined in terms of its physical and psychological parameters. It is of interest to be able to describe how they are utilized in the communication process. In spite of the fact that the processes attendant to the development and use of concepts play a major role in most forms of communication, there is relatively little known about how specific auditory dimensions are utilized in a simple CI task.

An understanding of the way in which normal-hearing individuals utilize specific auditory dimensions in the kind of task used in this experiment may make it possible to determine ways in which a hearing impairment affects this part of the communication process. The present investigation was designed to further delineate normative data.

Experimental Design

The purpose of the present investigation was to determine the rate at which the dimensions of pitch, loudness, and duration, as represented in a pure-tone stimulus are utilized in a concept identification task. Twenty-four normal-hearing adult female subjects were presented with twelve CI problems each containing one bit of relevant information and no irrelevant information. Either pitch, loudness, or duration was the relevant dimension in each problem. The subjects' task was to sort each of the stimulus presentations comprising a problem into one of two available response categories on the basis of the relevant dimension. Problem solution was defined as ten consecutively correct responses.

The instrumentation used in this investigation consisted of modular programming equipment and apparatus for generating and controlling the frequency, intensity, and duration of a pure-tone signal. The series of events comprising the test sequence consisted of the pure-tone signal, a subject-determined response interval, the subject's response, and feedback. All of the events in the test sequence with the exception of the response interval were controlled by the programming apparatus. The total number of correct and incorrect responses was tabulated and recorded by the equipment. The program automatically terminated the presentation of stimuli when ten consecutively correct responses occurred. Subject performance was measured in terms of the number of errors, the number of trials, and the elapsed time (in seconds) to criterion.

Results and Conclusions

The results of this study indicate that differences existed in the rate at which the dimensions of pitch, loudness, and duration, as represented in a pure-tone signal, were utilized by adult female subjects in a two-alternative, forced-choice concept identification task. Specifically, duration, when it was an initial problem in the series of problems which subjects were required to solve, was found to be a more difficult dimension to identify than either loudness or pitch. The dimension of pitch was easiest to identify. After repeated exposure to the auditory CI problems, however, no significant differences across dimensions were observed. Differences in subject performance across dimensions, therefore, were seen only in the initial CI problems which subjects were called upon to solve.

The above conclusions are drawn in spite of the fact that the response measure of time to criterion provided a somewhat different profile of subject performance than did either of the other two response measures. In contrast to the measures of trials and errors to criterion, an analysis of the measure of time to criterion showed differences between subject performance on the duration dimension and performance on the other two dimensions for problems three and four. The apparent difference between the measure of time to criterion and the other two measures when examining subject performance on duration problems three and four was attributed to the longer time required of the subject in making a duration judgment and, therefore, was thought not to reflect a real difference in the difficulty of those problems.

The observation that substantially more than one-half of the subjects were functioning at a near optimal level of performance after having solved only two problems suggested that the experimental task was quite easy for the subjects participating in this study.

The results of this study do not completely agree with those of previous investigations of auditory stimulus saliency. Such studies have all reported consistant differences in the rate at which auditory dimensions are identified in a CI task. It is suggested that the difference in results between these studies and the present investigation may have been due to the way in which the present investigation controlled for extraneous factors in the presentation of stimuli and in the selection of experimental subjects.

Suggestions for Further Research

The present study was designed to provide normative data on the utilization of non-verbal auditory dimensions in a concept identification task. It is suggested that a comparison of this data with that obtained from hearing-impaired subjects on the same task may provide information about the effect of hearing loss on an individual's ability to utilize certain auditory cues. The following suggestions for further research are offered as an extension of the original purpose of this investigation:

1. Replication of the present investigation using a matched sample of male subjects to determine the effects of the subject's sex on the rate of identification of auditory stimulus dimensions.

2. Replication of this study across different subject age groups to determine the effect of age on the saliency of auditory stimulus dimensions.

3. A study of the saliency of auditory stimulus dimensions in hearing-impaired subjects.

4. A study of the saliency of auditory stimulus dimensions as a function of the degree of hearing loss.

5. A study of the saliency of analogous visual stimulus dimensions.

6. A study of the saliency of analogous tactile stimulus dimensions.

7. A study of the saliency of various combinations of analogous auditory, visual, and tactile stimulus dimensions to determine factors of facilitation and inhibition.

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APPENDIX

TABLE 9

INDIVIDUAL SUBJECT DATA ON THE PITCH DIMENSION:
TIME TO CRITERION IN SECONDS

Subject	Problem	Time	Subject	Problem	Time
1	1	58.00	9	1	101.00
	2	73.00		2	70.00
	3	73.00		3	73.00
	4	56.00		4	82.00
2	1	92.00	10	1	64.00
	2	80.00		2	55.00
	3	69.00		3	61.00
	4	60.00		4	62.00
3	1	65.00	11	1	86.00
	2	66.00		2	54.00
	3	67.00		3	112.00
	4	63.00		4	62.00
4	1	66.00	12	1	66.00
	2	91.00		2	62.00
	3	83.00		3	58.00
	4	62.00		4	56.00
5	1	58.00	13	1	80.00
	2	52.00		2	67.00
	3	53.00		3	73.00
	4	55.00		4	63.00
6	1	57.00	14	1	64.00
	2	54.00		2	63.00
	3	58.00		3	59.00
	4	51.00		4	63.00
7	1	65.00	15	1	94.00
	2	60.00		2	62.00
	3	68.00		3	63.00
	4	77.00		4	62.00
8	1	52.00	16	1	73.00
	2	55.00		2	66.00
	3	65.00		3	65.00
	4	55.00		4	78.00

TABLE 9--Continued

Subject	Problem	Time	Subject	Problem	Time
17	1	79.00	21	1	55.00
	2	63.00		2	57.00
	3	67.00		3	79.00
	4	66.00		4	90.00
18	1	66.00	22	1	63.00
	2	91.00		2	67.00
	3	90.00		3	56.00
	4	79.00		4	54.00
19	1	76.00	23	1	94.00
	2	69.00		2	63.00
	3	63.00		3	92.00
	4	61.00		4	63.00
20	1	70.00	24	1	95.00
	2	89.00		2	67.00
	3	55.00		3	69.00
	4	59.00		4	58.00

Mean	68.1562
Variance	160.5542
Std. Dev.	12.6710

TABLE 10

INDIVIDUAL SUBJECT DATA ON THE PITCH DIMENSION: ERRORS TO CRITERION

Subject	Problem	Errors	Subject	Problem	Errors
1	1	.00	9	1	2.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	1.00		4	.00
2	1	.00	10	1	1.00
	2	.00		2	.00
	3	1.00		3	1.00
	4	1.00		4	1.00
3	1	2.00	11	1	3.00
	2	1.00		2	.00
	3	1.00		3	2.00
	4	1.00		4	1.00
4	1	.00	12	1	1.00
	2	1.00		2	1.00
	3	1.00		3	.00
	4	.00		4	.00
5	1	1.00	13	1	1.00
	2	.00		2	.00
	3	.00		3	1.00
	4	.00		4	1.00
6	1	1.00	14	1	2.00
	2	.00		2	1.00
	3	.00		3	1.00
	4	1.00		4	1.00
7	1	2.00	15	1	2.00
	2	.00		2	1.00
	3	.00		3	1.00
	4	.00		4	1.00
8	1	.00	16	1	1.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	.00		4	.00

TABLE 10--Continued

Subject	Problem	Errors	Subject	Problem	Errors
17	1	3.00	21	1	.00
	2	1.00		2	.00
	3	2.00		3	2.00
	4	1.00		4	1.00
18	1	1.00	22	1	2.00
	2	1.00		2	.00
	3	1.00		3	.00
	4	2.00		4	.00
19	1	2.00	23	1	1.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	.00		4	.00
20	1	3.00	24	1	1.00
	2	2.00		2	1.00
	3	.00		3	1.00
	4	1.00		4	.00

Mean	.8333
Variance	.5824
Std. Dev.	.7631

TABLE 11

INDIVIDUAL SUBJECT DATA ON THE PITCH DIMENSION: TRIALS TO CRITERION

Subject	Problem	Trials	Subject	Problem	Trials
1	1	10.00	9	1	12.00
	2	12.00		2	10.00
	3	11.00		3	11.00
	4	11.00		4	10.00
2	1	10.00	10	1	11.00
	2	10.00		2	10.00
	3	11.00		3	11.00
	4	11.00		4	11.00
3	1	12.00	11	1	14.00
	2	11.00		2	10.00
	3	11.00		3	19.00
	4	11.00		4	11.00
4	1	10.00	12	1	11.00
	2	11.00		2	11.00
	3	11.00		3	10.00
	4	10.00		4	10.00
5	1	11.00	13	1	12.00
	2	10.00		2	10.00
	3	10.00		3	12.00
	4	10.00		4	11.00
6	1	11.00	14	1	12.00
	2	10.00		2	11.00
	3	10.00		3	11.00
	4	11.00		4	11.00
7	1	12.00	15	1	16.00
	2	10.00		2	11.00
	3	10.00		3	11.00
	4	10.00		4	11.00
8	1	10.00	16	1	11.00
	2	11.00		2	10.00
	3	11.00		3	11.00
	4	10.00		4	10.00

TABLE 11--Continued

Subject	Problem	Trials	Subject	Problem	Trials
17	1	13.00	21	1	10.00
	2	11.00		2	10.00
	3	12.00		3	12.00
	4	11.00		4	11.00
18	1	11.00	22	1	12.00
	2	11.00		2	10.00
	3	11.00		3	10.00
	4	12.00		4	10.00
19	1	14.00	23	1	11.00
	2	12.00		2	10.00
	3	13.00		3	11.00
	4	10.00		4	10.00
20	1	13.00	24	1	15.00
	2	14.00		2	11.00
	3	10.00		3	11.00
	4	11.00		4	10.00

Mean	11.1041
Variance	1.9890
Std. Dev.	1.4103

TABLE 12

INDIVIDUAL SUBJECT DATA ON THE LOUDNESS DIMENSION:
TIME TO CRITERION IN SECONDS

Subject	Problem	Time	Subject	Problem	Time
1	1	70.00	9	1	60.00
	2	61.00		2	92.00
	3	65.00		3	82.00
	4	75.00		4	61.00
2	1	94.00	10	1	55.00
	2	75.00		2	53.00
	3	77.00		3	57.00
	4	71.00		4	67.00
3	1	67.00	11	1	297.00
	2	66.00		2	59.00
	3	58.00		3	59.00
	4	60.00		4	72.00
4	1	100.00	12	1	80.00
	2	118.00		2	60.00
	3	77.00		3	59.00
	4	100.00		4	61.00
5	1	55.00	13	1	75.00
	2	61.00		2	65.00
	3	61.00		3	57.00
	4	74.00		4	72.00
6	1	113.00	14	1	67.00
	2	61.00		2	57.00
	3	54.00		3	53.00
	4	59.00		4	56.00
7	1	77.00	15	1	97.00
	2	84.00		2	57.00
	3	66.00		3	48.00
	4	62.00		4	57.00
8	1	60.00	16	1	70.00
	2	78.00		2	66.00
	3	64.00		3	75.00
	4	58.00		4	79.00

TABLE 12--Continued

Subject	Problem	Time	Subject	Problem	Time
17	1	65.00	21	1	69.00
	2	59.00		2	79.00
	3	81.00		3	59.00
	4	73.00		4	66.00
18	1	111.00	22	1	65.00
	2	63.00		2	59.00
	3	70.00		3	78.00
	4	64.00		4	72.00
19	1	61.00	23	1	75.00
	2	57.00		2	181.00
	3	74.00		3	62.00
	4	64.00		4	84.00
20	1	74.00	24	1	91.00
	2	65.00		2	63.00
	3	96.00		3	68.00
	4	74.00		4	67.00

Mean	73.2812
Variance	846.3726
Std. Dev.	29.0924

TABLE 13

INDIVIDUAL SUBJECT DATA ON THE LOUDNESS DIMENSION: ERRORS TO CRITERION

Subject	Problem	Errors	Subject	Problem	Errors
1	1	1.00	9	1	.00
	2	.00		2	1.00
	3	.00		3	.00
	4	1.00		4	.00
2	1	3.00	10	1	.00
	2	1.00		2	.00
	3	.00		3	.00
	4	.00		4	1.00
3	1	2.00	11	1	18.00
	2	2.00		2	1.00
	3	.00		3	1.00
	4	.00		4	2.00
4	1	3.00	12	1	2.00
	2	2.00		2	1.00
	3	2.00		3	.00
	4	2.00		4	1.00
5	1	2.00	13	1	2.00
	2	1.00		2	1.00
	3	1.00		3	.00
	4	2.00		4	2.00
6	1	2.00	14	1	3.00
	2	1.00		2	.00
	3	.00		3	.00
	4	1.00		4	.00
7	1	2.00	15	1	2.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	.00		4	.00
8	1	1.00	16	1	1.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	.00		4	.00

TABLE 13--Continued

Subject	Problem	Errors	Subject	Problem	Errors
17	1	1.00	21	1	.00
	2	.00		2	.00
	3	2.00		3	1.00
	4	1.00		4	2.00
18	1	2.00	22	1	1.00
	2	.00		2	.00
	3	1.00		3	1.00
	4	1.00		4	1.00
19	1	1.00	23	1	1.00
	2	.00		2	3.00
	3	1.00		3	.00
	4	1.00		4	.00
20	1	2.00	24	1	2.00
	2	1.00		2	.00
	3	2.00		3	1.00
	4	1.00		4	.00

Mean	1.1145
Variance	3.7656
Std. Dev.	1.9405

TABLE 14

INDIVIDUAL SUBJECT DATA ON THE LOUDNESS DIMENSION: TRIALS TO CRITERION

Subject	Problem	Trials	Subject	Problem	Trials
1	1	11.00	9	1	10.00
	2	10.00		2	11.00
	3	10.00		3	10.00
	4	12.00		4	10.00
2	1	15.00	10	1	10.00
	2	12.00		2	10.00
	3	10.00		3	10.00
	4	10.00		4	11.00
3	1	12.00	11	1	42.00
	2	12.00		2	11.00
	3	10.00		3	11.00
	4	10.00		4	14.00
4	1	13.00	12	1	12.00
	2	18.00		2	11.00
	3	12.00		3	10.00
	4	12.00		4	11.00
5	1	13.00	13	1	13.00
	2	11.00		2	11.00
	3	11.00		3	10.00
	4	13.00		4	12.00
6	1	20.00	14	1	14.00
	2	11.00		2	10.00
	3	10.00		3	10.00
	4	11.00		4	10.00
7	1	14.00	15	1	17.00
	2	12.00		2	10.00
	3	11.00		3	11.00
	4	10.00		4	10.00
8	1	11.00	16	1	12.00
	2	13.00		2	10.00
	3	11.00		3	11.00
	4	10.00		4	10.00

TABLE 14--Continued

Subject	Problem	Trials	Subject	Problem	Trials
17	1	11.00	21	1	10.00
	2	10.00		2	10.00
	3	13.00		3	11.00
	4	12.00		4	12.00
18	1	13.00	22	1	11.00
	2	10.00		2	10.00
	3	11.00		3	11.00
	4	11.00		4	11.00
19	1	11.00	23	1	13.00
	2	10.00		2	21.00
	3	11.00		3	10.00
	4	11.00		4	10.00
20	1	13.00	24	1	14.00
	2	11.00		2	10.00
	3	14.00		3	11.00
	4	12.00		4	10.00

Mean	11.8229
Variance	13.7472
Std. Dev.	3.7077

TABLE 15

INDIVIDUAL SUBJECT DATA ON THE DURATION DIMENSION:
TIME TO CRITERION IN SECONDS

Subject	Problem	Time	Subject	Problem	Time
1	1	151.00	9	1	126.00
	2	60.00		2	82.00
	3	68.00		3	74.00
	4	76.00		4	75.00
2	1	127.00	10	1	227.00
	2	74.00		2	103.00
	3	85.00		3	83.00
	4	76.00		4	77.00
3	1	400.00	11	1	162.00
	2	69.00		2	62.00
	3	65.00		3	98.00
	4	62.00		4	82.00
4	1	93.00	12	1	64.00
	2	75.00		2	79.00
	3	73.00		3	84.00
	4	75.00		4	84.00
5	1	68.00	13	1	99.00
	2	74.00		2	66.00
	3	60.00		3	73.00
	4	63.00		4	69.00
6	1	97.00	14	1	93.00
	2	71.00		2	77.00
	3	77.00		3	93.00
	4	64.00		4	73.00
7	1	104.00	15	1	127.00
	2	87.00		2	162.00
	3	73.00		3	64.00
	4	75.00		4	62.00
8	1	91.00	16	1	60.00
	2	85.00		2	84.00
	3	95.00		3	81.00
	4	62.00		4	83.00

TABLE 15--Continued

Subject	Problem	Time	Subject	Problem	Time
17	1	364.00	21	1	114.00
	2	91.00		2	74.00
	3	82.00		3	74.00
	4	67.00		4	80.00
18	1	80.00	22	1	156.00
	2	78.00		2	80.00
	3	76.00		3	76.00
	4	72.00		4	72.00
19	1	98.00	23	1	83.00
	2	93.00		2	81.00
	3	74.00		3	84.00
	4	71.00		4	86.00
20	1	205.00	24	1	65.00
	2	83.00		2	80.00
	3	74.00		3	74.00
	4	53.00		4	80.00

Mean	91.8020
Variance	2622.1604
Std. Dev.	51.2070

TABLE 16

INDIVIDUAL SUBJECT DATA ON THE DURATION DIMENSION: ERRORS TO CRITERION

Subject	Problem	Errors	Subject	Problem	Errors
1	1	4.00	9	1	4.00
	2	1.00		2	1.00
	3	.00		3	.00
	4	1.00		4	.00
2	1	6.00	10	1	12.00
	2	.00		2	2.00
	3	1.00		3	1.00
	4	1.00		4	2.00
3	1	37.00	11	1	9.00
	2	.00		2	1.00
	3	.00		3	3.00
	4	.00		4	2.00
4	1	2.00	12	1	.00
	2	.00		2	2.00
	3	.00		3	1.00
	4	.00		4	2.00
5	1	1.00	13	1	2.00
	2	1.00		2	.00
	3	1.00		3	1.00
	4	.00		4	.00
6	1	4.00	14	1	1.00
	2	1.00		2	2.00
	3	2.00		3	1.00
	4	.00		4	1.00
7	1	3.00	15	1	3.00
	2	1.00		2	7.00
	3	2.00		3	.00
	4	1.00		4	.00
8	1	4.00	16	1	1.00
	2	3.00		2	1.00
	3	2.00		3	1.00
	4	.00		4	1.00

TABLE 16--Continued

Subject	Problem	Errors	Subject	Problem	Errors
17	1	33.00	21	1	3.00
	2	3.00		2	1.00
	3	2.00		3	1.00
	4	.00		4	1.00
18	1	1.00	22	1	6.00
	2	1.00		2	1.00
	3	.00		3	.00
	4	.00		4	.00
19	1	2.00	23	1	1.00
	2	2.00		2	1.00
	3	.00		3	1.00
	4	.00		4	1.00
20	1	12.00	24	1	.00
	2	2.00		2	1.00
	3	.00		3	1.00
	4	.00		4	2.00

Mean	2.3125
Variance	27.9013
Std. Dev.	5.2821

TABLE 17

INDIVIDUAL SUBJECT DATA ON THE DURATION DIMENSION: TRIALS TO CRITERION

Subject	Problem	Trials	Subject	Problem	Trials
1	1	23.00	9	1	15.00
	2	12.00		2	11.00
	3	10.00		3	10.00
	4	11.00		4	10.00
2	1	19.00	10	1	37.00
	2	10.00		2	17.00
	3	11.00		3	13.00
	4	11.00		4	12.00
3	1	71.00	11	1	22.00
	2	10.00		2	12.00
	3	10.00		3	14.00
	4	10.00		4	12.00
4	1	13.00	12	1	10.00
	2	10.00		2	12.00
	3	10.00		3	13.00
	4	10.00		4	13.00
5	1	12.00	13	1	14.00
	2	12.00		2	10.00
	3	11.00		3	11.00
	4	10.00		4	10.00
6	1	15.00	14	1	13.00
	2	11.00		2	12.00
	3	14.00		3	14.00
	4	10.00		4	11.00
7	1	15.00	15	1	21.00
	2	11.00		2	25.00
	3	12.00		3	10.00
	4	11.00		4	10.00
8	1	15.00	16	1	11.00
	2	14.00		2	11.00
	3	15.00		3	11.00
	4	10.00		4	11.00

TABLE 17--Continued

Subject	Problem	Trials	Subject	Problem	Trials
17	1	63.00	21	1	16.00
	2	14.00		2	11.00
	3	13.00		3	11.00
	4	10.00		4	11.00
18	1	11.00	22	1	24.00
	2	11.00		2	11.00
	3	10.00		3	10.00
	4	10.00		4	10.00
19	1	14.00	23	1	12.00
	2	14.00		2	11.00
	3	10.00		3	11.00
	4	10.00		4	11.00
20	1	30.00	24	1	10.00
	2	12.00		2	12.00
	3	10.00		3	11.00
	4	10.00		4	12.00

Mean	13.8854
Variance	80.1446
Std. Dev.	8.9523