AN INVESTIGATION OF THE PRACTICE EFFECT IN WORD RECOGNITION

AN INVESTIGATION OF TWO DETERMINANTS OF THE PRACTICE EFFECT IN TACHISTOSCOPIC WORD RECOGNITION: RESPONSE STRENGTH AND FIXATION

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JANET M. HAY, M.A.

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AUTHOR: Janet M. Hay, B. A. (University of Manitoba)

M. A. (McMaster University)

SUPERVISOR: Dr. P. L. Newbigging

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Five experiments, involving 265 subjects, were performed with the objective of extending the analysis of response probability as a determinant of the practice effect in tachistoscopic word recognition. The results showed that the response probabilities of words may be manipulated and act as a determinant of the practice effect under certain limited experimental conditions. A more powerful determinant appears to be a general skill in tachistoscopic recognition which improves as a function of the number of stimuli recognized and transfers to the recognition of different stimuli. This skill was examined in the final experiment. The overall results were discussed in terms of both response probability and a general tachistoscopic skill.

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CHAPTER ONE

INTRODUCTION

The problems dealt with in this thesis arose from the findings of an earlier experiment by Newbigging and Hay (1962). That experiment involved the tachistoscopic recognition of nine different lists of words by nine groups of subjects. Each list was made up of words of one of three frequencies of occurrence (50+/1,000,000, 1/1,000,000, or 1/3,600,000)[1], and one of three lengths (4, 7 or 10 letters). For example, one list contained four-letter words which occurred fifty or more times per million words, while another list consisted of seven-letter words which had a frequency of occurrence of once in every 3.6 million words. The results indicated that the decrement in recognition thresholds with practice was a function of both word frequency and word length, with the greatest decrement being shown for the most infrequent and longest words.

In addition, evidence was presented which suggested that the practice effect was a function of an increasing response probability for the specific frequency of occurrence of the words in the list. This evidence was obtained by a comparison of the similarity between the response given immediately prior to correct recognition of the stimulus word (RT-1) and the stimulus word itself. In this instance,

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1. Frequency estimates were taken from the Thorndike-Lorge (1944) word count.

an index of similarity was computed by counting one point for each letter in the RT-1 response which was the same as a letter in the stimulus word, and to this total adding an extra point for each pair of letters which were correct, adjacent and in the right order. The index of similarity obtained in this way was found to decrease with increasing practice in recognition of words in the list.

Assuming this index to be an estimate of the size of fragment required for correct identification of the word, and that the smaller the required fragment the higher the response probability of the word, it was suggested that the decrement in similarity over words could be indicative of an increasing response probability of the particular frequency class of the words in the list. This argument assumed that the difference between the size of the fragment perceived at the exposure duration associated with RT-1 and that perceived at the next longer exposure which resulted in the recognition of the word (RT) remained constant for all words in the series; that is, if on the first word five letters were perceived at RT-1 and six letters at RT, then the difference between the perceived fragments which elicited these same responses for subsequent words in the list would continue to be one letter. Since it is impossible to determine the size of the fragment perceived at RT, this being inevitably the correct response, this assumption may be incorrect. It therefore seemed advisable to make a more direct test of the response probability interpretation of the practice effect in tachistoscopic word recognition. The first experiment in the series of five reported in this thesis was designed for this purpose.

The second, third, and fourth experiments tested the effects of transfer of training on tachistoscopic word recognition. There is very little information in the literature concerning the transfer effect in word recognition, although it has occupied a prominent position in verbal learning. Nevertheless, two studies do suggest that transfer of training might be an important factor in the word recognition task. These are an experiment by Howes and Solomon (1951) which indicated that positive transfer played a part in the observed decrement in thresholds when a list of words of mixed frequencies were presented for recognition, and an experiment by Postman and Leytham (1951) which demonstrated negative transfer when nouns were presented following the recognition of a series of adjectives. Since both these results were only incidentally noted in the two studies, they cannot be considered crucial tests of the transfer phenomenon and a more detailed study is required. For this reason, Experiment 2 tested the influence of three different types of pre-training, that is high frequency words, numbers, and tachistoscopic adaptation, on the subsequent tachistoscopic recognition of infrequent words. Experiment 3 was designed to investigate the effects of three different levels of tachistoscopic training with high frequency words on the recognition of low frequency words. Experiment 4 was concerned with how much positive transfer would occur to the tachistoscopic recognition of infrequent words, when pre-training with low frequency words was given outside the tachistoscopic situation.

The fifth, and final, experiment tested an hypothesis suggested by the preceding experiments; that is, that learning to fixate immediately prior to the presentation of the stimulus word is an important determinant of word recognition.

It should be pointed out that, in view of the lack of well-established data in this area, these experiments were necessarily of an exploratory nature. However, the amount of research on tachistoscopic word recognition is considerable and diverse, as will become evident from the historical review to be presented in the next chapter.

CHAPTER TWO

HISTORICAL REVIEW

The experiments described in subsequent chapters of this thesis fall into the general area of perceptual learning. It would seem appropriate, therefore, to attempt a broad definition of perceptual learning before proceeding with a summary of the studies which form the background for this research, and to describe the manner in which tachistoscopic word recognition exemplifies a method of studying this topic. Recently two prominent authors in the field have offered different definitions which reflect to a considerable degree their individual approaches to perceptual learning. Eleanor Gibson (1963) defines perceptual learning as "any relatively permanent and consistent change in the perception of a stimulus array, following practice or experience with this array" (p. 29). Postman (1955), on the other hand, is much more explicit when he defines perceptual learning as "changes in stimulus-response relationships under controlled conditions of practice" (p. 440). Attention is directed particularly to the discrepancy in the terms used by these two authors to describe the important variables in the operation of perceptual change. For example, in Gibson's definition how can one measure "a change in the perception of the stimulus array"? This change can only be inferred from the responses an individual gives to the stimulus object. Thus, both definitions are ultimately reduced to the same terms, that is changes in the stimulus-response relationship. Because of the clarity and specificity of Postman's definition, future references to perceptual learning will imply this type of change.

The recognition of words, projected in a tachistoscope, has been one of the popular methods of studying perceptual learning. The tachistoscope, an instrument first used by Cattell in 1885 (Woodworth, 1938), permits the presentation of stimuli under controlled conditions of exposure time and illumination. A measure of the threshold of recognition of a stimulus is obtained by systematically varying one of these dimensions, while holding the other one constant. The typical procedure is to present the stimulus initially at a level well below that required for recognition, and then to increase either the exposure time or the brightness level in discrete steps until correct recognition has occurred. In addition to the data given by the recognition threshold measure, the responses given to each exposure of the stimulus provide the experimenter with a rough estimate of the amount of information perceived by the subject at successive levels of stimulation. These experimental operations permit an accurate measure of recognition thresholds, which in turn allow inferences to be made concerning the nature of perceptual learning.

Since the experiments carried out in this research are solely concerned with tachistoscopic recognition, a review of the literature of the area will be dealt with fully in this chapter. First, however, an attempt will be made to briefly characterize the historical background of the field, and to indicate the directions of contemporary research.

The Area of Perceptual Learning

Although perceptual learning has only recently been recognized as a distinctive area in psychology, speculation about perceptual experience as a learning process can be traced back to Locke, who proposed that individuals learned to form their perceptual world through the association of sensory elements. This notion, of course, was simply one aspect of the long-debated question of nativism versus empiricism. The nativists (for example, Descartes, Hering and Kant) assumed that the sensory organization of the external world was a 'given' to an individual at birth; changes occurred as new experiences developed, but the hard core remained the same. The empiricists (for example, Locke, Berkely, Hume and J. B. Mill) argued that the mind was a 'blank' in the beginning and it was only through the experiencing of things and events that knowledge was obtained. Although this argument erupts occasionally today, few contemporary psychologists accept a completely nativistic viewpoint.

One of the first empirical tests investigating the notion that perceptions are learned was performed by Sanford in 1888[1]. This author reported that practice in viewing a series of letters increased the visual acuity of his subjects. From that time until the present, a voluminous literature has accrued demonstrating the effects of learning on various types of perceptual processes. Since the area covered by this topic is almost as extensive as the concept of perception itself, it is beyond the scope of the present chapter to attempt a complete review of the literature. The reader is referred to books by Woodworth (1938), Boring (1942), and Woodworth and Schlosberg (1954), as well as

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1. See Woodworth (1938).

articles by Gibson (1953) and Ammons (1953) for a summary of the major studies covering the period until 1952.

With the assignment of a separate chapter in the 1960 volume of the Annual Review of Psychology, perceptual learning attained the status of a major area of research in psychology. In his chapter, Drever (1960) summarized the research of the previous decade. The more recent literature on perceptual learning has been covered in comprehensive reviews by Gibson (1963) and Postman (1963).

A perusal of the aforementioned publications indicates that perceptual learning can be divided into two well-defined, though overlapping, areas on the basis of the approach used to study the phenomena. The first approach deals with the development and modifications of perceptual processes during the life history of the individual. Typical experimental designs employed in this approach include (a) comparisons of perceptual development at different age levels, (b) sensory deprivation experiments, and (c) studies of extra-stimulation (Dember, 1960). The second approach is concerned with repeated experience of stimulus patterns during a limited time span. Here, perceptual changes are observed by comparing scores taken before and after practice, or by repeated measurements taken during a specific practice period. Our main concern will be with studies using the second approach, although it is obvious that the past experience of an individual enters into all perception and therefore it cannot be entirely excluded from consideration.

A further restriction on the scope of this Historical Review is necessary since a large number of studies subsumed under the second approach are irrelevant to this research. These include experiments on visual acuity, perceptual constancies, and illusions. These topics have already been summarized elsewhere, and the general conclusion is that perceptual judgments and discriminations of these types improve with practice (see Gibson, 1953; Brunswik, 1955, 1956; Ittelson, 1951, 1962).

Consequently, the studies chosen for report in this chapter are limited to those involving the tachistoscopic recognition of words, letters and numbers, and to the effects of practice on the identification of such stimuli. Attention will first be given to a few notable studies which laid the foundation for the later research on tachistoscopic word recognition. Following this, a summary of the more important contemporary experiments in this area will be presented.

Early Studies

A problem of considerable interest to experimenters during the last quarter of the nineteenth century concerned the relationship between eye movements and reading ability. In studying this question, Javal[1] (1878) noted that two definite receptor processes took place during the course of reading a line of print. He described the first as the quick, saccadic movements of the eyes from word to word, and the second as fixation pauses intervening between these movements. Some twenty years later, Erdmann and Dodge (1898) reported that it was only during the actual fixation pauses that information was received about the stimulus

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1. The review of experiments in this section is mainly taken from Woodworth (1938), Chapters XXIII and XXVIII, and Woodworth and Schlosberg (1954), Chapters 5 and 17.

and that only a blur appeared during movement of the eyes (Tinker, 1931; Jasper and Walker, 1931; and Clark, 1934, have since confirmed this, using more refined instruments). Following this discovery, Erdmann and Dodge (1898) suggested that each fixation pause in reading might be considered equivalent to one brief exposure of stimuli in the tachistoscope. Thus, this instrument was established as a tool for studying various facets of word recognition and reading behaviour.

Prior to the suggestion by Erdmann and Dodge (1898), Cattell (1885, 1886) had employed a tachistoscope to determine if words were recognized more readily than nonsense syllables. Cattell found that two short words could be identified at the same exposure duration as could three to four unconnected letters. He suggested that it was the 'total word picture' which permitted meaningful material to be recognized easier than mere letters. Pillsbury, in 1897, attributed a similar finding to the 'general shape of the word', including its length and the dominant letters. Both these findings, that it is the 'total word picture' and the 'general shape of the word' that are important, imply that an individual's familiarity with a stimulus is a major factor in its recognition.

In an ingenious experiment, Wilkins (1917) specifically investigated the influence of familiarity on the recognition of word stimuli. Wilkins presented a series of phrases to subjects for exposure durations varying between 50 and 100 milliseconds. The phrases were presented in the following manner: Washout at, Irvington and talder powcum. The experimenter found that there was a significant tendency for subjects to respond to these two phrases with "Washington Irving" and "talcum powder", respectively. Wilkins interpreted his results as indicative of the influence of familiarity in determining the recognition of words at short exposure times.

Another factor shown to be important in word recognition was the position of the letters in a word. A study by Wagner (1918) indicated that the first and last letters of a word were recognized more frequently than were the intermediate letters; further, when the middle letters were recognized, they did not always include those in the immediate fixation area, but tended to cover the entire stimulus field.

Thus, these early experimenters demonstrated the importance of familiarity, along with a number of stimulus variables in the determination of word recognition. At the same time, other investigators were studying the relationship between certain characteristics of the eye and the recognition of words presented tachistoscopically. For example, Ruediger in 1907 studied the distance from fixation at which a letter could be recognized. He found that a <u>letter</u> could be placed as far as from twelve to fifteen letters from the fixation point and still be identified. Hamilton (1907) reported, on the other hand, that when <u>words</u> were presented closer to fixation, a number of the letters in the word were frequently misperceived. The misperceptions, however, were usually similar in structure to the stimulus word; for example, '<u>there</u>' might be reported as '<u>these</u>'. An experiment by Korte (1923) indicated that capital letters could be recognized at greater distances from fixation than could lower case letters, and that both types of single letters could be read further from fixation than could words. Further, Korte found that the longer the word, the closer it must be to the fixation point to be recognized.

More recently, Woodrow (1938) repeated Ruediger's experiment using pairs of letters instead of only one, and varying the distance from fixation at which the letters were exposed. His results indicated that two letters could be reported correctly at considerably less distance from fixation than a single letter. Woodrow attributed this finding to a process of 'mutual inhibition', or masking of one letter by another, when more than one letter was exposed in indirect vision. Mutual inhibition could also account for the 'misperceptions' reported by Hamilton (1907), and for Wagner's (1918) finding that the first and last letters of a word were recognized sooner than were the middle letters. With first and last letters, masking would only occur on one side of the letter.

It is evident that these early studies not only contributed a well-controlled technique for measuring visual recognition thresholds, but they also suggested a number of variables that deserved further examination. Included amongst these were such stimulus factors as length and structure of words, position of letters, and the variable of word familiarity. Strangely enough, a long period of time was to elapse before further consideration was given to these variables. It was not until the late 1940's when attempts were made to demonstrate the influence of motivational and emotional variables on recognition thresholds that tachistoscopic word recognition once again became a popular area of research. In the following section we shall briefly summarize the two studies which stimulated this interest, and then deal at greater length with the experiments which have demonstrated the major determinants of tachistoscopic word recognition.

Recent Studies

The first of the two studies referred to above was by Bruner and Goodman (1947) and is described mainly because, as Prentice noted (1956, p. 29), it initiated a good deal of the recent experimentation on perception. These experiments attempted a "functional" analysis of perception described by Prentice (1956) as "a personal and goal-directed reaction, responsive to needs and attitudes, subject to training by success and failure, and forming a part of the uniqueness of each individual" (1956, p. 29). Allport suggested the term "New Look" to characterize the study of the effect of motivational and emotional variables on the perceptual process. Previously, research in the area was largely concerned with examining properties of the stimulus as determinants of perception.

In the first of the "New Look" studies, Bruner and Goodman (1947) had two groups of children estimate the sizes of coins of various denominations; the children in one group came from wealthy homes, while those in the other group came from poor homes. The results showed that the poor children overestimated the sizes of the coins significantly more than did the wealthy children, with the amount of overestimation increasing with the value of the coin. Bruner and Goodman (1947) interpreted these results as indicating that the subjective needs of an individual influence to some extent his perception of objects. In addition, they stated that "socially valued objects are susceptible to behavioral determinants in proportion to their value" (1947, p. 39.[1])

The second study, that by Postman, Bruner and McGinnies (1948), is of particular importance since the results reported led to the whole question of word frequency as a determinant of recognition thresholds. This study investigated the relation between an individual's value orientation and his recognition of words related to those values. An individual's values were determined by his scores on the Allport-Vernon Scale of Values (1946). The prediction was that recognition thresholds for words relevant to a subject's dominant value area would be significantly lower than for words related to a less valued area. The results supported this prediction; that is, a significant inverse relation was found between value scores and recognition thresholds. Postman et al (1948) concluded that an individual's value orientation selectively influences his perception of words (See also Haigh and Fiske, 1952; Vanderplas and Blake, 1949; Adams and Brown, 1953; Brown and Adams, 1954).

In addition to measuring the recognition thresholds of the words, Postman et al (1948) analyzed the responses given

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1. It might be noted incidentally that the results obtained by Bruner and Goodman (1947) have proved difficult to reproduce (see Carter and Schooler, 1949).

immediately prior to correct recognition (that is, RT-1). Their analysis showed that valued stimulus words tended to elicit covaluant words as responses, while low-valued stimulus words tended to evoke contravaluant words and nonsense syllables. The authors proposed two concepts to explain these results. The first, selective sensitization, suggested that individuals tend to selectively perceive objects and words that are important to them. The second concept, perceptual defense, implied that individuals tend to defend themselves from perceiving words and objects that are threatening to them. The introduction of these two concepts immediately caught the imagination of numerous psychologists, who proceeded to test the relationship between these hypothetical processes and various emotional and motivational stimuli. These studies have already been reviewed by Jenkins (1957), so no further reference will be made to them here.

At the same time, other psychologists were extremely critical of the sensitization and defense concepts, and began investigating other variables to account for the differential thresholds observed in the Postman et al (1948) study. These investigations are directly concerned with the problems studied in this thesis and will be discussed at length below.

The first, and probably the most persistent criticisms of the defense and sensitization concepts appeared in articles by

Howes and Solomon (1950, 1951)[1] and Solomon and Howes (1951). In this last-mentioned paper, the authors suggest that the results of the Postman et al (1948) experiment might be merely an artifact of the differential frequency of the words employed. They repeated this study, using words equated for frequency according to the Thorndike-

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1. In these two articles, Howes and Solomon (1950, 1951) criticize a study by McGinnies (1949) on perceptual defense. In this study, McGinnies reported significantly higher thresholds for taboo words than for neutral ones. In addition he found that the galvanic skin responses were greater for pre-recognition responses to taboo words. He interpreted these results in terms of a mechanism of defense, which operates below conscious awareness, thus defending the subject from perceiving inimical stimuli. (see also Lazarus and McCleary, 1951; McCleary and Lazarus, 1949).

This study was critized on two counts by Howes and Solomon (1950, 1951): (1) the frequency rating of the taboo words was lower than that of the neutral ones; and (2) it was possible that the subject was reluctant to repeat taboo words to the experimenter, and therefore suppressed his responses until he was sure he was correct. In support of their first criticism, Howes and Solomon (1951) repeated the McGinnies (1949) study with the frequency of the two different types of words equated; they failed to find a difference in threshold. However, McGinnies and Adornetto (1952) found higher thresholds for taboo words, even with the frequency variable controlled. It has been suggested that individuals differ in their use of taboo words, and these opposing results could be explained in terms of different populations of subjects. With regard to the second criticism, two lines of evidence seem to favor the response suppression interpretation. First, subjects have admitted that they deliberately withheld their reports (McGinnies, 1949; Cowen and Beier, 1950, Whittaker, Gilchrist and Fisher, 1952). Secondly, forewarning the subject of taboo words resulted in insignificant differences in threshold (Postman, Bronson and Gropper, 1953; Lacy, Lewinger and Adamson, 1953; Freeman, 1954). However, others have reported higher thresholds for taboo words even with forewarning (Beier and Cowen, 1953; Cowen and Beier, 1954 and Cowen and Obrist, 1958). The opposing results of these experiments have failed to resolve the issues concerning the perceptual defense concept.

Lorge (1944) general word count.[1] The words were chosen so that an equal number of high frequency and low frequency words were relevant to each of the value areas. The results indicated that the effect of frequency was highly significant, while the effect of values was insignificant. However, there was a significant interaction found between the low frequency words and values, suggesting that values were effective in reducing recognition thresholds when low frequency words were presented as stimuli. (see also Postman and Schneider, 1951). Solomon and Howes (1951) attributed this interaction to the idiosyncratic frequency of usage of words by the individual. They argue that a person who is keenly interested in a particular subject will read more material pertaining to that subject, thus familiarizing himself with the vocabulary. The authors conclude that lower thresholds for high value words and higher thresholds for low value words can readily be explained in terms of frequency of past usage. This point has been hotly debated by psychologists who view perception from a functional

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1. The Thorndike Lorge Word Counts (1944) are the most commonly used word frequency ratings in tachistoscopic experiments. The book contains 30,000 words, each listed with its frequency of occurrence per million words in written English. The estimates are based on the number of times each word was used in a sample of 4.5 million words of text, taken from five popular magazines published between 1928 and 1939. The words range in frequency from very common (those occurring over 100 times per million) to extremely uncommon words (those occurring once in every four million). The validity of these counts as estimates of frequency of usage of the words seems to be well-established for a population of undergraduate college students. Wispé and Dramberean (1953), Howes (1954a) and Zigler and Yospe (1960) have all reported highly significant correlation coefficients, ranging from +.78 to +.88 between students' ratings and the Thorndike-Lorge estimates of a large number of words.

viewpoint on the one hand, (e.g. Adkins, 1956; Bruner, 1957a, 1957b; Jenkins, 1957) and by those who subscribe to a stimulus-response interpretation on the other hand (e.g. Solomon and Postman, 1952; Howes, 1954b; Goldiamond, 1958). Since this controversy is quite irrelevant to the present research it will not be discussed further. We shall now turn our attention to an examination of certain of the variables which have been shown to facilitate tachistoscopic word recognition.

Stimulus Variables

Cattell (1886) and his contemporaries pointed to a number of properties of the stimulus word itself which were cues to its recognition. But it was only with the renewed interest in word recognition stimulated by the functional approach to the analysis of perception that these variables were re-examined. During the interim period, one significant change had taken place in the method of presenting word stimuli. Whereas early experimenters tended to type the words in lower case print, current investigators almost without exception print the stimulus words in capital letters. This modern method tends to destroy some of the structural features found when lower case print is used; such as projections of letters above the line of print (l, f, t, etc.) and the dot over the letter 'i'. Although capital letters do reduce some of the cues, the structure of different words cannot be entirely controlled by this practice. For example, Howes and Solomon (1951) observed that letters composed of only a few constant lines (I, J, L, T) tended to have low recognition thresholds, while those letters having a number of lines (M, N, S, W) and those bearing a similarity to other letters (C, G, O) tended to have high thresholds. When words are used as stimuli, it is impossible to equate their similarity. However, since most words of any length are a heterogeneous mixture of letters, it would be expected that the variability introduced into the data as a result of the shape of the letters would be minimal.

Another aspect of word structure which clearly serves as a cue in recognition is that of length. McGinnies, Comer and Lacey (1952) studied the effect of this variable on tachistoscopic word recognition, varying both the length of the word and its frequency. Their results indicated that recognition thresholds were a linear, increasing function of word length, and a linear, decreasing function of word frequency. That is, the longer the word the more difficult it was to recognize, and the higher the frequency of the word the easier it was to recognize. The authors also reported that longer words elevated thresholds more in the case of infrequent words than with frequent words. Similar findings were reported in a subsequent experiment by Newbigging and Hay (1962).

Rosenzweig and Postman (1958) investigated the influence of word length on both visual and auditory thresholds[1], holding the word frequency variable constant. The visual test showed the recognition

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1. Auditory thresholds are obtained by presenting the stimulus in the presence of a white noise. The signal-to-noise ratio is then gradually increased, in discrete steps, until recognition occurs.

thresholds to be an increasing function of word length, while the opposite effect was demonstrated in the auditory test, that is, recognition thresholds were a decreasing function of word length in audition. There were two aspects to the explanation suggested by the authors for the differential effects observed with the two sense modalities. First, the duration of stimulus exposure, a well-controlled factor in visual recognition, varied with the length of the word in aural presentation; long words took longer to say than did short ones. The fact that exposure duration was a direct function of word length in auditory recognition might well explain the differences noted between the two sense modalities. Second, Rosenzweig and Postman (1958) suggested that when long words were presented aurally, there was a greater chance of the subject responding correctly when he perceived only a fragment of the word. This suggestion followed from an examination of the pre-recognition responses, which indicated that significantly more complete words were given in the auditory test, while more nonsense syllables or mere letters were reported when words were presented visually. It appears, then, that the recognition process differs with the sense modality employed. With auditory presentation, the tendency is to guess a word when a fragment has been perceived; with visual presentation the process appears to be more analytic; that is the subject tends to respond with the letters he has perceived, and then builds onto this fragment with successive exposures (see also Postman and Rosenzweig, 1956). The role of perceived fragments in the correct identification of tachistoscopically presented words will be the subject of more extended discussion in a later section.

Attention will now be given to the variables of meaningfulness, frequency and recency. These variables are difficult to classify since they are obviously a function of both the stimulus word and the individual subject being tested. We have, therefore, adopted Brown's (1961) term, 'stimulus-tied', to identify the variables described in the following section.

Stimulus-tied Variables

The effect of word meaningfulness on tachistoscopic recognition thresholds has been investigated using various indices of meaningfulness. For example, Haslerud and Clark (1957), after obtaining the recognition thresholds for a number of infrequent words, merely asked their subjects if they knew the meaning of each word. They reported that the recognition thresholds were lower for words of known meaning than for those of unknown meaning.

Another measure of meaningfulness is provided in a Semantic Differential profile prepared by Jenkins, Russell and Suci (1960). This table lists 360 words, which are rated according to their connotative meaning on a number of Semantic Differential Scales. Johnson, Thomson and Frincke (1960), selecting words which had been rated at the extremes of the good-bad scale, found that 'good' words had much lower recognition thresholds than 'bad' words. This finding was also obtained in a later study by Newbigging (1961a).

Kristofferson (1957) used Noble's (1952) measure of meaning (m) in a study which tested the effects of both meaningfulness and frequency on recognition thresholds. The _m_ rating of a word is the number of associations it evokes in a given period of time. Kristofferson (1957) reported a significant negative correlation between thresholds and both meaningfulness and frequency, with the correlation being higher in the case of frequency.

Noble (1953) has pointed out that these two variables, meaningfulness and frequency, are not independent, and it may be that the two are measures of the same factor. If this is the case, then the experiments just reviewed provide scant evidence of a relationship between the recognition threshold of a word and its meaningfulness, which is independent of the frequency factor. The frequency of usage of a word, on the other hand, has been extensively investigated, and its effects on tachistoscopic recognition thresholds well-established. A number of references to the frequency variable have been made in the preceding pages of this chapter, but a detailed discussion was postponed until this point because of the extreme importance attached to this variable in the interpretations of the tachistoscopic recognition process to be described in the following section.

Howes and Solomon (1951) were among the first experimenters to examine the relationship between the recognition threshold of a word and its frequency of occurrence.[1] They presented seventy-five words,

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1. As noted above, these same authors (Solomon and Howes, 1951) attempted to provide an interpretation of the value-recognition threshold relation reported by Postman, Bruner and McGinnies (1948) in terms of word frequency as an alternative to perceptual sensitization and perceptual defense.

which varied widely in their frequency ratings, to subjects for tachistoscopic recognition. Three separate measures of recognition thresholds were obtained for each of the words; the mean, the median, and the mean of the ten lowest thresholds of each word for the 20 subjects. Howes and Solomon (1951) reported that the time required for the correct recognition of a word was an approximate linear, decreasing function of the relative log frequency of usage of that word. The authors suggested on the basis of these findings that the size of the threshold should be regarded as a function of the relative frequency of the response word; that is, frequency should be considered a response variable rather than a property of the stimulus word.

This inverse relationship between recognition thresholds and word frequency has been repeatedly demonstrated in studies using a wide variety of words. Howes (1954a) reported obtaining this same effect when the frequency of usage of a series of words was determined by both students' ratings and the Thorndike-Lorge (1944) estimates. Wispé and Dramberean (1953) found that frequency influenced recognition thresholds of need-related words, while DeLucia and Stagner (1953), and Fulkerson (1957) reported a similar finding with socially taboo words. Other experimenters who have demonstrated the word frequency-recognition threshold relationship include Freeman and Engler (1955), Engler and Freeman (1956) and Newbigging (1961b). The effects of frequency on value words and on word length were described earlier in this chapter in some detail (see p. 15 and 16 for 'value', and p. 18 for 'length').

In view of the evidence cited above, it is perfectly clear that word frequency must be considered one of the major determinants of word recognition. However, the results of these studies were based on frequency estimates taken from popular word counts; such counts fail to reflect individual differences in frequency of usage and these differences would undoubtedly produce considerable variability in the experimental data.

Solomon and Postman (1952) carried out an experiment designed to control this individual difference variable. First, the subject was required to read and pronounce 24 different nonsense words repeated with different frequencies on each of 100 cards. Ten of the nonsense words, that is, two from each of five different frequency categories, were then presented for tachistoscopic recognition, together with ten new nonsense words and ten English words. Solomon and Postman (1952) reported that the recognition thresholds varied inversely with the frequency of past experience, thus verifying the results obtained with words selected from the frequency tables. It was also observed that the greatest threshold differences occurred between the novel stimuli and the nonsense words that had been shown only once in the pre-training series, with a sizable drop between the once- and twice-experienced nonsense words, followed by a linear decrement between the two and twenty-five frequency values. The authors interpreted these results as indicative that the frequency of past usage of a word was an important determinant of the response strength of that word.

Other experimenters who have duplicated these results using a similar procedure include Vanderplas (1953), Cohn (1954), King-Ellison and Jenkins (1954), Baker and Feldman (1956), Leytham (1957) and Taylor (1958). Postman and Rosenzweig (1956), Forrest (1957) and Sprague (1959) reported the same inverse relationship when the frequency of prior experience with the stimuli was established by auditory training.

It is eminently clear that one of the most important variables in tachistoscopic recognition is frequency of past experience with the stimulus. In a later section, the role that word frequency has assumed in attempts to interpret the word recognition process will be discussed.

Postman and Solomon (1950) have reported that recency of prior experience with a stimulus word was also an effective variable in its recognition. Recency was established by having subjects first attempt to unscramble words in an anagram test. When the words were then presented for tachistoscopic recognition, those words which had been failed in the anagram test were found to have lower thresholds than completely novel words. The authors suggested that recency of experience in perceiving letters facilitated subsequent recognition of a word composed of those same letters (see also Miller 1954; Eriksen and Browne 1956).

In a similar experiment, Newton (1956) used words which had recently been seen in a paired-associate learning task. The author reported that the recognition thresholds were lower for the previously perceived words than for control words.

Summarizing the experiments on stimulus-tied variables, it is evident that both frequency and recency are significant factors in the tachistoscopic recognition of words, while the effect of meaningfulness remains somewhat ambiguous. However, it is possible that all three variables are confounded to some extent, since both recency and meaningfulness are known to be related to frequency.

Stimulus - Response Relations in Recognition

One of the earliest attempts to interpret the tachistoscopic recognition process was made by Solomon and Postman (1952). Working within an associative learning framework, the authors suggest that the recognition process is a joint function of sensory information and response probability. The probability of a response is to be inferred from the frequency of usage of the word. Sensory information, on the other hand, depends on cues provided by the stimulus word, and the duration of its exposure. It is assumed that at short exposure durations only a fragment of the stimulus word will actually be perceived. Since this fragment may be common to a number of words, several different responses are possible. The particular response given will depend on the relative response strengths of all the words containing the fragment. Since the probability of a response can be adequately predicted from its frequency of usage, the responses elicited at brief exposures will tend to be high frequency words. Thus, if the visually presented stimulus is a high frequency word, the correct response is probable. If, however, an infrequent stimulus word is presented, then the response is likely to be incorrect. Solomon and Postman (1952) refer to this latter situation, where a low frequency word elicits a high frequency response as 'response interference'. The authors further assume that, following an incorrect response, each successive exposure duration will tend to increase the size of fragment perceived, thus reducing the number of competing responses. The correct recognition of a low frequency word, then, depends on increasing the amount of effective stimulation and restricting the number of response alternatives.

This analysis of word recognition readily explains the inverse relationship found between recognition thresholds and word frequency. Further hypotheses suggested by this interpretation have recently been tested experimentally; these will be discussed below.

Response-related Variables[1]

Because response probability played such a major role in the Solomon and Postman (1952) formulation, the question was raised whether it was frequency of exposure to the stimulus, or frequency of responding to the stimulus that determined the recognition threshold. In other words, did frequency affect the process of perceiving or of reporting? This question was investigated by Postman and Conger (1954) in an experiment involving the tachistoscopic recognition of three letters which could be considered either as a word or as a trigram,

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1. Because of the difficulty of classifying these studies on the basis of the variables examined, we have roughly called them "Response-related Variables" and "Stimulus-related Variables".

(that is, part of a word). For example, the letters FOR could be a word in itself, or part of a longer word such as FOREIGN. The Thorndike-Lorge word counts (1944) furnished an estimate of the frequency of occurrence of the letters as words, while their frequency as trigrams was taken from a count of trigrams published by Pratt. The authors found the typical inverse correlation between word frequency and recognition thresholds, and an insignificant correlation between trigram frequency and recognition. Postman and Conger (1954) argued from these results that it was the frequency of responding to stimulus units, and not the frequency of visual exposure, that determined ease of recognition. They stated: "the speed of recognition of letter sequences varies significantly with the strength of the verbal habits associated with such stimuli. There are no demonstrable effects of sheer frequency of exposure" (1954, p. 673).

Neisser (1954) examined the same question as Postman and Conger (1954) but employed a different experimental procedure. Neisser's subjects were first given a list of twelve words to study for one minute. Tachistoscopic recognition thresholds were then obtained for five words from this list, five words which were homonyms of words in the list, and five control words. The results indicated that the recognition thresholds for the previously experienced words were lower than for either the homonyms or the controls, which did not themselves differ. Neisser concluded: "Since the same verbal response is employed in a homonym as in reporting the word itself, it appears that the effect of a set of this type is to facilitate recognition processes without generally facilitating the corresponding verbal responses" (1954, p. 402). Ross, Yarczower and Williams (1956) repeated Neisser's experiment, but found that homonyms did tend to give lower thresholds. Neither of these two studies, however, can be considered completely adequate tests of the frequency of perception-frequency of response question. When a homonym is used as the stimulus both the configuration and the meaning of the original word tends to be lost. This might account for Neisser's contrary results.

An experiment by Goldiamond and Hawkins (1958) suggests that response probability is the <u>sole</u> determinant of word recognition. These experimenters used the same training technique as Solomon and Postman (1952) had employed in their study to establish differential frequencies of past experience with nonsense syllables. Following an interpolated activity, the subjects were told that the <u>same</u> stimuli which they had previously experienced would be presented in the tachistoscopic task. However, instead of printed nonsense syllables, blank cards were presented. The correct response for each card was arbitrarily pre-determined by the experimenters. This technique yielded an inverse relationship between the frequency of prior experience with nonsense syllables and "recognition thresholds". Goldiamond and Hawkins (1958) argued that recognition threshold experiments can be explained simply in terms of response bias, without recourse to any additional stimulus or organismic variable.

Newbigging (1960) repeated the experiment by Goldiamond and Hawkins, but employed value-related words as training stimuli instead of nonsense syllables. Newbigging found that the "recognition thresholds" for words congruent with dominant values were lower than those for words congruent with non-dominant values. In interpreting the results, Newbigging pointed to an important difference between the pseudo-perceptual task given in these two experiments and the commonly used tachistoscopic procedure. In the two preceding experiments the subjects were informed that one of the previously experienced stimuli would be presented, thus severely limiting the number of responses that could be given. In the usual tachistoscopic experiment, the number of possible responses is unlimited, and therefore the subject must receive some cues from the stimulus before he can be expected to identify it correctly. Thus, the Goldiamond and Hawkins (1958) study indicates that response bias can be established to a limited number of words through training. However, it is obvious that response bias cannot explain the inverse relationship found between word recognition thresholds and word frequency[1].

It will be recalled that Solomon and Postman (1952) in their discussion of the tachistoscopic recognition process suggested that increasing the amount of stimulation has the effect of restricting the number of alternative responses, thus raising the probability of the correct one. In studying the effects of response restriction[2], two different procedures have been used. In the first, the subject is given

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1. Postman (1963) makes substantially the same point in his discussion of the Goldiamond and Hawkins (1958) study.

2. These studies have also been referred to as establishing a response set for a particular class of stimuli. (see Postman, 1953).

information concerning the class of stimuli to be presented. Experimenters who have employed this procedure include Postman and Bruner (1949); Postman, Bronson and Gropper (1953); Freeman (1954); and Taylor (1956). These authors all agreed that previous information concerning the class of stimuli to be presented increased the probability of the correct response, and this increase in response probability was manifested in a decrement in the recognition threshold. The second method employed to restrict the number of alternative responses involves the recognition of a series of stimuli, which have a specific characteristic in common. Illustrative of this method is a study by Fulkerson (1957), who measured recognition thresholds for a random series of taboo and neutral words. The results showed that the first taboo word had a much higher recognition threshold than the other taboo words in the series, while this effect was not found with the neutral words (see also Bitterman and Kniffin, 1953). Fulkerson attributed these findings to 'habituation' to taboo words; that is, following the recognition of the first taboo word, the subject limited his responses to this word class, thus increasing his chances of being correct at shorter exposure durations. With the neutral words there was, of course, no common characteristic available, and consequently no change in threshold was to be expected.

The results of these studies tend to support the proposal that restricting the number of alternative responses either by instructing the subject, or by having him recognize a series of stimuli of one particular class, has the effect of increasing the probability of the correct response.

Stimulus-related Variables

Most of the evidence on changes in sensory information obtained on successive presentations of a stimulus word has been based on data provided by pre-recognition responses. For example, Boardman (1957) analyzed the pre-recognition responses for a series of words which had been presented tachistoscopically. The results of this analysis indicated that the similarity between the pre-recognition responses and the stimulus word increased progressively with successively longer exposures.

In a more extensive study, Newbigging (1961b) obtained similar results. This author defined the recognition process as one in which the stimulus word is redintegrated from a seen fragment. The assumption is made that at each longer exposure of the stimulus, a larger fragment of the stimulus word is perceived; the perceived fragment is then incorporated into the verbal response given by the subject. Ultimately, a sufficiently large fragment is perceived to elicit the correct response. Further evidence in favor of a redintegrative process came from Newbigging's (1961b) report that the similarity between the responses immediately preceding correct recognition (RT-1) and the stimulus word varied inversely with the frequency of occurrence of the stimulus word being presented. This finding agrees with Solomon and Postman's belief that a larger fragment must be perceived for recognition of a low frequency word than for recognition of a high frequency one. Finally, Newbigging (1961b) observed that the pre-recognition responses given to infrequent words were significantly less frequent in occurrence than those given to frequent words. Since infrequent words take longer to recognize, this finding appears to be consistent with Solomon and Postman's suggestion that the frequency of the response word varies inversely with the duration of exposure of the stimulus.

Additional support for a redintegrative process in tachistoscopic recognition came from a series of studies on the non-independence of successive response (see Blake and Vanderplas, 1950; Verplanck, Collier and Cotton, 1952; Bricker and Chapanis, 1953; Collier and Verplanck, 1958). These studies revealed that the probability of a response on a given presentation of the stimulus word depended to some extent on previous responses given to that word[1].

An interesting experiment was reported by Postman and Adis-Castro (1957). These authors compared the recognition thresholds for a list of words which had been presented to one group of subjects using the Ascending Method of Limits and to another group by the Method of Random Series. In their experiment, use of the Ascending Method of Limits involved presenting a word first at 20 milliseconds, and then increasing the exposure duration by 10 millisecond steps until the word was correctly

1. Studies reported by Bricker and Chapanis (1953), Murdock (1954) and Lysack (1954) afford further evidence for the non-independence of successive responses. These authors observed that when subjects were allowed more than one response at each exposure of the stimulus word thresholds were lower than those obtained when subjects were permitted only one response. This finding suggests that if the first response elicited by a perceived fragment is incorrect, the next response will be the second most probable word which incorporates the fragment. This is consistent with the redintegration process for tachistoscopic recognition proposed by Newbigging (1961b)

recognized.[1] With the Method of Random Series, all of the words were first presented at 20 milliseconds, and at each longer exposure all words were shown again in a different random order. This procedure was continued until the entire list of words had been recognized. While the Method of Limits yielded slightly lower threshold scores than did the Method of Random Series, the difference was not significant. This suggests that previous responses to a stimulus word do not actually facilitate the recognition of that word; rather they serve as cues to the process of recognition.

A study by Haselrud and Clark (1957) was concerned with the parts of a stimulus word which constituted the effective fragment. Wagner had earlier suggested that the first and last letters of a random sequence of eight letters were recognized more readily than the middle ones (see p. 11, this chapter). Haselrud and Clark (1957) presented their subjects with nine-letter words for recognition at a constant exposure duration of 40 milliseconds. Each subject was requested to first guess the identity of the word, and was then given a list of five words from which to select the one exposed. All of the words which made up this list had the same first and last letters as the stimulus word, but were otherwise different. The analysis of the subject's guesses gave results consistent with Wagner's in showing that the end letters of a word are more easily recognized than are the intermediate letters. The authors suggested that the sharp contrast gradient between the end letters and the white background facilitated the recognition of the

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1. This is the most generally used method of measuring recognition thresholds.

letters in these positions. Interestingly enough, in the multiple choice task where the end letters were not available as cues, since they were the same for all the words in the list, the middle letters were found to aid recognition. It appears from these results that the redintegrative process involves the recognition of letters at the ends of the word at the earlier exposure durations, and then on subsequent exposures one or more of the middle letters, until a sufficiently large fragment is perceived for correct identification of the word.

It would seem reasonable to conclude from the results of the studies just reviewed that tachistoscopic recognition consists of a process of identifying the word presented from a perceived part or fragment of the word. Further, if the word has a high frequency of occurrence, and thus a high probability as a response, or if its probability as a response is increased by such experimental procedures as restricting the number of alternative responses, it would be expected that the stimulus word would be correctly identified from a relatively small fragment. Since, as Newbigging (1961b) has shown, the size of a perceived fragment appears to be a simple function of the exposure duration of the word, the low thresholds of high frequency words and of words from a restricted list can be readily understood. Thus, the experimental evidence would appear to support Solomon and Postman's (1952) interpretation of the process of tachistoscopic recognition as involving both sensory information and response probability.

Other interpretations of the recognition process (e.g. Howes, 1954a; Eriksen and Browne, 1956; Spence, 1957) have also been concerned with the relation between sensory information and response probabilities. Howes (1954b),for example, presented a statistical interpretation, which he termed a R-emission theory. According to this formulation, the emission of a response word depends on the relative strength of its base probability (that is, frequency of past experience), plus its momentary probability. The momentary probability fluctuates with changes in environmental and organismic conditions. Since these two factors summate to determine the emission of a response, it follows that a high frequency word (a word having a high base probability) will require less stimulus information (that is, momentary probability) than will a low frequency word. While this interpretation affords a feasible explanation of the inverse relationship between word frequency and recognition thresholds, it does not lend itself readily to further experimental study.

In their interpretation of the word recognition process, Eriksen and Browne (1956) and Spence (1957) suggest that the probability that a response will be emitted at any given time depends upon its position in the response hierarchy of the individual. The level in the hierarchy of a particular response word is determined by its past frequency of usage, and also by a number of organismic and environmental events associated with that word. At any point in time, the position of a word in the response hierarchy may be altered by frequent usage, and/or by changes in the organism and environment. According to this interpretation, then, frequent words and those associated with rewards will have lower thresholds when presented tachistoscopically than infrequent words and words associated with punishment. The predicted effects of the frequency factor have already been clarified, while the effects of reward and punishment on word recognition have not as yet been determined.

It is clearly evident that neither of these explanations (that is, R-emission or response hierarchy) differs essentially from the interpretation proposed by Solomon and Postman (1952) to explain the tachistoscopic recognition process. In all three analyses, consideration is given both to the role of response probability and sensory information (or organismic and environmental events). Solomon and Postman (1952) and Howes (1954b) emphasize word frequency as a determinant of response probability, while the response hierarchy theorists tend to lay more stress on the role of reward and punishment. Since all three interpretations would tend to make the same predictions concerning the problems dealt with in this thesis, no further discussion of them is necessary.

The next, and final, section considers the effects of learning on tachistoscopic word recognition, a topic of central interest to the experiments which are described in the following chapters.

Tachistoscopic Learning

In a recent article, Gibson (1953) has provided a comprehensive review of those studies of perceptual learning, "which deliberately manipulate practice in the experimental situation, or at least quantify practice which took place outside it" (1953, p. 402). Included in this review were studies dealing with acuity, sensory thresholds, discrimination of relative differences, absolute estimation and rating, and recognition of patterned stimuli under impoverished conditions of stimulation. A relatively small amount of space was devoted to tachistoscopic studies which simply reflects the rather meagre amount of experimental work carried out in the area prior to 1953.

In addition to describing the number and variety of conditions under which perceptual learning occurs, Gibson (1953) summarized studies which had investigated the effects on perceptual learning of such parameters as amount and distribution of practice, and reinforcement. Also singled out for particular discussion were the phenomena of transfer and retention.

Ammons (1954), in a review limited to experiments investigating the effects of learning on visual form perception, identified as in need of further study essentially the same parameters discussed by Gibson (1953).

Our intention in the next few paragraphs is to summarize the few studies which have examined the effects of learning in tachistoscopic word recognition. The scarcity of experimental data in this area limits our discussion to studies concerned with amount of practice, reward and punishment, and transfer of training.

Amount of Practice

Although Renshaw (1945) had observed a practice effect in the tachistoscopic recognition of numbers, Howes and Solomon (1951) were the first to describe the relationship between the amount of practice and the recognition of words. These authors plotted the threshold scores for sixty words which varied widely in their frequency of occurrence. They reported a negatively accelerated, decreasing curve, with approximately three-fourths of the practice effect occurring in the first quarter of the list. In addition, they noted that the curve was still falling at the sixtieth word.

Newbigging and Hay (1962) investigated the effects of practice in the tachistoscopic recognition of words which differed in both frequency and length. In their study, nine groups of subjects were required to recognize nine different lists of words. Three lists were made up of high frequency words, three of medium frequency words and three of low frequency words. Within each frequency, one list contained four-letter words, one seven-letter words, and the other ten-letter words. Plotting the individual curves for the nine groups, the authors reported that for all lists recognition thresholds showed an early sharp drop and then a more gradual decrease with further practice. The greatest decrease, however, was observed for the longest and most infrequent words. With short and frequent words the initial thresholds tended to be low so that little decrement with practice could be demonstrated.

It is apparent from both studies that practice has its greatest effect early in the series, although performance continues to improve over a long list of words. This finding is similar to that observed in a variety of other learning situations.

Reward and Punishment

While a number of studies have demonstrated that reward affects perceptual learning in general (see Gibson, 1953; Ammons, 1954), only one experimenter has reported the influence of reward on word recognition. Rigby and Rigby (1956), using small children as subjects, found that recognition thresholds were lower for capital letters that had previously been associated with token rewards than for letters not associated with such rewards. Cohn (1954) attempted a similar experiment with adult subjects, using nonsense syllables as stimuli, but failed to obtain significant results. The apparent conflict in the findings of these two studies could be attributed to the fact that the children found tokens rewarding, while the adults did not.

The effect of shock on recognition thresholds has been the subject of investigation in a number of studies, but the results are not altogether clear. For example, Lazarus and McCleary (1951) measured the recognition thresholds of a list of ten nonsense syllables, five of which had been paired with shock in a preliminary session and five not. These authors reported that there was no significant difference in threshold scores between the shocked nonsense syllables and the neutral ones, although the galvanic skin response which was also recorded was greater for the shock-paired syllables when they were presented at exposures too brief to result in recognition. Using a similar procedure, both Lysak (1954) and Hatfield (1959) found that shock syllables had significantly lower thresholds than did non-shock syllables.

In a somewhat different type of study, Reece (1954) presented a list of nonsense syllables, all of which had been paired with shock, to two groups of subjects for tachistoscopic recognition. In both cases, the shock began with the presentation of the syllable. However, with the first group the shock was terminated immediately the word was correctly reported; with the second group the shock was not terminated until the stimulus had been removed. In other words, the subject was rewarded for emitting the correct response in the first instance, while in the second he was not. Following this training, the subjects were presented with the same nonsense syllables for tachistoscopic recognition. Reece (1954) reported that the group trained under the 'avoidable shock' conditions had lower thresholds for the shocked nonsense syllables than did the group trained under the 'unavoidable shock' conditions. These findings are in agreement with the response hierarchy interpretation of word recognition. That is, words which have previously been associated with reward ('avoidable shock') will move up in the response hierarchy, thereby increasing their probability as responses and lowering their recognition thresholds. Just the opposite would be predicted for the 'unavoidable shock' words.

While this experiment suggests that reward and punishment influence word recognition, there is insufficient evidence to arrive at any definite conclusions concerning the relation between these parameters and recognition thresholds.

Transfer of Training

This topic is of considerable importance to the present thesis and will, therefore, be dealt with at some length.

Both Weber (1942) and Renshaw (1945) have reported that practice in the tachistoscopic recognition of stimuli improved reading speed. However, Weber (1942) reported that transfer from the tachistoscopic situation to a non-tachistoscopic situation did not occur when the stimuli presented under the two conditions differed. Renshaw (1945), on the other hand, found that reading skill improved following tachistoscopic training with numbers. Gibson (1953), in her review of studies concerned with the recognition of forms and other types of stimuli, tended to agree with Weber's (1942) conclusion when she stated that "perceptual learning with the tachistoscope transfers only insofar as the test and training tasks are similar" (1953, p. 419).

Transfer from a non-tachistoscopic training task to the recognition of the same stimuli presented tachistoscopically has been demonstrated in a number of studies. (i.e. Vanderplas, 1953; Cohn, 1954; Baker and Feldman, 1956). For example, Solomon and Postman (1952) presented nonsense syllables different numbers of times outside the tachistoscopic situation, and then presented these same nonsense syllables for tachistoscopic recognition. The results showed clearly that the thresholds varied as a function of frequency of past experience.

The effect of transfer of training from one sense modality to another has been studied in a number of experiments. (e.g. Postman and Rosenzweig, 1956; Forrest, 1957; Sprague, 1959). In these studies, the stimuli have been presented either aurally (by having the experimenter repeat the word out loud to the subject), or visually (by having the subject read the word). Following training the subjects were presented with the same stimuli either tachistoscopically, or in the presence of a 'white' noise.

The most extensive investigation of this type was carried out by Postman and Rosenzweig (1956). These authors found that significantly more transfer was obtained when the same sense modality was used for training and testing, than when two different modalities were used. In addition, they observed that transfer from vision to audition was much more pronounced than transfer from audition to vision. As an explanation of this latter finding Postman and Rosenzweig (1956) suggested that under conditions of visual training the subject could repeat the words sub-vocally, and that this would mediate transfer to auditory recognition. A similar mediating mechanism would be unavailable to the aurally-trained subjects as it is unlikely they would visualize the spoken words. This is consistent with the results of an experiment by Sprague (1959) who found that oral practice (that is, repeating the nonsense syllables after the experimenter) had practically no effect on subsequent recognition of the same stimuli presented tachistoscopically.

Contrary findings were reported by both Forrest (1957) and Weissman and Crockett (1957), who observed that stimuli presented aurally had the effect of significantly lowering visual recognition thresholds. These authors, however, employed different experimental procedures from those used by Postman and Rosenzweig (1956). Weissman and Crockett (1957) gave a paired-associate learning task as auditory training, while Postman and Rosenzweig merely repeated words aloud to their subjects. In the Forrest (1957) study, the procedure used to determine visual thresholds differed from that used in the Postman and Rosenzweig experiment; in the former, the word was first projected as a blurred image and gradually brought into focus. The threshold was taken as that level of focus at which the subject correctly identified the word. Postman and Rosenzweig employed the more usual procedure of gradually increasing the brightness level at which the word was exposed. These differences might well explain the contradictory results.

Another relevant experiment demonstrated the effect of negative transfer on tachistoscopic learning. Postman and Leytham (1951) presented a list of seventeen words for tachistoscopic recognition. The first fifteen words presented were adjectives descriptive of personal traits, while the final two words were nouns. The usual practice effect was found for the first fifteen words. However, for the sixteenth word there was a significant rise in the recognition threshold, and then a sharp drop occurred on the seventeenth. Postman and Leytham (1951) attributed the sudden increase in threshold for the first noun to a 'set' for adjective responses established during previous training. In support of this explanation, they reported that a large proportion of the pre-recognition responses to the first noun-stimulus were trait-adjectives, although these same responses tended to bear a structural resemblance to the noun-stimulus. These results suggest that, despite the fact that the perceived fragment was large enough to elicit a structurally-similar response, the high response probability established for trait adjectives interfered with the emission of the correct response. This, of course, is the explanation proposed by Solomon and Postman (1952) for the frequency-threshold relationship.

The results of the different studies on tachistoscopic learning appear to warrant the following conclusions. The studies unanimously find that recognition thresholds decrease as a function of practice; the practice effect, in turn, is found to be a function of both word frequency and word length. On the other hand, the effects of reward and punishment remain obscure, with different experimenters reporting conflicting results. In respect to transfer of training, both positive and negative transfer effects have been secured, although no detailed study of the phenomena has been made.

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The experiments to be described in the following five chapters of this thesis examine several features of the tachistoscopic learning process. They are concerned with response probability as a determinant of the threshold decrement with practice, various aspects of the transfer phenomenon and, finally, with the role of fixation in tachistoscopic recognition.

CHAPTER THREE

EXPERIMENT 1

Solomon and Postman's (1952) interpretation of the frequency effect in tachistoscopic word recognition which was discussed in the previous chapter involves two factors; the first is the sensory information provided by brief exposures of the stimulus word, while the second is the probability as response of words belonging to the same frequency class as the stimulus word itself. Briefly restated, the interpretation is that at brief exposure durations only a fragment of the stimulus word will be recognized by the subject. The shorter the exposure, the smaller will be the perceived fragment and the larger the number of words which will include it as a common component. If the frequency of occurrence of a word is taken as a measure of its probability as a response, then responses to small perceived fragments will be high frequency words. Larger fragments, common to fewer words, will need to be perceived to elicit infrequent words as responses. Since it has been shown (Newbigging, 1961b) that the size of the fragment recognized is a simple function of exposure duration, the inverse relationship found between word frequency and recognition threshold may be explained in this way.

Newbigging and Hay (1962) extended this interpretation to account for the substantial practice effect commonly observed in tachistoscopic word recognition. They propose that recognition of successive words from the same frequency class will increase the response probability of words in that frequency class. If this is the case, then the correct response will be elicited by progressively smaller fragments as successive words are recognized. The experiment by Newbigging and Hay (1962) provides evidence which strongly supports this suggestion.

However, their method of estimating the size of fragment required to elicit the correct response is indirect. They compare the response immediately preceding correct recognition (RT-1) with the stimulus word to obtain an index of similarity. This index is derived by assigning one point to each letter in the response word which is the same as a letter in the stimulus word; then, to the total number of points obtained in this way is added one point for each pair of letters which is correct, adjacent, and in the right order. Thus, if the response "COAT" were given to the stimulus word "CODE", it would receive three out of a possible seven points, and be scored 43% similar. It is then assumed that on the following presentation the subject perceives only sufficiently more of the stimulus word to form a large enough fragment to elicit the correct response. Further, when it is observed that the similarity of the RT-1 response decreases as successive words are recognized, it is concluded that the correct response for a word in position N is elicited by a smaller fragment than is required for the first word in the list.

This conclusion is based on the assumption that the gain in stimulus information on the exposure that results in the correct response remains constant from word to word. That is, for example, if there is a 10% increase in stimulus information on the final exposure of the first word, there is also a 10% increase on the final exposure of a word later in the list. It is possible however, that a subject's skill in tachistoscopic viewing increases in such a manner that with a constant increase in exposure duration he is able to discriminate progressively more of the stimulus word. That is, the progressive decrease in similarity between the RT-1 response word and the stimulus word need not necessarily be paralleled by a decrease in the similarity of the fragment which elicits the correct response and the stimulus word.

There would appear to be no way of directly determining the size of fragment which elicits the correct response since that response is, of course, 100% similar to the stimulus word. However, alternative approaches to investigating the role of changes in response probability to account for the decrement in word recognition thresholds with practice are possible. One such alternative is based on the argument that a greater decrement in the threshold will be observed when successive words presented for recognition are all from the same frequency class than when they are from different frequency classes. In the former case, appropriate response probabilities will be built up, while in the latter case they will not. If, alternatively, increases in response probability are not a factor in the practice effect, varying the frequency of occurrence of successive words presented for recognition will not affect the threshold decrement. The following experiment was designed to examine this possibility.

METHOD

The basic apparatus and procedures, which were common to all five experiments, will be described in detail only for Experiment I. Differences in procedural detail of the subsequent experiments will be described in the appropriate Method section.

Subjects

The subjects were forty-five male and female students enrolled in Summer School Psychology courses. Their average age was 27.3 years, ranging from 20 to 35 years.

Apparatus

The basic apparatus was a Gerbrand's tachistoscope. This apparatus is essentially an L-shaped box with a half-silvered mirror inside, set so as to bisect the right angle of the L. A viewing aperture is located on the base of the L so that the subject looks directly at the middle of the mirror. Provision is made for independently illuminating the field at either end of the box. When the field at the base of the L and to the subject's right is illuminated, any stimulus material displayed is reflected by the mirror and so visible. This field is referred to as the <u>pre-exposure</u> field and, in these experiments, displayed the fixation aids. Illumination in the other arm of the box enables the subject to see through the mirror any stimulus material displayed in the end directly facing him. This field is referred to as the <u>exposure</u> field, and is used for the presentation of the stimulus words.

A mechanical timer controlled the illumination in both fields. When it was set for some particular interval such as 20 milliseconds, it darkened the pre-exposure field, illuminated the exposure field for that interval, and then illuminated the pre-exposure field again. Thus the pre-exposure field was constantly illuminated except when the exposure field was on. The timer provided for illuminating the exposure field for any interval between 10 milliseconds and 1 full second, in 10 millisecond steps.

The fixation pattern in the pre-exposure field for the first four experiments consisted of two black, horizontal, parallel lines, four inches in length and two inches apart. The stimulus always appeared in the exact center of the two lines.

Stimulus Material

Three lists of thirty, seven-letter words were selected from the Thorndike-Lorge (1944) word lists. One list was made up of words occurring fifty or more times per million (high frequency words), and a second list of words occurring once per three million words (low frequency). The third list was composed of fifteen words chosen randomly from each of the other two lists. Thus, each of the subjects who was presented with the mixed frequency list for recognition received a somewhat different list, although the frequency composition was the same. Further, a restriction was imposed on the order in which the high and low frequency words appeared in the mixed list, so that three of each frequency occurred in each successive block of six words. Each word was typed in black, élite capital letters on a white card.

Experimental Design

The forty-five subjects were randomly assigned to one of three groups, with the restriction that each group include nine males and six females. Each group was presented with a different word list; that is, high frequency, low frequency or mixed frequency. The lists were presented in a different random order to each subject for tachistoscopic recognition.

Procedure

Each subject was tested individually, and was read the following instructions:

> "I am going to present some words to you, one at a time. If you look in the eye-piece of this apparatus, you will see two lines. The words I shall show you will appear directly between the lines. Each word will be presented for a very short period of time, and you may not be able to tell what the word is at first. However, after each presentation I would like you to make a guess as to what the word was. Remember, even if you do not recognize the word, I still want you to tell me what you <u>think</u> it was. Each word will be presented to you several times until you have correctly recognized it. I shall inform you when you are correct, and then I shall show you another word. I shall say 'ready' before each word is flashed. Are there any questions?"

If the subject asked any question, relevant parts of the instructions were re-read to him.

The ascending method of limits was used. The initial exposure duration for each of the high frequency words was 20 milliseconds, while that for each of the low frequency words was 50 milliseconds. A slight modification was made in the initial exposure time for the subjects in the mixed frequency group; here, the first presentation of each high frequency word was at 30 millisecond and of each low frequency word at 40 millisecond. This alteration in initial exposures was introduced to prevent the subjects from anticipating the frequency class of the stimulus word from cues provided by the differential exposure times. Following the initial exposure, the duration of each successive presentation was increased by 10 milliseconds, until the word was correctly identified. Each of the subject's responses to each word was recorded on a score sheet opposite the appropriate time.

RESULTS

The main results of this experiment are presented graphically in Figure 1, and a summary of an analysis of variance of the data is given in Table I. It is apparent from the figure, and confirmed by the analysis of variance, that the effects of treatments (that is, composition of the word list), serial position, and the interaction between treatments and serial position are all statistically significant. The effect of serial position was, of course, expected, and simply confirms the previously reported practice effect found in word recognition (Howes and Solomon, 1951; Newbigging and Hay, 1962). The main effect of treatments and the

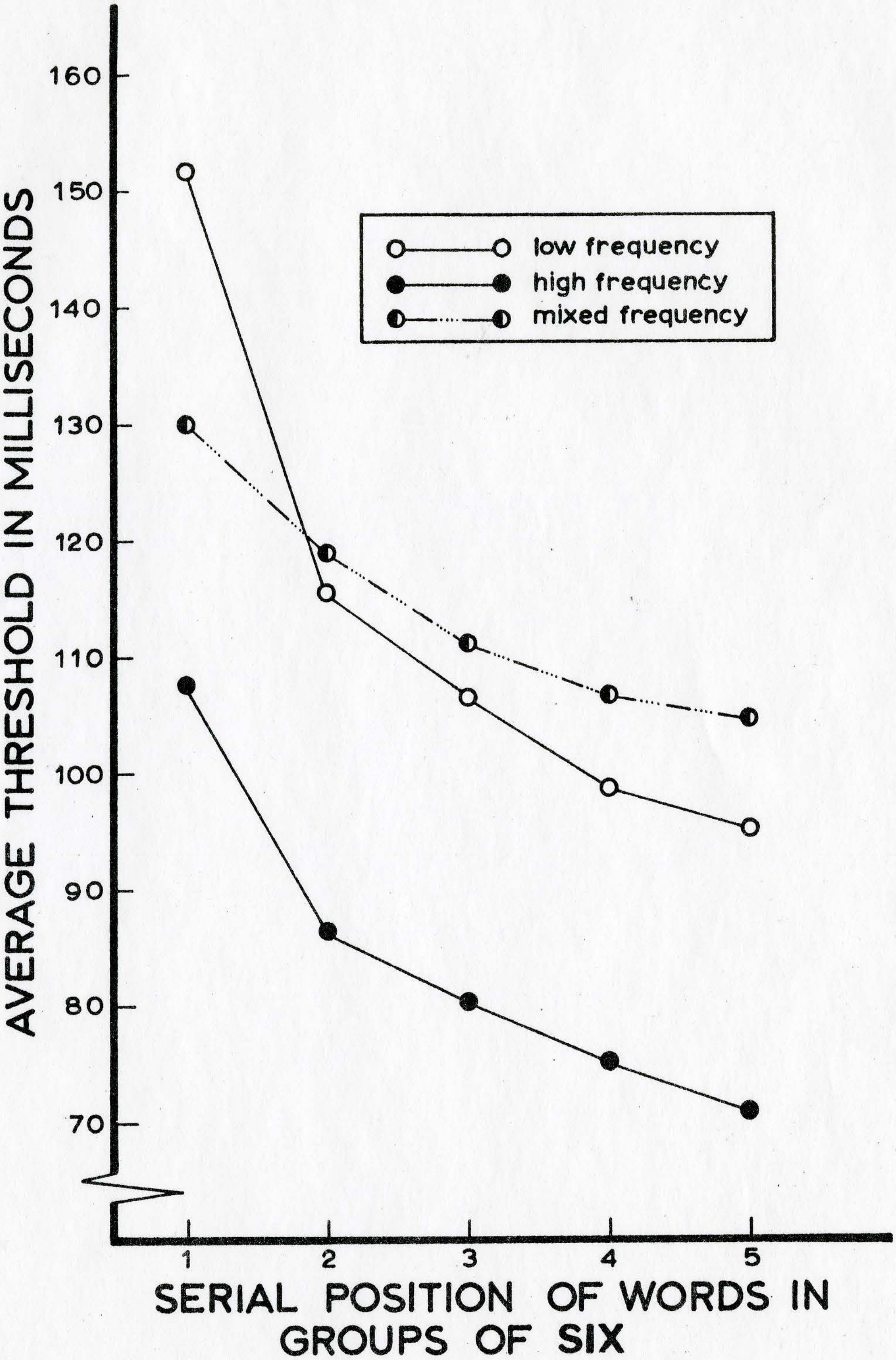

FIGURE 1. Average threshold in milliseconds as a function of serial position of words in groups of six (Experiment 1).

TABLE 1

SUMMARY OF ANALYSIS OF VARIANCE

OF THRESHOLD DATA FOR THREE GROUPS

Source	df	MS	F	P
Treatments (T)	2	8083.48	10.16	< .01
Error (b)	42	795.95		
Serial Position (SP)	4	4125.95	62.84	<.01
T x SP	8	251.22	3.83	<.01
Error (w)	168	65.66		

treatments x serial position interaction are directly relevant to the purpose of this experiment, and are examined in more detail below.

With regard to the effect of treatments, it is clear from an examination of Figure 1 that the significant difference is attributable to the fact that thresholds for the high frequency list are lower than those for the low frequency and mixed frequency lists. This was confirmed by a comparison of the overall means of the three groups by application of Tukey's Multiple Comparison Test (Ryan, 1959). This test showed that the means of the high frequency group differed from those of both the low frequency and mixed frequency groups ($p. < .05$ in both cases), while the means of these two groups did not differ from each other. The fact that these means did not differ is in itself an important finding when it is recalled that the average frequency of the mixed list was exactly intermediate between that of the low and high frequency lists. The mixed list was composed of fifteen words from each of the other two. Apparently mixing the two word frequencies has the effect of raising the overall average threshold above that which would be predicted from the known effect of word frequency on the threshold alone. Indeed, apart from the first point, the curve for the mixed list lies slightly above that for the low frequency list.

Turning now to the treatments by serial position interaction, it is again apparent from an examination of Figure 1 that the rate of decrement of the thresholds, as successive words are recognized, is greater for the high and low frequency lists than for the mixed frequency list. Evidently, the effect of mixing the frequencies of the words to be recognized operates over the entire list, and offsets to a considerable degree the substantial practice effect expected in this task.

A more detailed analysis of these data shows the effect of mixing word frequencies in a striking way. In this analysis, the high and low frequency words appearing in the mixed list were separated, and their thresholds compared directly with the thresholds for the high and low frequency words occupying the same serial position in the homogenous list. If, for example, a given subject who recognized a mixed list received the high and low frequency words in the first block of six in the following order: LF, HF, HF, LF, HF, LF, then for a subject presented with a low frequency list, the average of the scores in position 1, 4 and 6 was obtained; similarly, for a subject who recognized a high frequency list the average thresholds for words in positions 2, 3, and 5 was obtained. These averages were then compared with those for the appropriate low and high frequency words from the mixed list. This procedure was carried out for all subjects over all blocks of six words, yielding four sets of five scores each. Thus, only half the threshold scores were used for each subject in the groups which received the homogenous low frequency and high frequency lists. The four sets of s cores are shown graphically in Figure 2, where the average thresholds in milliseconds are plotted against the serial position of the words in groups of three. The word frequency effect is apparent from the figure, with both high frequency curves lying

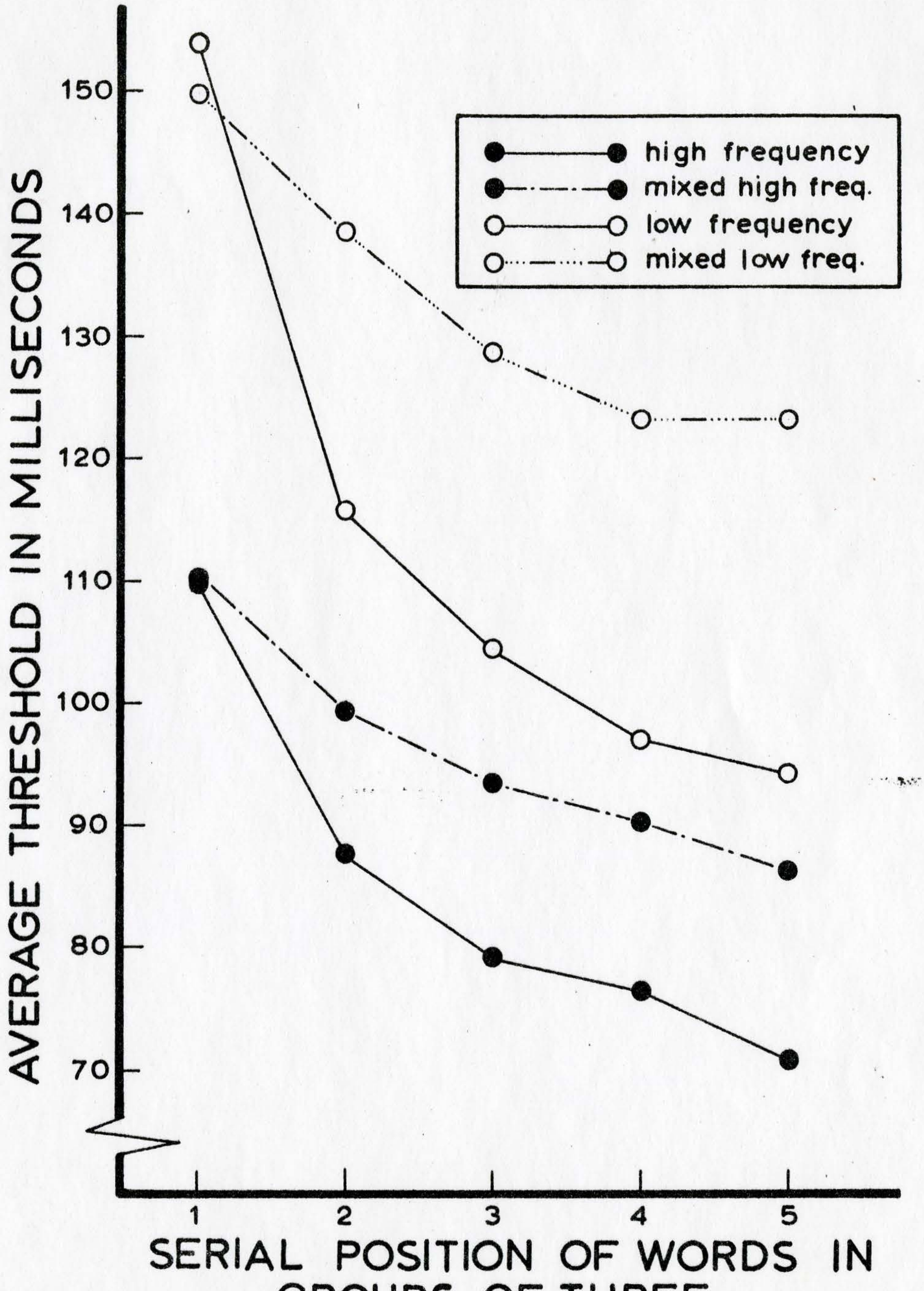

FIGURE 2. Average threshold in milliseconds as a function of serial position of words in groups of three (Experiment 1).

below the two low frequency curves. It can also be seen that the thresholds for both high and low frequency words presented in the mixed list are higher than words of the same frequency, and occupying the same serial position, in the homogenous frequency lists.

Since the same subjects are represented in the mixed high and low frequency scores, separate analyses of variance were performed on the two sets of data; summaries of these are presented in Table II. Considering first the analysis of threshold scores in blocks of three for the words in the high frequency list (HF) and the mixed high frequency list (MHF), it will be noted that only the effect of serial position is significant. However, an examination of the appropriate curves in Figure 2 shows that they start at essentially the same point, and then diverge. An analysis of variance performed on the last block of words alone showed that the two groups were significantly different at this point ($F = 10.62$ with 1 and 28 degrees of freedom, $p < .01$). The failure to demonstrate a significant overall effect of treatments would appear to be due to the similarity in performance of the two groups on the first block of words.

The analysis of variance of the threshold scores in blocks of three for the words in the low frequency list (LF) and the mixed low frequency list (MLF) yielded a significant main effect of serial position, and a significant treatments x serial position interaction. An inspection of the appropriate curves in Figure 2 shows that they are similar initially, but the one based on thresholds for words from the homogenous low frequency list drops precipitously, while that

TABLE II

SUMMARY OF ANALYSES OF VARIANCE OF THRESHOLD DATA

HF - MHF GROUPS

Source	df	MS	F	P
Treatments (T)	1	420.01	3.58	NS
Error (b)	28	117.45		
Serial Position (SP)	4	406.65	31.33	<.01
T x SP	4	25.52	1.97	NS
Error (w)	112	12.98		

LF - MLF GROUPS

Source	df	MS	F	P
Treatments (T)	1	1278.96	3.30	NS
Error (b)	28	387.34		
Serial Position (SP)	4	853.88	19.80	<.01
T x SP	4	122.08	2.83	<.05
Error (w)	112	43.12		

based on words from the mixed list decreases more gradually. While the overall treatment effect is not significant, an analysis of variance on the last block of scores alone showed that the groups did differ significantly at this point ($F = 6.31$, with 1 and 28 degrees of freedom, $p < .025$).

DISCUSSION

The results of this experiment appear quite clear-cut in their support of an interpretation of the practice effect in tachistoscopic word recognition which includes the variable of response probability. Apparently, when successive words from the same frequency class are presented for recognition, the probability increases that subjects will respond with words from that frequency class at progressively shorter exposure durations, thus increasing their chances of being correct. These response probabilities evidently increase gradually since the threshold decrement continues over the entire list of thirty words.

It is not surprising that successive presentations of low frequency words has a greater effect on the threshold decrement than has the successive presentation of high frequency words, since the response probability of the latter is already high. Nevertheless, even with high frequency words the threshold decrement is retarded when these are presented intermixed with low frequency words. This is shown by the significant differences in the average thresholds between the high frequency and mixed high frequency lists on the last block of words.

While it appears established that increases in response probability for word frequency is an important variable in accounting for the threshold decrement in tachistoscopic recognition, it is clear that other variables are also involved. For example, it will be recalled from Figure 1 that a threshold decrement was obtained with the mixed frequency list, which was more gradual than that shown by the homogenous frequency lists. Howes and Solomon (1951) also reported a decrement in thresholds over a mixed frequency list of sixty words. In neither of these cases would it be expected that response probabilities could increase in a manner necessary to account for this decrement. The following experiments were performed in an attempt to further clarify the role of response probabilities in the practice effect in word recognition, and to examine certain other variables that might account for this effect.

CHAPTER FOUR

EXPERIMENT 2

The experiment just reported, while supporting the view that increases in the probability as responses of words in the frequency class to be recognized is an important variable in accounting for the practice effect, leaves unanswered a number of questions. These concern the way in which response probabilities enhance or retard the threshold decrement, depending on whether they are appropriate or inappropriate to the stimuli to be recognized, and the duration of their effect. Further, there is the question of the nature of other variables that apparently contribute to the decrement. Possibilities include general adaptation to the tachistoscopic situation, and the development of some general skill in tachistoscopic recognition that is independent of the stimulus material employed. The following experiments attempted to answer some of these questions.

The present experiment was designed to investigate the effects of recognizing high frequency words and numbers, as well as the effect of general adaptation to the tachistoscopic situation, on the subsequent recognition of low frequency words. A fourth group, which recognized low frequency words prior to the recognition of the test list of low frequency words, provided the control against which the effects of the other types of pre-training could be assessed.

METHOD

Subjects

The subjects were 40 male and 40 female students enrolled in the Introductory Psychology class. They ranged in age from 18 to 40 years, with an average age of 24.6 years.

Stimulus Materials

Three different lists of stimulus material, all nine items in length, were made up for the pre-training session. One list consisted of seven-letter words with a frequency of occurrence of 50 or more times per million; one of seven-letter words with a frequency of occurrence of once per three million, and one of seven digit numbers chosen from a table of random numbers. The test list of words consisted of eighteen seven-letter words having a frequency of occurrence of once per three million. All stimulus items were typed in black, élite capital letters on white cards.

Experimental Design

The subjects were randomly assigned to one of four experimental groups with the restriction that there should be 10 males and 10 females in each group. The groups differed in the type of pre-training they received, one being presented with high frequency words, a second with low frequency words, a third with numbers, and a fourth, the adaptation group, was simply presented with 54 exposures of blank white cards. Following the pre-training or adaptation procedure, and without any interruption, each of the subjects in all four groups was required to recognize the test list of eighteen low frequency words.

Procedure

Both the pre-training and the test stimuli were presented for recognition in a Gerbrand's tachistoscope. The instructions to all subjects, including those in the adaptation group, were the same as those used in Experiment 1. The order of presentation of the words or numbers within each list was mixed by shuffling the cards for each subject.

Because of the varying difficulty of the stimulus material as far as tachistoscopic recognition is concerned, the initial exposure duration was adjusted in an attempt to equate the groups with regard to the amount of practice (that is, the number of presentations of the stimuli) during the pre-training session. Thus, the initial exposure for high frequency words was set at 20 milliseconds, 50 milliseconds for low frequency words, and 100 milliseconds for numbers. The duration of each exposure of the blank white card for the adaptation group was 10 milliseconds. For the test series for all four groups, the initial exposure of each word was 50 milliseconds.

RESULTS

The threshold scores averaged over blocks of three stimulus items are plotted for both the pre-training and test series in Figure 3. The adaptation group is not represented in the pre-training part of the figure since, of course, no threshold values could be obtained for the presentation of blank cards. The pre-training and test data were separately analyzed. Further, since it might be expected that the effect of pre-training would be greatest during the initial part of the test series, threshold scores for the first block and for the first word were also separately analyzed.

Pre-training series

A summary of the analysis of variance of the data shown in the three curves to the left in Figure 3 is presented in Table III. It will be noted that the main effects of treatments (that is, type of stimulus material), serial position and the treatments x serial position interaction are all significant. These effects are apparent in Figure 3, and little further description would seem to be required. It might be noted, however, that the treatments x serial position interaction seems due mainly to the sharp drop in thresholds on the second block of words for the group recognizing number stimuli.

Test series

Threshold data for the test series of words for the four groups are shown to the right of Figure 3. Apart from the first block, on which

TABLE III

SUMMARY OF ANALYSIS OF VARIANCE

OF THRESHOLD DATA TRAINING SERIES

Source	df	MS	F	P
Treatments (T)	2	7827.38	52.29	$<$ .01
Error (b)	57	149.69		
Serial Position (SP)	2	2265.91	75.08	$<$ .01
T x SP	4	189.01	6.26	$<$ .01
Error (w)	114	30.18		

threshold scores for the adaptation group are higher than for the other three groups, the curves are strikingly similar. A summary of an analysis of variance of these data is presented in Table IV. The significant main effect of serial position simply confirms again the well-established practice effect, and is of little interest here. The significant main effect of treatments (type of pre-training), and the significant treatments x serial position interaction appear from Figure 3 to be mainly attributable to the adaptation group. This impression was confirmed by application of Tukey's Multiple Comparison Test (Ryan, 1959) to the overall means for the four groups. This test showed that the mean for the Adaptation group differed from the means of the other three groups ($p < .05$) in all cases, while none of the latter three means differed from each other.

An analysis of variance of the data for the first block of words showed the effect of treatments (that is, different types of pre-training) to be significant ($F = 7.06$, with 3 and 76 degrees of freedom, $p < .01$). Application of Tukey's Test to these data showed that, as was the case for the over-all means, the adaptation group differed from the other three groups ($p < .05$) in all three cases, but that these did not differ from each other.

Apparently, pre-training with different types of stimulus material had no detectable effect on either the overall or initial thresholds of the test series. Recognition of high frequency words, low frequency words, or numbers, results in the same amount of positive transfer to the recognition of low frequency words. On the other hand,

TABLE IV

SUMMARY OF ANALYSIS OF VARIANCE

OF THRESHOLD DATA

Test Series				
Source	df	MS	F	P
Treatments (T)	3	1057.04	4.18	<.01
Error (b)	76	252.60		
Serial Position (SP)	5	1259.56	63.81	<.01
T x SP	15	82.14	4.16	<.01
Error (w)	380	19.74		

simple adaptation to the tachistoscopic situation appears in no way to facilitate performance on the recognition of low frequency words. Examination of Figure 3 shows that the first three points on the curve for the adaptation group are practically identical with the three points for the pre-training curve for the low frequency word pre-training group.

It may be, nevertheless, that the different types of pre-training did have an effect on performances on the test list, but of such a fragile and transitory nature that it is not detected by the threshold measure. This is suggested by a more detailed examination of the threshold scores for the first three test words. A Tukey's multiple comparison test of the treatment means of the first test word for the four groups indicated that the means of the low frequency and numbers pre-trained groups differed significantly from that of the adaptation group, ($p < .05$) while the high frequency trained group did not. It would therefore appear that at this stage of training, the high frequency trained group were responding in a manner similar to that of the group trained in the absence of stimuli, rather than like the two other groups pre-trained with stimuli. However, for the second word in the test list, the threshold scores of the high-frequency trained group dropped slightly below those of the low frequency- and number-trained group, and the three groups continued at approximately the same level throughout the remainder of the test session.

It will be recalled that Solomon and Postman (1952) suggested as part of their interpretation of the word frequency-recognition threshold relationship that the tendency to respond with high frequency words interfered with, and thus raised the thresholds, for low frequency words. An analysis of the pre-recognition responses of the subjects in the four groups does, in fact, suggest such an effect for the first test word.[1] What was done was to note the last word given as a response by each subject in each group prior to the correct response to the first stimulus word in the test series. The frequency of occurrence of these words was then ascertained from the Thorndike-Lorge (1944) word list. When a nonsense word was given, it was assigned a frequency of zero (0).[2] The mean frequencies of occurrence of these responses for each group are given below with the number of responses on which the mean is based being shown in the brackets following each mean. The means are: high-frequency pre-training group, 18.0/million (14); low-frequency pre-training group, 1.5/million (10); numbers pre-training group 18.6/million (9); and adaptation group 18.2/million (14). The only one of these means that is apparently different is that for the low frequency pre-trained group. The effect of pre-training on this group resulted in a closer approximation of their responses to the frequency of the stimulus words. Pre-training with

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1. It must be noted, however, that although subjects were instructed to respond to every presentation of the word, they were inconsistent in their behavior, sometimes responding and sometimes not. The pre-recognition data are, therefore, fragmentary and can be taken only as suggestive.

2. The presence of these nonsense responses accounts for the relatively low average frequencies reported.

high-frequency words, numbers or blank white cards resulted in almost identical frequencies for pre-recognition responses. Within the limits of this experiment the effect of pre-training on pre-recognition responses is at best, puny, and is of little help in explaining the threshold data obtained for the test series.

DISCUSSION

The failure in this experiment to demonstrate a differential effect of pre-training with high or low frequency words, or with numbers on the recognition thresholds of low frequency words is somewhat surprising. Particularly unexpected, on the basis of Experiment 1, is the finding that pre-training with high frequency words facilitates the recognition of low frequency words to the same extent as pre-training with other low frequency words. It may be that the response probability of high frequency words built up by pre-training declines rapidly when the nature of the stimuli to be recognized is abruptly changed, and that the threshold measure is not sufficiently sensitive to detect this effect. Alternatively, the recognition of nine high frequency words may be insufficient to increase the response probability of high frequency words to an extent which would have a demonstrable effect on the threshold of low frequency words. This possibility receives tentative support from the analysis of pre-recognition responses since, it will be recalled, the frequency of these responses for the high frequency group did _not_ differ from the frequency of those given by either the numbers or adaptation groups. When high and low frequency words are randomly intermixed however, as was the case for one group in Experiment 1, the effect on the threshold, and on the threshold decrement is substantial.

The results of this experiment seem to clearly support the view that the tachistoscopic recognition of a variety of stimuli results in the acquisition of a skill which facilitates the recognition of a quite different type of stimulus material. General adaptation to the tachistoscopic situation does not appear to have any such facilitative effect on the recognition of actual stimuli. One aspect of this skill is examined in Experiment 5, reported below. Prior to that, however, two further experiments are reported which attempt to extend the analysis of the role of changes in response probabilities in accounting for the word recognition threshold decrement with practice.

CHAPTER FIVE

EXPERIMENT 3

A suggested interpretation of the failure in Experiment 2 to show an expected differential effect of pre-training with high and low frequency words on the subsequent recognition thresholds of low frequency words, was that recognition of nine high frequency words in pre-training was insufficient to increase the response probability of words in that frequency class. It seemed, further, that recognition of any of the stimulus material employed resulted in the development of some general skill in tachistoscopic viewing which transferred to the recognition of low frequency words.

The present experiment follows up these suggestions. Since in Experiment 2 only one amount (9 items) of pre-training was given, this was varied in Experiment 3. Specifically, different groups of subjects were given one, three, or twenty-seven pre-training trials with high frequency words before being presented with a common list of low frequency words to recognize. It was felt that recognition of twenty-seven high frequency words should raise the response probability of words in this class enough to interfere with the recognition of low frequency words, at least initially. Further, this procedure should provide information on the way in which amount of pre-training with one type of stimulus material affects the development of a general skill in tachistoscopic recognition, and the extent to which this transfers to the recognition of different stimulus material.

METHOD

Subjects

The subjects were 30 male and 30 female students attending the Introductory Psychology course at McMaster University. Their ages ranged from 18 to 30 years, with a mean of 23.6 years.

Stimulus Material

Two lists of seven letter words were randomly selected from the Thorndike-Lorge (1944) word count. One list consisted of twenty-seven high frequency words, while the second list was made up of nine low frequency words. Each word was typed in black, élite capital letters on a white card.

Experimental Design

The sixty subjects were randomly assigned to one of three experimental groups, which differed in the number of high frequency words presented in pre-training. The groups were trained with 1, 3, or 27 words, which were chosen randomly from the high frequency word list. Immediately following, and without any interruption in procedure, each subject was presented with the same list of low frequency words. In all cases where a list consisted of more than one item a different order was obtained for each subject by shuffling the tachistoscopic cards.

Procedure

The procedure was identical to that employed in Experiment 2. The initial exposure of high frequency words was 20 milliseconds, while for low frequency words it was 50 milliseconds.

RESULTS

The threshold data are presented graphically in Figure 4, where only the average scores for the last word of the pre-training series are shown. An analysis of variance performed on the last word of pre-training revealed that the effect of treatments was highly significant ($F = 25.41$, with 2 and 57 degrees of freedom, $p < .001$). This is not surprising in view of the marked differences between these three points in the Figure.

A summary of an analysis of variance performed on the test data is shown in Table V where it can be observed that the effects of treatments (amount of pre-training) and serial position are both significant, while the treatments x serial position interaction is not. It is obvious from an inspection of Figure 4 that the treatment effect can only be due to the difference in threshold scores between the one and three word pre-training groups on the one hand, and the twenty-seven word pre-training group on the other. This observation was confirmed by Tukey's Multiple Comparison Test (Ryan, 1961) performed on the treatment means. ($p < .05$).

Figure 5 depicts, in a different form than Figure 4, the relation between amount of pre-training with high frequency words and average

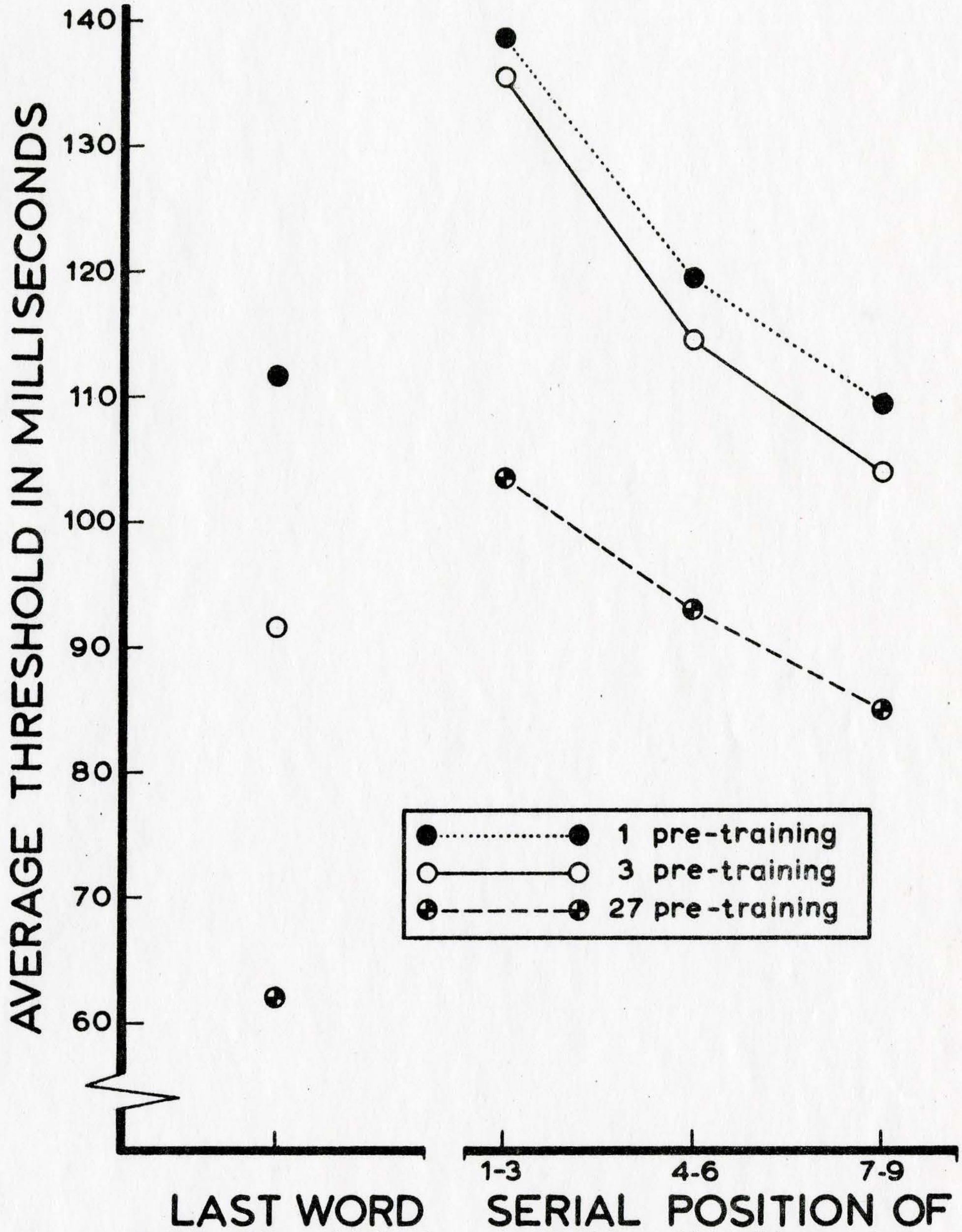

FIGURE 4. Average threshold in milliseconds as a function of serial position of words in groups of three (Experiment 3).

TABLE V

SUMMARY OF ANALYSIS OF VARIANCE

OF THRESHOLD DATA

Test Series				
Source	df	MS	F	P
Treatments (T)	2	1294.12	7.04	$< .01$
Error (b)	57	183.77		
Serial Position (SP)	2	964.68	55.98	$< .01$
T x SP	4	24.75	1.43	NS
Error (w)	114	1964.34	17.23	

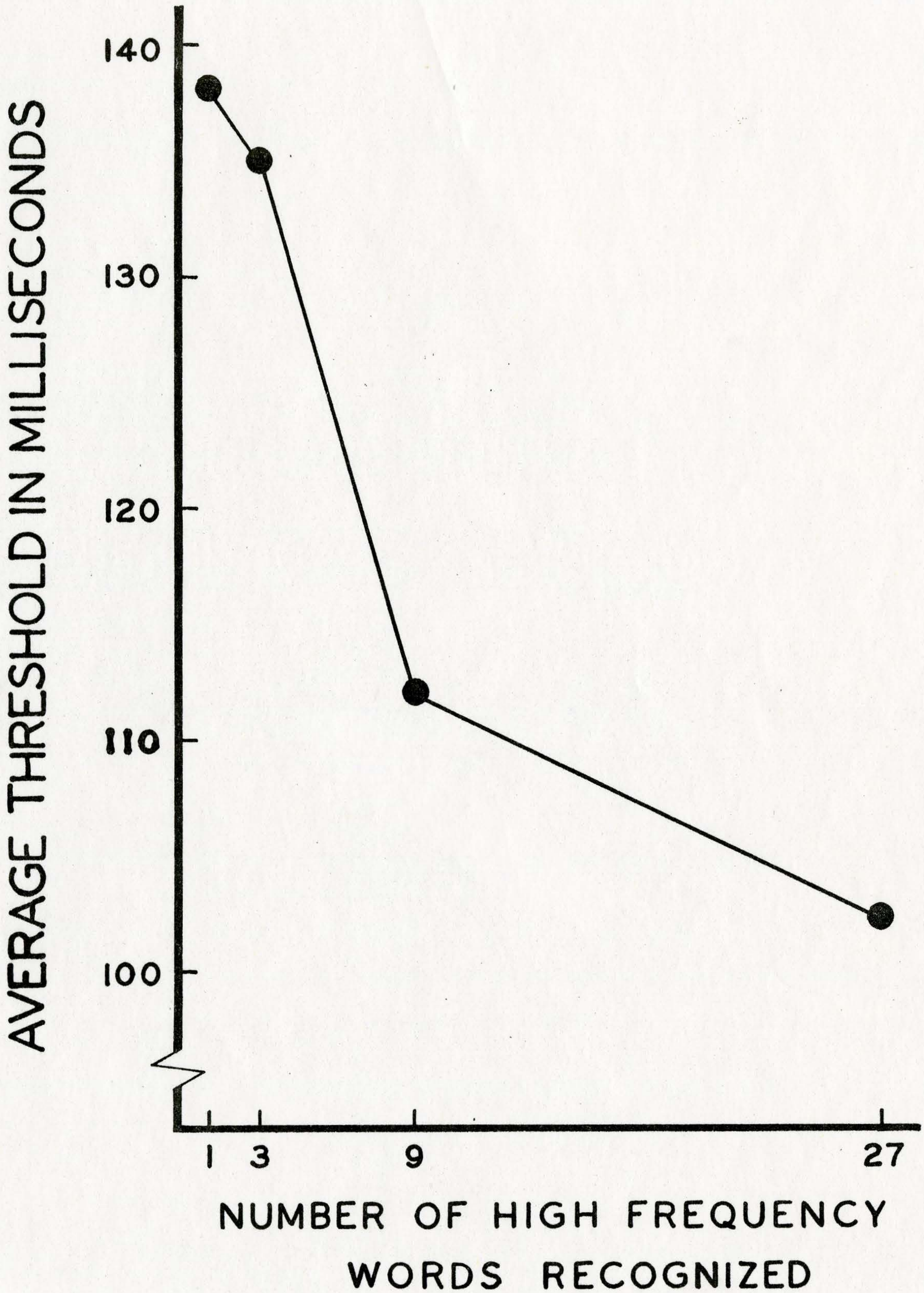

FIGURE 5. Average threshold in milliseconds for the first block of low frequency test words as a function of amount of pre-training with high frequency words. (The threshold score for the group trained with 9 high frequency words is taken from Experiment 2). (Experiment 3).

recognition thresholds on the first block of three low frequency words. It will be noted that, in this Figure, results from the group in Experiment 2 which recognized nine high frequency words are shown along with the results of the three groups from this experiment. Clearly, the threshold for this first block of low frequency words is a negatively accelerated decay function of amount of practice on high frequency words.

The last response by all subjects prior to correct recognition of the first low frequency word was examined to see if any effect of amount of high frequency training could be demonstrated.[1] This would be the case if the frequency of pre-recognition responses varied with the amount of pre-training. The average frequency of these responses (Thorndike-Lorge 1944) with the number of responses upon which the average is based appearing in brackets, are 13.67 (15), 18.29 (14) and 13.50 (18) for the 1, 3 and 27 word trained groups respectively. These averages are little different from each other, and what differences there are bear no relation to amount of pre-training or to the thresholds of the first block of low frequency test words.

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1. The same caution is given here regarding these data as was given in Experiment 2. Despite explicit instructions to respond to every presentation of the words, subjects failed to do so, with the result that these data are fragmentary and of little more than suggestive value. Also, as in Experiment 2, the presence of nonsense responses, which were assigned a frequency of zero, accounts for the relatively low average frequencies reported.

DISCUSSION

The results of this experiment seem quite clear-cut. Facilitation of the recognition of low frequency words is clearly a function of the amount of prior practice with high frequency words. There is no evidence at all that the recognition of as many as twenty-seven high frequency words increases the probability to respond with words from this class beyond that determined by recognizing a single high frequency word. Such an increase in response probability would seem to be the only way in which recognizing high frequency words could interfere with the recognition of low frequency words, and so raise the threshold. The only condition under which such interference effects appear to develop is that which pertained in Experiment 1. When, as in that case, high and low frequency words are intermixed, thresholds for both frequency classes are raised. This finding would seem to have important implications for a theory of the word recognition process, and these will be fully discussed in the final chapter of this thesis.

It is of course impossible to generalize beyond the conditions of this particular experiment. Nevertheless, the finding that improvement in performance in the recognition of low frequency words was directly related to amount of practice in recognizing high frequency words, may be taken as presumptive evidence of a more general relation between tachistoscopic practice and performance. That is, skill in tachistoscopic recognition is a function of amount of practice, and independent of the type of stimulus material employed. This general statement is given some plausibility by the outcome of this experiment since negative transfer effects in the form of interference would seem more likely from high to low frequency words than for less similar stimuli, and yet none could be detected. Further, considering the results of Experiment 2, the same amount of training with high frequency words, low frequency words, and numbers, facilitated equally the recognition of a common list of low frequency words. This, too, will be the subject of fuller discussion in the final chapter of this thesis.

CHAPTER SIX

EXPERIMENT 4

This experiment is concerned with a somewhat different aspect of the response probability-recognition threshold problem. In the previous experiments, attempts to manipulate response probabilities have been confined to *tachistoscopically* presenting the class of stimuli of interest and then inferring the effects of this procedure from the thresholds of different stimuli. It is also of interest to determine if response probabilities built up *outside the tachistoscopic situation* will transfer to that situation. What was done in this experiment was to present different numbers of low frequency words to different groups of subjects using a non-tachistoscopic procedure, and then have them recognize different low frequency words presented tachistoscopically in the usual way.

It has already been shown that the frequency with which nonsense syllables are presented to subjects in a non-tachistoscopic manner has a large effect on the subsequently determined tachistoscopic thresholds for these *same* words. Indeed, in a study of this type by Solomon and Postman (1952) the drop in the threshold of syllables presented only once, as compared with one not previously seen, was greater than the difference in thresholds of syllables presented once and twenty-five times. Thus it is clear that non-tachistoscopic frequency of the same words does transfer to the tachistoscopic situation. Of course the

the whole word frequency effect in tachistoscopic recognition is based on transfer of this type. The more often a word is seen and used in reading and speaking, the lower its tachistoscopic threshold.

The question of whether varying the number of times a subject sees and says words with initial low base probabilities will affect the probabilities of other words in that frequency class and their tachistoscopic thresholds, is one of some interest. The present experiment is an attempt to investigate this problem.

METHOD

Subjects

The subjects were 30 male and 30 female students enrolled in the Introductory Psychology course. Their ages ranged from 18 to 20 years, the average age being 19.2 years.

Stimulus Material

Two lists of seven-letter low frequency words were randomly chosen from the Thorndike-Lorge (1944) word count. Each of the 81 words in the first list was typed in black, élite capital letters in the center of a three inch by five inch white card and constituted the pre-training list. Each of the 18 words which made up the test list was typed in the same print on a white card for tachistoscopic presentation.

Experimental Design

The sixty subjects were randomly assigned to one of three experimental groups with the restriction that there be an equal number of males and females in each group. Each group received pre-training with either 3, 9 or 81 words chosen from the pre-training list. The test list of 18 words was identical for the subjects in the three groups.

Procedure

Before being presented, the 3, 9 or 81 pre-training cards were shuffled and placed in a holder directly in front of the subject. The subject was instructed to look at each word carefully, and then to pronounce it out loud. At the end of five seconds, the experimenter turned the card down, and a new word was exposed. This procedure was repeated until all of the words had been presented.

Following this pre-training the subject was seated in front of the tachistoscope and was presented with the test list of 18 words for recognition. The tachistoscopic procedure was identical to that followed in the preceding experiments.

RESULTS

Figure 6 presents the threshold scores for the three groups as a function of blocks of three words. A summary of an analysis of variance carried out on these data is shown in Table VI, where it can be seen that the only significant effect is that of serial position. Although the main effect of treatments (amount of pre-training) was not significant, Tukey's Test (Ryan, 1959) was applied to the overall means. None of the differences, however, was significant.

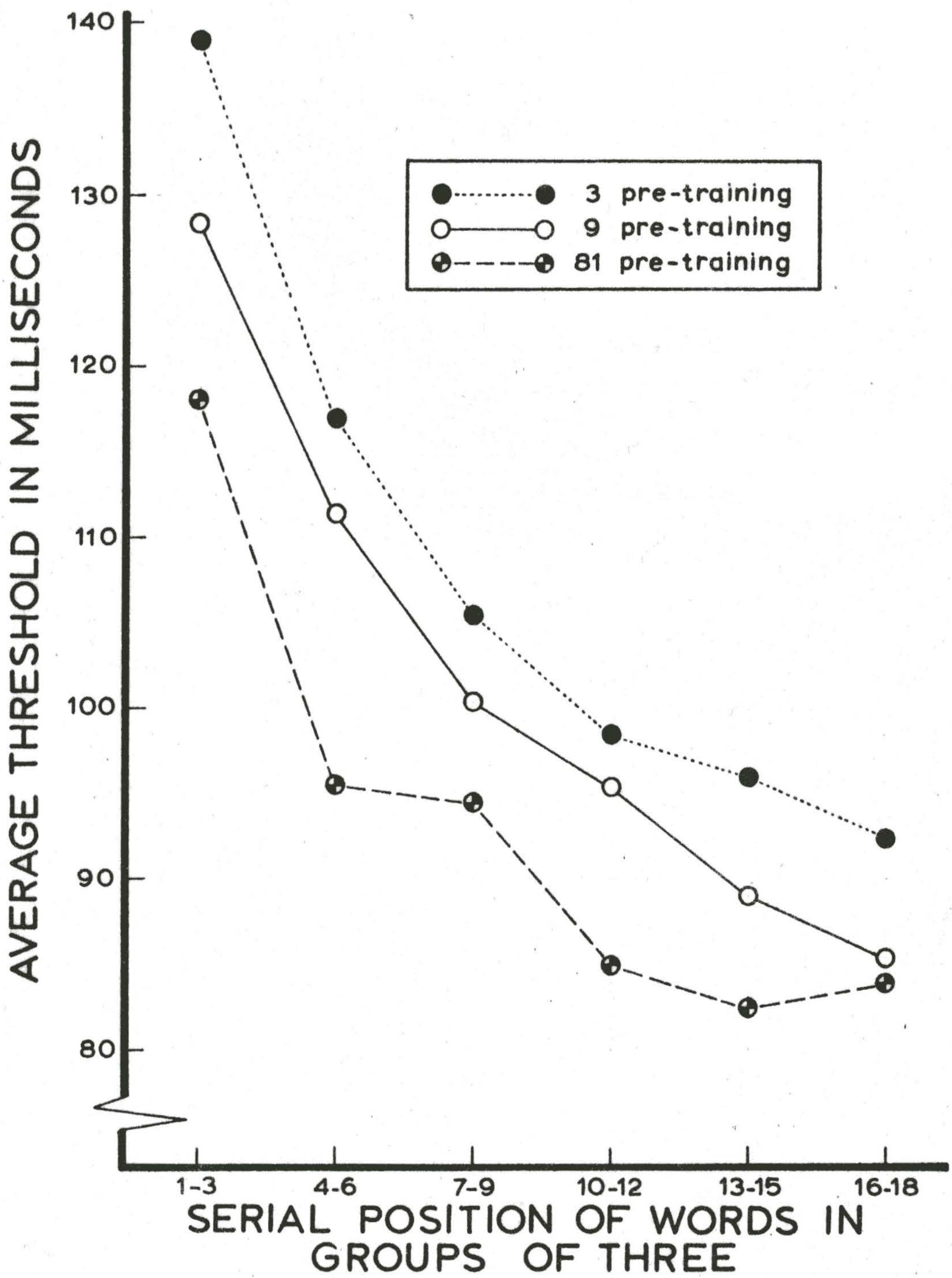

FIGURE 6. Average threshold in milliseconds as a function of serial position of words in groups of three (Experiment 4).

TABLE VI

SUMMARY OF ANALYSES OF VARIANCE OF THRESHOLD DATA

Source	df	MS	F	P
Treatment (T)	2	588.81	1.86	NS
Error (b)	57	316.18		
Serial Position (SP)	5	1259.57	48.48	$<.01$
T x SP	10	16.77		
Error (w)	285	25.98		

Since the first block of words should reveal the greatest effect from the different amounts of pre-training, a separate analysis of variance was performed on these scores; but, again, no significant differences were found between the three groups.

Although the effect of amount of pre-training is not significant, it will be noted from Figure 6 that the three groups are in the expected order. If the average threshold on the first pre-training block for the low frequency group in Experiment 2 is included with the comparable means for the three groups from this experiment the obtained values in milliseconds are 147.8 (0)[1], 139.0 (3), 128.3 (9) and 117.3 (81). Taken in order of magnitude then, these means correlate perfectly with amount of pre-training. This may be taken to suggest that if a sufficiently large number of words were presented during pre-training, perhaps impracticably large, a significant effect could be demonstrated.

DISCUSSION

The interpretation of the failure in this experiment to demonstrate an effect of the pre-training procedure is not clear. It may be that the procedure failed to affect the base response probability of low frequency words. Alternatively, it may be that the base probability was in fact increased but failed to transfer to the tachistoscopic recognition situation.

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1. The numbers in brackets refer to the number of words presented in pre-training.

There are two lines of evidence that show that the response probability for a <u>class</u> of words can be increased. The first is represented by an experiment by Maltzman, Bogartz, and Breger (1958). In this study an experimental group was required to make five different associations to each member of a set of stimulus items. A control group made only one association to each stimulus item. Both groups were then presented with a new list of words for association. The authors reported that the fifth association of the experimental group to items in the training list included more 'uncommon' (that is, low frequency) words than the first association. Also, the experimental group responded more often with 'uncommon' words in the test list than did the control group. The conclusion was that practice in saying 'uncommon' words in the training session increased the response probability of this <u>class of words</u> and that this effect transferred to the test series. It is relevant to note that the transfer observed in this experiment was from one situation to another <u>highly similar</u> situation.

The second line of evidence is represented by the Newbigging and Hay (1962) study, which was described in detail in Experiment 1 in the present series. In this experiment, evidence was reported which showed that the response probability of a class of words increased as successive words from that <u>same class</u> were presented for tachistoscopic recognition, and that this accounted in part for the observed threshold decrement with practice. For example, when a number of low frequency words were recognized, the response probability of this class of words increased and this <u>transfered</u> to the situation represented by the next low frequency word presented for recognition. As in the Maltzman, et al (1958) study, the observed transfer of response probabilities was from one situation to another highly similar one.

These two lines of evidence are consistent in suggesting that the response probability of low frequency words as a class can be increased and that this effect transfers to situations similar to that in which the increase occurred. At the beginning of this discussion, two alternative explanations for the failure of the pre-training procedure in the present experiment to manifest an effect were suggested. One was that the pre-training task did not result in an increase in the response probabilities of low frequency words, the other that the probabilities were increased but failed to transfer to the tachistoscopic situation. The second of these two seems more likely.

CHAPTER SEVEN

EXPERIMENT 5

The results of the previously reported experiments, particularly Experiments 2 and 3, suggested that one of the major effects of practice was the acquisition of some general skill in tachistoscopic viewing that was independent of the stimulus material on which the practice was gained. This skill appeared to account in substantial part for the observed threshold decrement as successive words were recognized. In Experiment 2 it was noted that practice with any one of high frequency words, low frequency words, or numbers, facilitated equally the recognition of low frequency words. As general adaptation to the experimental situation, in the form of repeated presentations of a blank exposure field, was demonstrated to have no effect, it seemed clear that it was the recognition of stimuli that was important. The results of Experiment 3 supported this view. In that experiment it was shown that thresholds of low frequency words were a function of the amount of previous practice in recognizing high frequency words.

It occurred to us that one component of this general tachistoscopic skill might be learning precisely where to fixate prior to the presentation of the word, thus maximizing the amount of stimulus information gained from each presentation. It will be recalled that in all of the experiments reported in this thesis the pre-exposure field contained only two horizontal black lines, each four inches in length and set two inches apart. The subject was instructed that the word to be presented would appear centred between these two lines, but obviously this fixation aid was not very precise and allowed considerable scope for error in judgment of the stimulus position.

An examination of the procedures used in a number of word recognition experiments showed that practice with respect to the provision of a fixation aid has varied widely.[1] In some, two lines have been used to demarcate a small area in which the word was subsequently presented (Newbigging, 1961a, 1961b; Newbigging and Hay, 1962), while in other experiments the pre-exposure field was left completely blank (Howes and Solomon, 1951; Taylor, 1958). Not infrequently, no reference at all was made to this aspect of the procedure (King-Ellison and Jenkins, 1954; Postman, Bruner and McGinnies, 1948; Postman and Schneider, 1951).

It seemed desirable therefore, as the last experiment in this series, to undertake a preliminary examination of the effect on word recognition thresholds of a precise fixation point.

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1. The only tachistoscopic studies that have consistently used a precise fixation aid are those concerned with the problems of retinal locus and eye-movement habits established in reading as determinants of tachistoscopic word or letter recognition (Glanville and Dallenbach, 1929; Mishkin and Forgays, 1952; Orbach, 1952; Forgays, 1953; Melville, 1957; Heron, 1957; Terrace, 1959).

METHOD

Subjects

The subjects were ten male and ten female students attending Hamilton Teachers' College. Their ages ranged from 19 to 24 years, the average age being 20 years.

Stimulus Material

The same list of low frequency words that was presented in the test series in Experiment 2 was used. Each word was seven letters in length, and had a frequency of occurrence of once per three million words. The words were typed in black, élite capital letters on white cards.

Experimental Design

The subjects were randomly assigned to one of two experimental groups with the restriction that five males and five females appear in each group. The treatment of the groups differed only with respect to the presence of absence of a fixation point in the pre-exposure field.

Procedure

The pre-exposure field for the subjects in the first group contained a fixation point placed so that the middle letter of the word presented for recognition appeared directly above it. For the second group of subjects, the pre-exposure field was completely blank. Thus, these subjects had no aid in locating the position where the words would appear. For both groups, of course, the stimulus words were presented in exactly the same position.

Each of the subjects in both groups was presented with the identical list of 18 words for tachistoscopic recognition. The list of words was shown in a different random order to each subject. The initial exposure duration for all words for all subjects was 50 milliseconds.

RESULTS

The threshold data are presented graphically in Figure 7, and a summary of an analysis of variance performed on the data is given in Table VII. As will be seen from the Table, both the main effects of treatments (fixation versus no fixation) and serial position are significant, as is the treatments x serial position interaction.

The main effect of treatments simply shows that the provision of a precise fixation point results in overall lower thresholds as compared with the condition where no fixation aid is provided. The nature of the treatments x serial position interaction is apparent from Figure 7. The two groups start widely apart and converge as practice proceeds. The drop in threshold for the no-fixation group is particularly steep in its first half, and then tends to level off. The curve for the fixation group tends to drop more gradually throughout its length. An analysis of variance performed on the last block of words showed that the two groups did not differ at the end of practice ($F = 2.31$, with 1 and 18 degrees of freedom, $p < .25$). Evidently, the no-fixation group learned during the course of practice

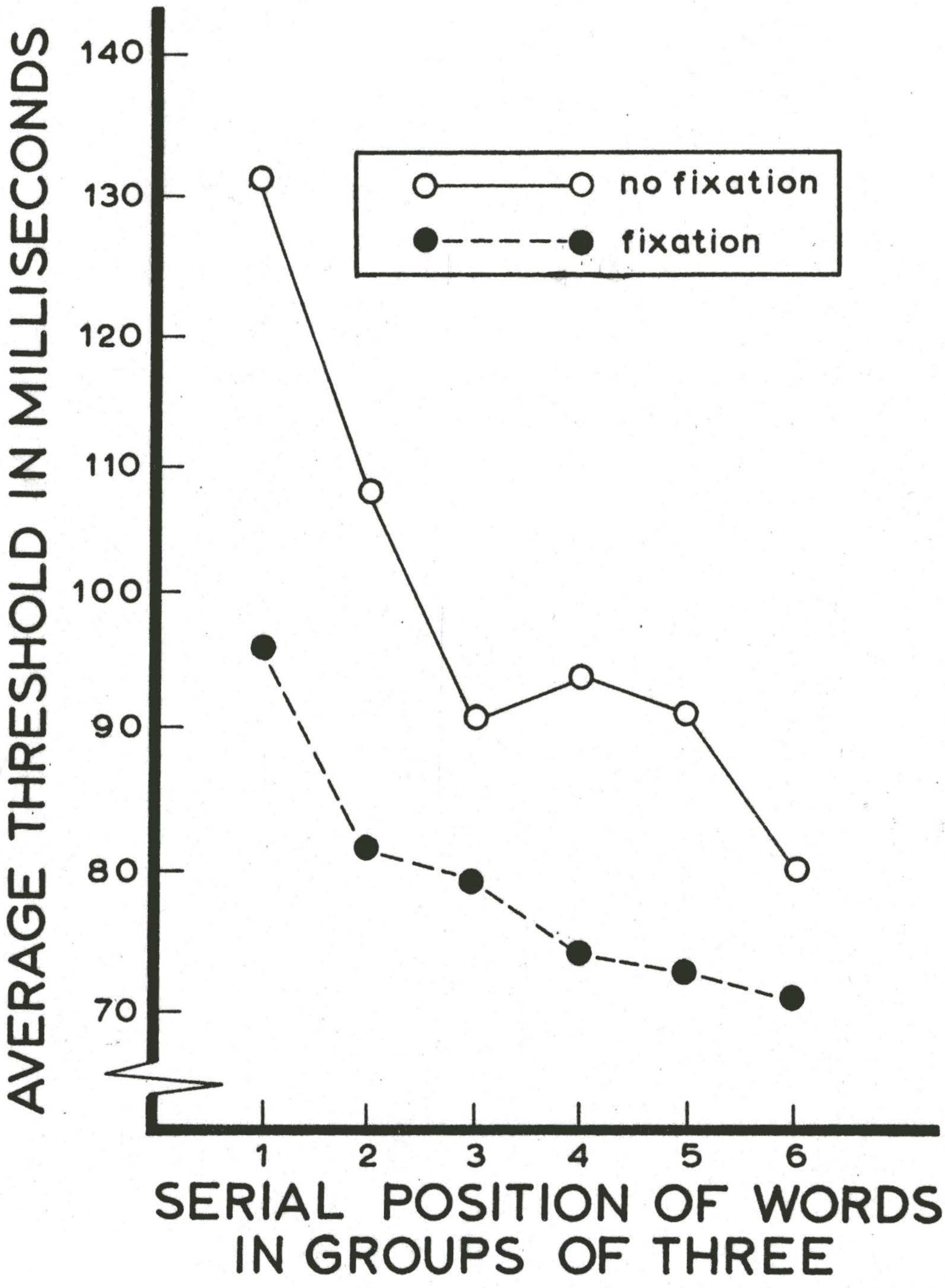

FIGURE 7. Average threshold in milliseconds as a function of serial position of words in groups of three (Experiment 5).

TABLE VII

SUMMARY OF ANALYSIS OF VARIANCE
OF THRESHOLD DATA

Source	df	MS	F	P
Treatments (T)	1	1134.67	10.23	< .01
Error (b)	18	110.97		
Serial Position (SP)	5	325.81	18.57	< .01
T x SP	5	46.14	2.63	< .05
Error (w)	90	17.54		

what the fixation point provided for the other group from the beginning.

In an attempt to gain more information about the way the fixation point facilitated recognition, an analysis was made of certain pre-recognition responses for both groups.[1] Specifically, what was done was to compare the first (R_1)[2], and last pre-recognition response (RT-1) with the stimulus word to which they were made. In this comparison, every letter in the response word that was the same as one in the stimulus word, regardless of its position, was assigned one point. These points for each letter position were then summed. For example, a total was obtained for the number of times the first letter of the stimulus word occurred in the first response (R_1) given by subjects in the fixation group; a similar procedure was carried out for the second and subsequent letters. These totals were also obtained for all letters in the stimulus words for the first responses (R_1) of

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1. Subjects for this experiment were drawn from a Teachers' College population, and not from the University population as was the case for all other experiments. This was necessary because the experiment had to run at a time when the University students were preparing for examinations, and were unavailable. The Teachers' College group was somewhat younger, and seemed generally more highly motivated to do well in the experiment. This may account both for the rather low threshold values obtained, even for the no-fixation group, and for the fact that these subjects complied with the instructions to respond to every presentation of the stimulus word. In any event, pre-recognition data from this experiment was quite complete and usable.

2. By first response is meant the first usable response. Initial exposures often elicited 'blank', 'flash', or 'nothing' as responses. The first usable response was either a complete word, a nonsense word, or a number of letters.

the no-fixation group, and for the last responses (RT-1) of both groups. These totals were then computed as percentages of the total possible number of points. These percentages are plotted against letter position for both responses, and for both groups, in Figure 8.

Consider first the lower pair of curves in Figure 8. These are for the first responses for the two groups, and tend to be highly similar except for letters in positions 6 and 7. Evidently the fixation group incorporates more of the last letters in its first response than does the no-fixation group. Application of the Mann-Whitney U Test showed that the two points for the letters in position 7 were, in fact, significantly different ($U = 53.5$, $p < .002$).

Consider now the upper pair of curves. As expected, the subjects have incorporated more of the stimulus letters in their RT-1 responses than in their first responses. The two curves are highly similar throughout their lengths, the difference in the last letter position having largely disappeared. Application of the Mann-Whitney U Test to the two points for the letters in position 7 showed that they were not significantly different ($U = 110.5$, $p > .10$).

It needs to be noted further that the exposure durations at which the fixation group made its first, and RT-1 responses were shorter than those at which the no-fixation group made these same responses. This follows inevitably from the difference in average threshold values for correct identification of the stimuli. The fixation group made its first response on approximately the second exposure of the stimulus word (the average exposure duration associated with

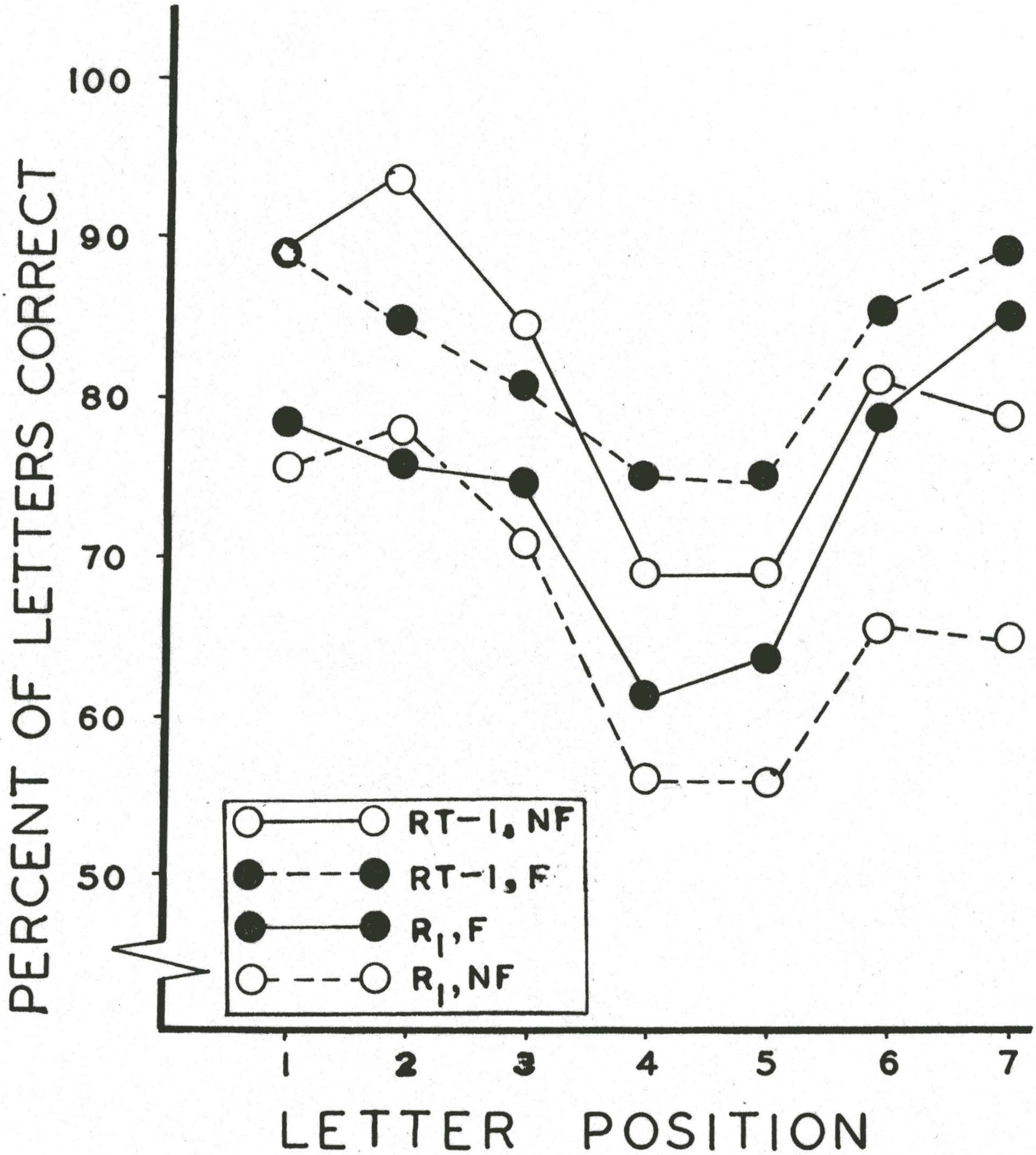

FIGURE 8. Percent of letters correctly identified by the Fixation and No-Fixation (F and NF) groups for the first (R_1) and last (RT-1) pre-recognition responses plotted against letter position. (Experiment 5).

this response for this group was 62.4 milliseconds)[1], and the RT-1 response on the fourth presentation (79.0 milliseconds). The no-fixation group, on the other hand, made its first response on the third presentation (72.0 milliseconds), and the RT-1 response on the sixth presentation (99.5 milliseconds) of the stimulus word. Thus, following the first response the no-fixation group required approximately three additional presentations of the stimulus word, at successively longer exposure durations, to recognize the same number of letters (that is, at RT-1) as the fixation group gained in two additional exposures (that is, second to fourth). This suggests, then, that with a fixation point more information about the stimulus is gained on successive exposures than is the case without such an aid. Further, it appears that it is the recognition of letters at the end of the stimulus word that is mainly facilitated by the fixation point.

DISCUSSION

The finding in this experiment, that both the first and last letters of a tachistoscopically presented word enjoy some advantage as far as recognition is concerned, is not new. Wagner (as read in Woodworth, 1938, pp 742-744), for example, presented a curve for the recognition of random sequences of letters as a function of letter position which corresponds very closely in shape to the curves in Figure 8. More recently, Haselrud and Clark (1957) presented curves

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1. The initial exposure duration for all words was 50 milliseconds.

for the percent of letters recognized in nine-letter words as a function of letter position. Again the U-shaped curve that we report was obtained. These authors commented: "Apparently the fragmental cues most likely to be effective (in the tachistoscopic recognition of a word) are at the ends of the word despite fixation at the middle" (1957, p. 99).[1]

The U-shaped relation between recognizability and letter position, and the fact that letters at the beginning and end rather than middle letters constitute the usual fragment for the identification of tachistoscopically exposed words, both seem reasonably well established. The main contribution of the present experiment is in showing that the provision of a precise fixation point facilitates the recognition of the necessary end letters.

Findings by Heron (1957) suggest the way in which the fixation point may exert this facilitative effect. In one of his experiments, groups of letters were presented both on the right and left of a fixation point.[2] Under these conditions, he found that the letters on the left were more readily recognized than those presented on the right. Heron explained this finding in terms of two types of eye-movements developed in reading. The first, and dominant movement, was to move

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1. The fact that the letters at either end of a word are more readily discriminated is probably attributable to the sharp gradient between them and the white ground. Middle letters tend to mask each other because of their juxtaposition.

2. This is analagous to the situation for the fixation group in this experiment, since the fixation point was set directly below the middle letter of the word.

the eyes to the left to the beginning of the word when it was presented. The second consisted of a movement from left to right to the end of the word. In our experiment, the subjects who had the fixation point might have been able to eliminate the initial movement to the left, since they knew the beginning of the word would always appear on that side of the fixation point. If this was the case, they would be able to sweep their eyes rapidly to the end of the word during its exposure, and so identify the letters at both ends. The subjects without the fixation point had no precise information about the location of the word; thus, they would have had to make both types of eye-movements if, on its presentation, they happened to be fixating near the middle of the word. At short exposure durations there would be insufficient time to complete the movement to the right, and for this reason they were unable to identify the last letters. Since longer exposure durations would be required to complete both eye-movements, the recognition thresholds would naturally be higher. While this explanation may be incorrect in detail, it seems reasonable to suppose that prior to word presentation the fixation of these subjects would be somewhat erratic, thus rendering the scanning process less efficient than with a fixation point present.

While this may explain the initially higher thresholds of the no-fixation group, it fails to account for the fact that the thresholds for the two groups were not significantly different at the end of the list of words. It might be that, during the course of the experiment, the fixation of the group without any obvious aid became more precise. Just how this might have occurred is not entirely clear. One possibility is that, with practice this group acquired some proficiency in judging the location of the word to be presented on the basis of cues provided by the edges of the pre-exposure field; these cues might have come to serve almost as well as a distinct fixation point.

Although direct comparisons cannot be made, we suggest that some similar improvement in judgment of the position of the stimulus word might account, in part, for the practice effect observed in other experiments in this series. Since the precise location of the stimulus word with respect to the horizontal plane seems to be crucial, it is difficult to see how the two horizontal lines used to demarcate the fixation area in the other experiments could have been of much help. It might well be that improvement in judgment of the type referred to above could constitute, in part, the general skill in tachistoscopic recognition previously mentioned.

CHAPTER EIGHT

CONCLUSIONS AND DISCUSSION

Our objective in this final Chapter is to discuss the general implications of these experiments as they relate to the process of tachistoscopic recognition. In view of the number of experiments involved, a summary will precede the discussion. Rather than simply restate details of results which are fully described elsewhere, we have chosen to present this summary in the form of a series of conclusions which, within the limits of the experiments, the results seem to warrant.

Conclusions

1. Changes in the response probability of a frequency class of words presented for tachistoscopic recognition contribute to the rate of threshold decrement with practice under the following conditions:

(a) When the words to be recognized are all from the same low frequency class; under this condition, the recognition of a number of words appears to increase the probability as responses of other words in that same frequency class. This increase in response probability facilitates the recognition of subsequently presented words. (Experiment 1)

(b) When the words to be recognised are from widely different frequency classes, and these are presented for recognition in a <u>mixed</u> order. Under this condition, higher recognition thresholds and a retardation of the rate of threshold decrement with practice are observed compared with the condition where the list of words to be recognised is homogenous with respect to frequency. (Experiment 1)

2. The effects of seeing and saying low frequency words outside the tachistoscopic situation has no significant effect on the subsequent tachistoscopic recognition of <u>different</u> words from the same frequency class. Transfer of response probabilities built up in non-tachistoscopic practice seems only to occur, at least to any appreciable extent, when the <u>same</u> words are involved in both tasks. (Experiment 4)

3. General adaptation to the tachistoscopic situation appears to have no effect on the recognition of subsequently presented stimuli. (Experiment 2)

4. When a number of stimulus items of one type are recognised and then, without warning or further instruction to the subject, stimulus items of a different type are presented, recognition thresholds for the new stimuli are a decreasing function of the amount of prior practice, and independent of the nature of the stimuli on which the practice was gained. Recognition of a variety of stimuli appears to improve tachistoscopic performance through the development of some general skill, and this transfers to the recognition of stimuli of a different type. (Experiments 2 and 3)

5. In part, the general skill in tachistoscopic recognition seems to consist of improvement in judging the position where the stimulus will appear. This facilitates the scanning of the stimulus, which process may also improve with practice, and permits identification at shorter exposure durations. In the case of words, it appears that it is the recognition of the last letters that is particularly helped and that these, along with the first letters, are the most effective in aiding the identification of the word. The provision of a precise fixation point in the pre-exposure field obviates the need for improvement in judging stimulus position, with the result that initial thresholds are significantly reduced. (Experiment 5)

Discussion

The first issue to be taken up in this discussion arises from the apparent conflict between the results of Experiment 1 and those obtained in Experiments 2 and 3. In Experiment 1 we found that presenting high and low frequency words for recognition in a mixed order had the effect of raising the thresholds for both classes of words. Experiments 2 and 3, however, showed that the recognition of different numbers of high frequency words facilitated the recognition of low frequency words; the more high frequency words recognized, the lower the thresholds of the subsequently presented low frequency words. This finding was unexpected. What was expected on the basis of Experiment 1 was that the prior recognition of high frequency words would increase their probability as responses and that this would interfere with the recognition of low frequency words, so raising their thresholds. This is what seemed to be happening in the case of the mixed list in Experiment 1.

The apparent conflict between these results may be resolved on the basis of two assumptions. First, assume that the response probability of high frequency words is asymptotic prior to the experiment and cannot be increased by experimental manipulations. Second, assume that the response probability of high frequency words can, however, be depressed by experimental manipulations, which include the intermixing of low frequency words in a list presented for recognition. The data presented in Figure 2 (following page 55) may now be re-examined in the light of these assumptions.

Consider first the lower two curves in the Figure which are for high frequency words. On the basis of the first assumption made, the decrease in thresholds with practice observed for the homogenous high frequency list would have to be explained solely in terms of the general skill in tachistoscopic viewing which was previously referred to and which is the subject of fuller discussion below. The more gradual decrease of the curve based on the high frequency words from the mixed list (the two curves are significantly different by the end of practice) may be attributed to the recognition of the intermixed low frequency words depressing the response probability of high frequency words, and so raising their thresholds.

Turning now to the upper pair of curves for low frequency words, the difference between the one based on the mixed list and that based on the homogenous list may simply be due to the fact that a greater number of low frequency words were recognised in the case of the homogenous list. It will be recalled that the points of these curves are based on only three threshold values from each block of six obtained. While the average threshold values shown for comparable points on the curves were obtained for words occupying the same serial position in the two lists, there is an important difference. The difference is that in the case of the curve based on the mixed list the threshold values not included were for high frequency words, while in the case of the curve based on the homogenous list they were for low frequency words. Obviously then, subjects presented with the homogenous list recognized twice as many low frequency words as did the other group. If the response probability of low frequency words is a function of the number of such words recognized, then the observed difference between the two curves can be explained in this way.

Now to extend this explanation to the results of Experiments 2 and 3. As far as Experiment 2 is concerned, discussion is limited for the time being to the results obtained from the group trained on high frequency words. In the case of this group, and of the three groups trained with different numbers of high frequency words in Experiment 3 prior to the recognition of low frequency words, it was found that performance in recognising low frequency words was inversely related to the number of high frequency words previously recognized. If it is assumed that the probability of high frequency words is asymptotic prior to the training session, this result is not surprising. The amount of training with high frequency words would leave the response probability of this frequency class unaffected. The facilitating effect of recognising high frequency words on the recognition of low frequency words may be attributed to the acquisition of a general skill in tachistoscopic recognition.

The upshot of this explanation is that one would be able to demonstrate interference in recognizing one class of words from prior training with another, only if the probability of the latter as responses could be increased. The pre-recognition data presented in the results section of both experiments 2 and 3 suggested that the presentation of high frequency words had no effect on their probability as responses, thus supporting the first assumption. In Experiment 2 the frequency of words given as responses to the first low frequency test word were the same for the numbers and adaptation group as for the high frequency trained group. In Experiment 3, the frequency of these same responses did not vary with amount of high frequency pretraining; indeed, only small differences were observed. The Postman and Leytham (1951) experiment is instructive in this connection. They were able to show that when a noun was presented for recognition following the recognition of a series of fifteen adjectives, the threshold was significantly raised. The nouns and adjectives they used were equated for frequency of occurrence so that this finding must be interpreted as an increase in the probability of adjectives as responses interfering with the recognition of the noun. Their analysis of the pre-recognition responses to the noun does in fact bear out this interpretation. Subjects tended to continue to respond with adjectives bearing a structural similarity to the noun. For the second noun presented the threshold dropped sharply, suggesting that the interference effect was transitory in nature.

To briefly summarise, the apparent conflict between the results of Experiment 1 and those of Experiments 2 and 3 was based on the premise that recognising high frequency words increased their probability as responses and that this would interfere with the recognition of low frequency words. The evidence is, however, that the response probability of this class of words is asymptotic prior to experimental manipulation. If this is accepted, along with the assumption that intermixing low frequency words depresses the response probability of high frequency words, then the apparent conflict is resolved.

By implication at least, it has been suggested in a number of places above that a large part of the observed threshold decrement, and the positive transfer from recognising one type of stimulus material to recognising another, is attributable to an acquired skill in tachistoscopic recognition. Attention is now given to an explicit discussion of this skill.

In the discussion following Experiment 5 it was suggested that the initially higher thresholds of the group without a fixation aid, as compared with the group who had a fixation point, could be largely explained in terms of the necessity for the no-fixation subjects to learn precisely where the word would appear. This learning was necessary so that the word could be more effectively scanned at brief exposures, and the parts necessary for its identification recognized. Some improvement in the efficiency of the scanning process with practice was also suggested as a possibility for both groups. With this description of the general skill in tachistoscopic recognition in mind, we may now examine the experimental results.

Consider first the results of Experiment 2. Here it was found that pre-training with high frequency words, low frequency words, or numbers was equally effective in facilitating the recognition of low frequency words. These three pre-training conditions all have two features in common with each other and with the test condition. These are, first, the stimuli all appeared in the same place in the exposure field and, second, all required left to right scanning for their identification. Thus, all pre-training conditions provided equal opportunities to learn the location of the stimuli and to practice scanning at brief exposure durations. The adaptation group, since no stimuli were presented, had no opportunity to learn either aspect of this skill and showed no effect of the adaptation procedure.

In Experiment 3 the results are exactly what one would predict if tachistoscopic skill is gradually acquired in the course of recognising stimuli, and this skill is the only factor of consequence. The more high frequency words recognized, the greater the skill, and the greater the facilitative effect on recognizing low frequency words.

As far as the results of Experiment 4 are concerned, it may be that the subject's initial ineptness in tachistoscopic recognition was such as to mask any effects of the pre-training procedure. All of the experiments suggest that, while under some conditions changes in response probability have a demonstrable effect on the recognition threshold, this effect is relatively small compared with that of the general skill. Added to this of course is the possibility that transfer of response probabilities built up in one situation may transfer only to other highly similar situations. The final interpretation of Experiment 4, then, remains unclear.

There exists other, though inconclusive, evidence for the type of general tachistoscopic skill which we propose. This comes from studies concerned with the problem of improving reading skill by means of tachistoscopic training. For example, both Renshaw (1945) and Weber (1942) report significant increases in reading speed and comprehension following tachistoscopic training with digits and letters respectively. As Gibson (1953) points out, however, these and other experiments which report similar positive transfer either failed to control for changes such as increased motivation which may have accounted for the improvement in reading, or have failed to run suitable control groups with which the tachistoscopically-trained groups could be compared. The results, therefore, must be viewed with some caution. Nevertheless, such transfer seems plausible if tachistoscopic training results in the acquisition of a skill of the type we have suggested. The aspect of this skill which is relevant here has to do with the increased efficiency in scanning a briefly presented stimulus. This left to right scanning is common to both tachistoscopic recognition of words, series of letters, and series of numbers, and to reading ordinary printed material. Positive transfer would be expected on this basis.

As was stated in the Introduction to this thesis, the experiments which have been reported arose from an earlier experiment by Newbigging and Hay (1962). This experiment left unanswered some questions concerning the role of response probability in accounting for the threshold decrement characteristically observed in a word recognition task. Specifically, such questions as the conditions under which response probabilities for a class of words are increased, whether such response probabilities transfer to the recognition of other types of stimuli, and if so, the extent and duration of their effect, seemed in need of further investigation. While the present experiments by no means supply exhaustive answers to these questions, they at least provide data which any complete interpretation of the recognition process will have to take into account.

Perhaps the most important finding has to do with the identification of a general skill acquired in the course of tachistoscopic recognition. One part of this skill, learning to fixate in the proper place so that the stimulus may be effectively scanned, may seem of little generality or importance. The simple expedient of providing a fixation point eliminates the necessity for this learning. However, it must be remembered that experimenters working in this area of tachistoscopic recognition have largely ignored the whole question of receptor orientation, and it is in this context that this finding should be evaluated.

The other aspect of the skill, and the one of greatest interest, concerns the apparent improvement in the subject's ability to scan the stimulus and so recognise the parts necessary for its identification at progressively shorter exposure durations. Further experimental examination of this mechanism may well enable us to specify the conditions under which transfer from one tachistoscopic task to another will occur, and when tachistoscopic training may be expected to facilitate non-tachistoscopic performance. It may well be that only when the eye-movements are the same in two tasks can positive transfer from one to the other be expected. It may also be, however, that some increased sensitivity of the central aspects of the perceptual mechanism follow from tachistoscopic training. It is questions such as these which, on the basis of our experiments, we suggest should guide further research on tachistoscopic recognition.

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APPENDICES

APPENDIX A

LISTS OF STIMULUS WORDS

EXPERIMENT I

HIGH FREQUENCY WORDS

Words occurring fifty or more times per million*

ADVANCE	GENERAL	QUICKLY
AGAINST	HISTORY	REQUIRE
ALREADY	HOWEVER	SCATTER
BELIEVE	INCLUDE	SCIENCE
BREATHE	JUSTIFY	THOUGHT
CAPITAL	MACHINE	TROUBLE
DECLARE	MILLION	USUALLY
ELEMENT	OFFICER	VILLAGE
FEATURE	PERHAPS	WEATHER
FOREIGN	PICTURE	WRITTEN

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

LOW FREQUENCY WORDS

Words occurring on the average of three times per million*

ABETTOR	EUGENIC	OARLOCK
ACOLYTE	FLOTSAM	PILLION
BEATIFY	GANGLIA	QUINTET
BIOTITE	GENETIC	REGRESS
CASSAVA	HAULAGE	RUSTLER
CLINKER	ITERATE	SERRIED
CROUTON	JITTERY	SPICULE
DEMOTIC	MARABOU	TACTILE
ENDEMIC	MILKSOP	TRAWLER
ERASURE	MODISTE	VALENCE

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

EXPERIMENT II

PRE-TRAINING SERIES OF WORDS AND NUMBERS

HIGH FREQUENCY Fifty or more times per mil.*	LOW FREQUENCY On the average of three per million*	NUMBERS
ADVANCE	BIOTITE	4954013
CAPITAL	CASSAVA	6157006
GENERAL	DEMOTIC	1132254
HOWEVER	ERASURE	4336128
JUSTIFY	JITTERY	9380620
MILLION	MARABOU	3135283
QUICKLY	MODISTE	5704886
SCATTER	REGRESS	4331001
TROUBLE	SERRIED	1174269

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

TEST SERIES - LOW FREQUENCY WORDS

Three times per million words

ABETTOR	EUGENIC	QUINTET
ACOLYTE	GANGLIA	RUSTLER
BEATIFY	GENETIC	SPICULE
CLINKER	ITERATE	TACTILE
CROUTON	MILKSOP	TRAWLER
ENDEMIC	PILLION	VALENCE

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

EXPERIMENT III

PRE-TRAINING SERIES - HIGH FREQUENCY WORDS

Words occurring fifty or more times per million*

ADVANCE	GENERAL	QUICKLY
AGAINST	HISTORY	REQUIRE
ALREADY	HOWEVER	SCATTER
BELIEVE	JUSTIFY	SCIENCE
BREATHE	MACHINE	THOUGHT
CAPITAL	MILLION	TROUBLE
ELEMENT	OFFICER	USUALLY
FEATURE	PERHAPS	WEATHER
FOREIGN	PICTURE	WRITTEN

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

TEST SERIES - LOW FREQUENCY WORDS

Words occurring on the average of three times per million*

ABETTOR	ENDEMIC	PILLION
CLINKER	GANGLIA	SPICULE
CROUTON	ITERATE	TACTILE

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

EXPERIMENT IV

PRE-TRAINING SERIES - LOW FREQUENCY WORDS

Words occurring on the average of three times per million*

ANNULET	IMPOUND	RAPPORT
ASEPTIC	INANITY	REGRESS
AUTOPSY	INGENUE	ROGUERY
BEDIZEN	INTREAT	SALABLE
BEJEWEL	JITTERY	SCALPEL
BIOTITE	JUGULAR	SEDUCER
CAESURA	LAMELLA	SELVAGE
CASSAVA	MARABOU	SERRIED
COARSEN	MASQUER	SLEIGHT
COGNATE	MAXILLA	SOOTHER
CUMULUS	MELODIC	STEARIN
DELIMIT	MIDIRON	STEPSON
DEMOTIC	MISGAVE	STERNUM
DISTAIN	MODISTE	STROPHE
ENCHASE	MUGWUMP	SUITING
EPOCHAL	NIRVANA	TAPSTER
ERASURE	OARLOCK	TERRAIN
FADDIST	OPTIMUM	TOLUENE
FISSION	ORTOLAN	TREACLE
FLOTSAM	OUTFACE	TUMBRIL
GALLOON	OVERACT	TWISTER
GERMANE	PALATAL	TWOSOME
GOSHAWK	PALMATE	VEDETTE
GRANTEE	PARQUET	VERSIFY
HANGDOG	PIEBALD	VOLTAIC
HAULAGE	PLIANCY	WAXWORK
HEPATIC	PRIMULA	WIDGEON

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

TEST SERIES - LOW FREQUENCY WORDS

Words occurring on the average of three times per million*

ABETTOR	EUGENIC	QUINTET
ACOLYTE	GANGLIA	RUSTLER
BEATIFY	GENETIC	SPICULE
CLINKER	ITERATE	TACTILE
CROUTON	MILKSOP	TRAWLER
ENDEMIC	PILLION	VALENCE

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

EXPERIMENT V

TEST SERIES - LOW FREQUENCY WORDS

Words occurring on the average of three times per million*

ABETTOR	EUGENIC	QUINTET
ACOLYTE	GANGLIA	RUSTLER
BEATIFY	GENETIC	SPICULE
CLINKER	ITERATE	TACTILE
CROUTON	MILKSOP	TRAWLER
ENDEMIC	PILLION	VALENCE

*Frequency of occurrence according to the Thorndike-Lorge (1944) general count

APPENDIX B

RAW DATA FOR EXPERIMENT I

GROUP I - HIGH FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Serial Position of Words	Subjects 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11	10	11	10	13	16	15	11	10	10	7	10	20	12	17
2	8	8	8	11	11	14	17	9	9	11	9	8	18	10	15
3	8	8	9	9	11	15	14	11	10	13	8	8	12	10	14
4	9	8	8	8	9	13	17	11	10	10	8	8	18	10	13
5	9	8	9	8	10	14	13	8	11	11	8	7	14	9	15
6	10	8	8	9	9	10	13	9	10	9	8	8	15	9	12
7	8	8	7	10	9	9	14	9	9	10	8	9	11	8	10
8	8	8	8	10	7	14	10	7	9	8	6	7	11	8	9
9	7	9	7	9	9	10	11	7	9	8	8	8	13	7	9
10	8	8	9	9	8	10	9	8	9	10	6	6	10	8	10
11	8	7	7	9	8	9	10	8	11	7	7	8	10	8	9
12	9	8	7	9	7	9	9	8	8	9	7	7	9	7	10
13	7	8	7	9	8	9	10	8	8	9	6	7	11	8	9
14	9	7	7	7	7	8	8	8	8	8	7	7	10	7	10
15	8	9	8	8	7	9	10	7	8	8	6	6	11	7	9
16	8	8	8	9	8	10	8	6	9	8	6	8	9	9	9
17	7	8	7	8	6	9	9	7	9	9	6	7	10	7	9
18	8	7	7	7	8	9	8	7	8	8	7	7	10	8	9
19	8	8	7	8	6	8	10	6	8	7	6	7	9	8	10
20	8	8	7	8	7	9	8	7	8	8	5	6	9	6	8
21	8	7	6	8	7	8	8	8	8	8	5	6	8	7	8
22	7	8	6	8	9	8	9	7	9	8	5	7	9	7	11
23	7	6	7	8	7	8	8	7	9	6	7	6	9	8	10
24	7	7	7	7	6	7	8	6	7	8	7	6	8	7	9
25	7	7	6	6	6	7	7	6	8	7	5	7	7	8	9
26	6	7	6	7	6	8	9	7	7	8	6	6	9	7	8
27	7	7	7	7	7	7	8	6	8	8	5	7	9	7	10
28	6	6	7	8	6	7	9	7	7	7	6	6	9	7	8
29	6	7	6	6	6	8	7	7	8	7	5	6	9	8	9
30	7	8	6	7	7	7	8	6	7	8	6	6	9	7	9

GROUP II - LOW FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Serial Postion of Words	Subjects														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	18	15	17	34	16	10	9	20	11	16	26	16	17	17	13
2	20	19	14	18	12	10	8	14	11	19	24	16	19	17	20
3	17	11	11	20	13	11	9	15	14	25	25	13	13	15	17
4	15	9	13	21	17	8	8	17	12	18	19	15	23	10	12
5	14	10	12	14	19	10	8	13	11	19	21	18	11	15	26
6	10	27	19	16	17	12	7	11	11	14	24	12	12	11	11
7	13	11	11	17	11	8	8	18	14	15	14	10	11	10	19
8	15	10	10	22	17	10	10	17	17	14	13	9	9	12	9
9	14	9	11	17	13	8	9	9	11	9	14	8	7	11	11
10	15	11	10	19	9	9	8	17	9	12	11	7	9	11	10
11	14	13	10	15	10	9	8	13	10	10	13	7	9	8	9
12	16	11	11	18	12	8	8	10	12	14	12	8	8	9	13
13	14	20	10	16	11	9	7	11	9	11	12	9	9	8	11
14	14	11	9	15	9	9	7	14	10	10	9	7	9	12	10
15	15	12	10	16	11	10	7	14	9	12	16	7	8	13	9
16	16	11	10	12	9	9	9	12	10	7	17	8	8	7	9
17	15	11	11	17	9	10	9	12	12	7	12	10	7	8	11
18	14	10	10	18	12	7	6	12	9	10	10	8	9	10	9
19	12	20	9	15	8	7	7	9	13	8	11	7	7	9	15
20	11	12	9	10	14	7	7	10	9	12	9	8	9	8	10
21	13	10	9	14	12	9	7	9	8	11	13	8	8	9	9
22	12	10	8	13	10	8	8	10	11	9	10	7	7	11	10
23	18	10	13	15	9	9	6	10	9	7	13	7	6	8	9
24	11	17	10	14	9	8	8	10	8	9	11	7	7	8	8
25	13	9	9	12	10	8	7	7	8	10	9	7	7	9	11
26	9	9	9	13	12	8	6	11	16	7	12	9	8	13	15
27	15	10	11	12	8	7	6	10	7	7	12	7	7	8	9
28	13	11	9	13	9	9	7	11	7	9	11	7	7	11	9
29	14	14	8	14	10	8	7	10	7	8	8	8	8	7	8
30	11	9	10	16	8	8	6	7	11	8	12	7	7	9	16

GROUP III - MIXED FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Serial Position of Words	Subjects														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	27	12	10	14	14	116	15	12	18	13	28	13	13	14	11
2	15	22	19	9	11	17	8	10	17	12	14	14	11	11	8
3	13	17	10	11	11	20	12	24	11	12	18	14	8	10	9
4	17	14	12	8	8	32	10	11	10	13	23	8	10	8	12
5	10	24	8	10	9	24	14	8	9	10	16	9	8	10	8
6	12	12	9	8	7	20	12	8	8	16	22	8	9	9	9
7	13	27	11	7	12	16	14	10	8	12	10	12	12	10	9
8	19	15	12	9	14	15	13	8	9	11	20	8	8	13	10
9	9	21	11	10	7	20	12	23	18	9	20	8	9	14	9
10	11	17	7	9	12	14	13	14	8	10	21	9	11	11	8
11	18	16	8	12	9	17	12	8	8	12	12	10	9	11	8
12	17	11	7	13	8	16	12	8	8	10	9	12	7	12	9
13	10	12	10	8	8	15	12	9	14	8	18	13	7	14	9
14	11	15	9	10	9	14	9	11	7	10	25	8	7	13	8
15	12	7	25	8	9	13	12	8	6	8	11	11	10	9	8
16	12	18	20	9	7	18	13	11	12	8	9	10	7	12	8
17	12	11	9	11	11	11	21	8	19	10	18	8	10	10	10
18	16	10	7	25	7	14	10	7	10	13	11	7	10	12	8
19	10	25	8	10	9	14	10	10	7	10	8	7	9	8	8
20	9	19	9	10	8	13	19	8	8	9	22	8	7	14	11
21	13	25	15	8	11	10	18	8	11	8	9	7	8	20	7
22	16	11	8	8	11	12	13	12	7	8	14	7	8	11	8
23	9	12	7	6	8	12	12	8	7	9	18	10	10	10	6
24	13	9	8	8	8	11	17	8	13	8	9	9	8	19	9
25	15	7	8	8	7	15	10	11	7	9	12	11	9	15	8
26	9	23	8	8	11	9	10	22	10	8	12	10	10	9	7
27	16	13	7	9	12	10	17	8	7	10	15	7	7	11	9
28	10	18	8	7	7	19	20	8	7	8	13	8	9	12	8
29	12	11	9	7	7	10	15	7	9	7	21	8	8	16	9
30	9	21	8	8	7	12	9	7	13	9	14	8	7	9	7

GROUP I - HIGH FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

(Scores used in HF - MHF comparison)

Serial Position of Words	Subjects														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		10	11			16		11		10		10	20		
2		8		11		14	17			11	9		18		15
3	8		9			15	14		10		8		12		14
4		8		8	9		17		10			8		10	
5	9		9		10			8		11	8			9	15
6	10			9	9			9	10			8		9	
7	8			10		9	14		9		8			8	10
8		8		10		14		7		8		7	11		
9	7			9	9		11			8		8	13		
10	8		9			10	9			10		6		8	
11		7	7		8			8	11		7			8	9
12		8	7		7			8	8		7		9		10
13	7			9	8			8		9	6		11		9
14		7	7			8	8		8			7	10		
15		9		8		9		7		8	6			7	9
16	8			9	8		8			8	6		9		9
17	7		7			9		7	9			7		7	
18		7	7		8		8		8			7		8	
19	8		7		6		10		8		6			8	10
20	8		7		7			7	8			6	9		
21	8			8		8		8		8	5		8		8
22		8		8		8	9			8		7		7	
23		6		8	7			7	9			6		8	
24		7	7			7	8			8	7		8		9
25		7		6	6		7		8		5		7		9
26	6		6			8	9			8	6			7	8
27		7	7			7		6	8			7	9		
28	6			8	6			7	7			6		7	
29		7		6		8		7		7		6	9		
30	7		6		7		8			8	6			7	9

GROUP II - LOW FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

(Scores used in LF - MLF Comparison)

Serial Position of Words	Subjects 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	18			34	16		9		11		26			17	13
2	20		14		12			14	11			16		17	
3		11		20	13			15		25		13		15	
4	15		13			8		17		18	19		23		12
5		10		14		10	8		11			18	11		
6		27	19			12	7			14	24		12		11
7		11	11		11			18		15		10	11		
8	15		10		17		10		17		13			12	9
9		9	11			8		9	11		14			11	11
10		11		19	9			17	9		11		9		10
11	14			15		9	8			10		7	9		
12	16			18		8	8			14		8		9	
13		20	10			9	7		9			9		8	
14	14			15	9			14		10	9			12	10
15	15		10		11		7		9			7	8		
16		11	10			9		12	10			8		7	
17		11		17	9		9			7	12		7		11
18	14			18		7		12		10	10		9		9
19		20		15		7		9		8		7	7		
20		12		10		7	7			12	9			8	10
21		10	9		12		7		8			8		9	
22	12		8		10			10	11		10		7		10
23	18		13			9	6			7	13		6		9
24	11			14	9			10	8			7		8	
25	13		9			8		7		10		7		9	
26		9		13	12			11	16			9	8		
27	15			12	8		6			7	12			8	9
28		11	9			9	7			9	11		7		9
29	14		8		10		7		7		8			7	8
30		9		16		8		7	11			7	7		

GROUP III - HIGH FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

(Scores used in HF - MHF comparison)

Serial Position of Words	Subjects														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		12	10			16		12		13		13	13		
2		22		9		17	8			12	14		11		8
3	13		10			20	12		11		18		8		9
4		14		8	8		10		10			8		8	
5	10		8		9			8		10	16			10	8
6	12			8	7			8	8			8		9	
7	13			7		16	14		8		10			10	9
8		15		9		15		8		11		8	8		
9	9			10	7		12			9		8	9		
10	11		7			14	13			10		9		11	
11		16	8		9			8	8		12			11	8
12		11	7		8			8	8		9		7		9
13	10		[illegible]	8	8			9		8	18		7		9
14		15	9			14	9		7			8	7		
15		7		8		13		8		8	11			9	8
16	12			9	7		13			8	9		7		8
17	12		9			11		8	9		[illegible]	8		10	
18		10	7		7		10		10			7		12	
19	10		8		9		10		7		8			8	8
20	9		9		8			8	8			8	7		
21	13			8		10		8		8	9		8		7
22		11		8		12	13			8		7		11	
23		12		6	8			8	7			10		10	
24		9	8			11	17			8	9		8		9
25		7		8	7		10		7		12		9		8
26	9		8			9	10			8	12			9	7
27		13	7			10		8	7			7	7		
28	10			7	7			8	7			8		12	
29		11		7		10		7		7		8	8		
30	9		8		7		9			9	14			9	7

GROUP III - LOW FREQUENCY WORDS

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

(Scores used in LF - MLF Comparison)

Serial Position of Words	Subjects 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	27			14	14		15		18		28			14	11
2	15		19		11			10	17			14		11	
3		17		11	11			24		12		14		10	
4	17		12			32		11		13	23		10		12
5		24		10		24	14		9			9	8		
6		12	9			20	12			16	22		9		9
7		27	11		12			10		12		12	12		
8	19		12		14		13		9		20			13	10
9		21	11			20		23	18		20			14	9
10		17		9	12			14	8		21		11		8
11	18			12		17	12			12		10	9		
12	17			13		16	12			10		12		12	
13		12	10			15	12		14			13		14	
14	11			10	9			11		10	25			13	8
15	12		25		9		12		6			11	10		
16		18	20			18		11	12			10		12	
17		11		11	11		21			10	18		10		10
18	16			25		14		7		13	11		10		8
19		25		10		14		10		10		7	9		
20		19		10		13	19			9	22			14	11
21		25	15		11		18		11			7		20	
22	16		8		11			12	7		14		8		8
23	9		7			12	12			9	18		10		6
24	13			8	8			8	13			9		19	
25	15		8			15		11		9		11		15	
26		23		8	11			22	10			10	10		
27	16			9	12		17			10	15			11	9
28		18	8			19	20			8	13		9		8
29	12		9		7		15		9		21			16	9
30		21		8		12		7	13			8	7		

APPENDIX C

RAW DATA FOR EXPERIMENT II

GROUP I - HIGH FREQUENCY WORDS

PRE-TRAINING SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Serial Position of Words								
		1	2	3	4	5	6	7	8	9
Summer School Population	1	25	9	8	7	8	8	7	9	8
	2	14	11	11	9	9	11	15	10	8
	3	8	7	6	6	8	6	8	6	7
	4	15	9	13	7	7	9	7	7	7
	5	12	16	14	8	8	8	9	10	8
	6	8	10	9	7	15	9	8	8	9
	7	9	6	6	5	8	6	5	8	7
	8	11	13	11	10	12	9	10	10	9
	9	15	9	12	10	11	7	7	8	6
	10	8	20	22	15	11	11	9	9	8
Winter School Population	11	9	9	7	7	7	8	7	8	6
	12	9	6	5	6	7	6	8	6	6
	13	6	6	6	6	5	6	5	6	5
	14	12	7	9	6	9	10	6	5	6
	15	10	13	9	7	8	8	9	8	8
	16	9	9	8	15	7	9	8	6	7
	17	13	10	9	12	8	9	9	7	9
	18	9	6	9	7	7	6	12	7	6
	19	6	7	6	5	8	7	7	7	5
	20	9	9	8	8	7	7	8	7	6

GROUP I

TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Serial Position of Words																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Summer School Population	1	26	9	9	6	10	15	12	16	11	10	9	10	9	9	7	7	10	10
	2	19	12	11	10	12	12	15	9	15	9	13	9	12	9	13	9	10	9
	3	9	7	6	7	24	7	8	8	9	7	20	7	10	8	12	7	8	7
	4	12	11	8	16	9	8	8	8	9	8	9	9	10	9	9	9	8	8
	5	13	13	11	10	10	14	10	9	17	19	10	8	8	13	11	10	11	11
	6	15	18	15	20	11	15	16	14	13	8	15	15	14	9	11	9	10	12
	7	8	8	13	7	7	7	7	9	6	7	10	7	6	7	9	8	6	8
	8	17	25	10	21	23	10	11	19	10	19	9	8	14	11	12	15	10	8
	9	15	15	14	8	9	8	9	17	8	9	7	15	12	11	10	9	12	8
	10	15	13	12	12	13	10	12	10	12	8	12	14	13	9	7	9	9	7
Winter School Population	11	10	9	12	8	10	8	7	9	6	7	6	7	7	8	8	8	6	6
	12	8	7	8	8	7	6	9	6	5	7	6	5	5	6	5	7	5	7
	13	7	6	8	8	7	8	6	7	6	7	8	5	7	7	8	6	8	6
	14	9	10	7	15	8	7	7	8	8	7	9	6	8	11	5	6	6	7
	15	12	9	13	13	10	17	9	11	8	7	10	13	9	9	10	10	9	10
	16	16	8	7	10	13	9	11	7	10	18	10	8	10	7	8	7	8	10
	17	10	10	11	11	13	9	13	8	9	11	10	10	9	8	9	9	9	7
	18	16	8	8	9	7	7	6	7	6	10	7	14	7	7	8	7	7	7
	19	9	8	9	9	8	8	6	7	9	7	8	6	7	6	9	6	6	6
	20	14	8	8	7	8	9	8	8	8	9	9	9	7	9	7	6	7	9

GROUP II - LOW FREQUENCY WORDS

PRE-TRAINING SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Serial Position of Words								
		1	2	3	4	5	6	7	8	9
Summer School Population	1	25	11	11	13	11	9	7	21	15
	2	13	15	15	9	9	9	7	13	11
	3	14	16	15	14	16	11	14	11	17
	4	16	22	18	20	16	27	20	16	18
	5	19	10	12	9	10	9	23	7	17
	6	11	9	11	9	12	9	9	8	9
	7	33	18	10	22	15	10	14	10	16
	8	22	14	22	13	22	9	14	11	12
	9	14	9	10	8	9	8	11	7	8
	10	24	26	15	14	13	27	20	16	16
Winter School Population	11	16	14	12	13	12	10	13	13	8
	12	26	15	14	13	11	8	10	8	8
	13	13	11	8	9	8	13	14	7	8
	14	23	10	9	8	10	10	7	12	13
	15	11	13	7	10	10	9	8	8	14
	16	20	11	9	10	9	10	10	9	7
	17	23	8	16	9	12	18	12	15	14
	18	21	16	15	11	12	11	10	9	6
	19	15	10	15	12	11	9	8	9	8
	20	6	9	11	8	11	9	9	8	11

GROUP II

TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects		Serial Position of Words																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Summer School Population	1	14	21	7	9	7	9	8	9	11	8	8	8	15	8	7	8	7	6
	2	10	12	7	8	17	9	9	7	7	7	8	9	8	11	7	7	9	7
	3	9	8	10	8	7	12	12	11	12	10	8	9	7	8	11	7	11	7
	4	12	10	16	16	11	13	11	9	15	8	10	11	14	7	7	11	9	7
	5	11	9	8	9	8	6	9	6	7	9	7	7	9	12	10	9	8	9
	6	8	11	7	8	12	8	12	8	9	11	9	7	8	8	10	8	9	6
	7	20	11	11	11	11	15	14	11	9	9	11	11	14	10	10	11	9	10
	8	10	12	11	9	11	11	8	11	9	10	10	8	12	9	9	9	8	8
	9	7	8	8	7	9	7	16	7	9	8	7	6	7	10	7	7	7	7
	10	15	16	13	13	11	9	11	18	12	9	11	12	12	14	18	13	13	10
Winter School Population	11	9	8	11	7	10	8	9	8	8	10	8	9	7	8	8	10	7	8
	12	12	15	10	10	8	8	8	8	9	8	8	11	10	8	7	8	8	10
	13	9	7	14	7	6	9	7	6	7	6	10	7	6	11	7	5	5	5
	14	10	16	8	11	10	10	11	15	10	9	9	10	13	9	10	12	11	9
	15	10	7	13	7	11	9	8	10	15	11	7	8	8	8	8	10	7	6
	16	10	8	11	7	10	7	8	8	17	10	7	8	17	10	7	7	8	7
	17	11	15	10	11	13	7	15	14	13	7	7	10	13	10	6	7	6	7
	18	9	10	7	6	9	9	7	7	9	7	7	8	7	6	6	6	6	7
	19	10	8	10	11	8	8	7	7	16	8	12	12	8	9	7	6	8	7
	20	9	8	9	8	8	10	8	6	10	7	8	9	9	7	9	7	8	7

GROUP III - SEVEN - DIGIT NUMERALS

PRE-TRAINING SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects		Serial Position of Words								
		1	2	3	4	5	6	7	8	9
Summer School Population	1	42	24	24	18	13	15	11	15	13
	2	19	18	12	15	13	11	17	12	11
	3	23	18	18	15	13	17	14	16	17
	4	14	20	19	13	15	16	19	13	12
	5	23	21	18	13	13	22	18	20	19
	6	25	18	19	15	12	16	15	15	11
	7	25	17	16	18	15	22	17	12	13
	8	18	20	14	19	13	19	12	12	11
	9	20	20	17	21	17	14	13	13	13
	10	23	17	17	15	14	11	13	13	11
Winter School Population	11	29	21	21	22	19	17	12	14	14
	12	18	16	17	15	19	13	11	14	13
	13	26	18	21	11	12	12	13	12	12
	14	25	21	20	21	19	18	19	15	16
	15	30	23	22	18	21	18	18	18	18
	16	18	16	13	15	11	13	13	11	12
	17	24	16	17	16	12	12	11	11	14
	18	21	12	14	13	13	13	13	12	10
	19	17	17	18	13	12	12	12	11	14
	20	21	18	15	15	14	12	12	11	11

GROUP III

TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Serial Position of Words																	
	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Summer School Population	1	10	15	11	15	16	15	17	9	10	12	10	11	8	9	10	11	9	9
	2	12	9	8	6	6	7	8	7	6	7	7	6	8	7	7	6	8	7
	3	18	8	22	9	9	10	11	11	8	12	8	11	7	12	9	8	7	7
	4	8	8	9	10	8	9	7	7	8	9	7	9	7	8	6	6	8	7
	5	21	21	17	16	12	19	21	15	20	17	15	17	9	14	17	19	13	11
	6	7	6	7	5	6	6	5	6	5	6	6	7	8	7	8	6	6	6
	7	9	9	11	7	6	10	10	6	7	6	9	8	6	6	6	7	8	6
	8	9	11	9	9	9	8	7	10	11	13	7	7	7	9	7	9	8	15
	9	14	24	14	10	17	15	16	9	8	12	15	9	10	10	10	9	9	9
	10	23	18	10	12	12	10	9	12	16	9	12	10	19	16	9	11	10	8
Winter School Population	11	16	18	9	23	9	14	13	8	20	17	17	10	12	10	11	7	15	11
	12	11	14	8	9	13	10	7	9	10	9	7	10	9	7	7	8	6	6
	13	10	8	13	7	11	7	9	8	8	7	7	9	7	11	6	7	8	8
	14	7	8	11	10	8	8	8	8	9	7	7	7	7	8	6	6	7	7
	15	21	23	22	19	16	17	10	14	13	11	14	13	15	9	9	9	11	10
	16	7	15	11	9	12	7	6	8	5	6	9	8	6	6	6	7	6	5
	17	14	22	10	7	9	9	7	7	6	7	8	6	7	8	8	5	11	10
	18	5	6	6	8	6	6	6	9	6	8	9	5	6	6	7	5	8	6
	19	8	7	8	8	11	7	8	7	7	7	6	6	7	6	7	6	8	7
	20	10	7	9	7	9	11	7	6	9	10	9	6	6	5	7	10	6	6

GROUP IV

TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Serial Position of Words: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Summer School Population	1	10	10	16	13	9	13	8	10	12	9	8	14	6	6	13	8	7	7
	2	23	16	29	23	16	27	15	19	17	15	16	11	8	11	10	9	8	15
	3	9	10	9	11	8	7	7	7	9	9	8	11	12	7	6	9	6	8
	4	15	11	12	15	12	8	8	13	10	13	13	11	9	9	8	11	8	9
	5	17	20	16	10	11	8	12	11	22	12	8	11	8	7	19	11	11	11
	6	12	18	18	12	8	9	15	11	10	13	12	9	10	8	12	7	9	10
	7	13	23	11	10	12	10	12	16	15	10	11	9	9	8	10	11	10	11
	8	23	8	9	10	12	16	10	16	9	14	9	13	12	8	13	10	10	6
	9	25	19	19	11	17	11	15	15	18	13	12	11	13	12	12	10	8	7
	10	13	13	17	13	8	12	11	8	14	10	12	7	8	10	9	11	9	8
Winter School Population	11	16	9	26	11	9	8	10	8	18	17	15	11	8	14	13	9	13	7
	12	12	8	9	9	7	8	12	9	7	7	7	11	7	6	7	7	7	8
	13	14	12	13	12	12	11	8	11	12	13	12	10	8	7	11	9	9	7
	14	11	12	13	13	7	8	8	7	11	9	8	8	9	8	7	7	7	9
	15	20	21	17	16	10	19	17	7	9	8	7	9	9	15	8	8	7	9
	16	24	18	13	11	13	13	13	13	17	12	15	16	12	8	17	16	11	13
	17	12	20	11	8	12	9	9	11	12	8	10	11	10	7	9	8	8	13
	18	24	20	14	17	9	11	7	11	11	14	9	8	8	11	10	7	8	9
	19	16	24	15	16	19	12	20	14	13	14	18	15	14	13	15	13	14	11
	20	12	9	8	10	10	11	9	8	8	8	7	8	9	8	8	7	8	7

APPENDIX D

RAW DATA FOR EXPERIMENT III

GROUP I

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

		Pre-Training Word	Test Series								
			Serial Position of Words								
	Subjects	1	1	2	3	4	5	6	7	8	9
Summer School	1	10	11	20	8	9	7	8	11	7	7
	2	10	10	15	9	7	8	8	14	8	7
	3	10	27	12	12	13	15	9	13	17	19
	4	8	22	15	13	20	17	15	17	15	11
	5	9	22	13	17	13	19	23	17	12	9
	6	9	13	19	9	12	16	8	9	8	16
	7	12	15	13	15	10	14	14	11	11	8
	8	13	12	13	14	18	17	14	12	9	14
	9	9	14	15	12	8	13	8	9	16	7
	10	11	17	9	21	9	14	11	17	9	13
Winter School	11	9	9	8	7	10	7	7	8	10	8
	12	19	27	22	20	17	17	18	17	14	16
	13	13	13	9	9	12	10	9	8	10	8
	14	8	13	8	7	10	9	7	7	7	12
	15	11	10	9	9	7	7	8	8	9	8
	16	12	17	10	8	10	10	7	8	8	6
	17	11	20	9	16	9	15	12	9	10	11
	18	14	16	12	15	12	13	16	9	8	10
	19	15	20	17	12	17	20	14	17	13	12
	20	10	14	13	15	8	12	9	9	14	8

GROUP II

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

	Subjects	Pre-Training 1	Pre-Training 2	Pre-Training 3	Test Series 1	Test Series 2	Test Series 3	Test Series 4	Test Series 5	Test Series 6	Test Series 7	Test Series 8	Test Series 9
		Serial Position of Words											
Summer School	1	10	12	7	15	15	8	13	11	12	9	14	16
	2	11	7	7	14	8	14	12	17	12	8	13	10
	3	12	7	7	9	11	14	9	7	7	9	7	8
	4	10	7	9	9	15	9	15	9	8	10	15	7
	5	13	12	8	14	10	11	10	7	16	9	14	11
	6	12	12	12	15	15	16	11	13	14	13	9	12
	7	9	7	10	18	13	17	10	10	8	10	13	8
	8	12	10	8	20	16	16	14	12	15	15	8	8
	9	14	10	9	23	12	14	14	19	10	11	13	12
	10	9	12	8	18	18	13	14	10	11	12	8	15
Winter School	11	13	18	9	9	9	12	10	11	8	13	13	7
	12	8	9	8	10	8	18	11	10	12	8	14	8
	13	8	8	11	15	15	12	14	7	8	9	11	6
	14	9	8	6	7	6	11	8	7	6	7	6	6
	15	14	16	13	23	19	19	16	12	19	15	20	14
	16	8	9	9	8	8	11	7	9	14	7	8	7
	17	9	7	8	11	8	9	8	7	11	7	7	7
	18	15	10	11	17	11	10	17	8	8	8	8	9
	19	16	13	16	27	17	23	17	19	18	21	16	14
	20	9	15	7	19	10	10	10	13	10	7	7	7

GROUP III

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Pre-Training Series

Serial Position of Words

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Summer School	1	9	7	7	7	7	7	8	7	9	7	7	7	6	7
	2	17	14	9	14	14	11	14	12	7	10	8	9	9	11
	3	12	9	11	8	9	11	10	7	9	9	8	9	9	8
	4	16	8	11	14	11	8	15	12	10	10	11	12	9	10
	5	10	9	10	10	8	9	7	9	6	8	7	8	14	6
	6	15	11	10	9	9	10	11	9	9	11	9	9	9	8
	7	8	8	7	7	7	8	7	7	9	8	7	8	7	8
	8	10	8	8	7	7	9	6	7	8	7	6	6	7	6
	9	17	10	14	9	10	10	9	8	9	7	8	8	8	7
	10	17	9	8	7	8	9	7	9	8	7	8	8	9	9
Winter School	11	8	9	8	8	7	8	9	7	7	9	7	7	10	8
	12	7	6	6	6	6	6	8	6	7	7	5	6	6	7
	13	13	8	11	8	7	7	10	9	8	10	7	7	6	7
	14	8	10	9	10	7	8	7	9	7	7	6	6	6	6
	15	8	7	7	7	6	7	6	7	6	6	6	6	6	7
	16	9	9	7	7	8	8	7	8	8	7	8	7	6	7
	17	9	7	10	8	9	7	10	7	8	7	10	8	11	9
	18	8	6	8	7	6	7	6	5	7	5	7	6	5	7
	19	7	8	7	7	7	6	6	7	7	7	8	7	6	7
	20	8	6	6	5	7	6	6	5	6	5	5	4	5	5

GROUP III

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Pre-Training Series (cont'd)

Serial Position of Words

	Subjects	15	16	17	18	19	20	21	22	23	24	25	26	27
Summer School	1	9	7	8	7	7	7	7	7	7	8	7	10	6
	2	8	9	13	7	10	11	8	9	10	9	9	9	7
	3	7	9	8	7	9	8	10	7	9	8	7	8	9
	4	10	9	11	14	12	9	10	9	9	8	12	11	8
	5	6	8	7	8	8	8	7	7	8	7	7	10	7
	6	9	8	9	8	8	8	9	7	9	8	7	7	7
	7	8	7	7	7	8	6	7	7	8	6	7	7	7
	8	7	7	6	8	5	6	6	7	7	5	6	6	5
	9	8	9	8	9	8	8	8	11	7	9	8	8	7
	10	7	8	8	8	7	8	7	8	7	8	9	7	7
Winter School	11	7	7	7	6	6	6	5	7	6	6	7	5	5
	12	6	7	6	7	6	7	6	6	5	6	6	5	5
	13	7	6	7	7	6	7	7	7	7	6	7	5	6
	14	5	5	6	6	6	6	6	5	6	5	5	5	5
	15	6	6	7	6	6	7	6	6	6	6	6	6	5
	16	7	8	7	7	6	5	8	6	6	6	5	6	6
	17	7	8	8	7	9	7	6	8	7	7	7	7	7
	18	6	6	6	6	5	6	5	6	5	6	5	5	5
	19	8	7	8	7	7	6	7	7	7	6	6	5	6
	20	6	4	4	6	6	5	6	5	6	5	5	5	4

GROUP III

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Test Series

Serial Position of Words

	Subjects	1	2	3	4	5	6	7	8	9
Summer School	1	13	11	10	11	11	11	8	7	10
	2	15	9	11	10	9	8	11	9	9
	3	9	10	11	20	9	15	9	10	9
	4	20	18	16	12	11	11	15	13	12
	5	8	13	9	7	9	8	11	9	10
	6	9	10	10	13	11	10	8	8	8
	7	16	8	10	7	8	8	8	9	8
	8	10	10	7	8	8	9	6	7	8
	9	16	12	19	11	12	10	9	10	10
	10	10	10	9	11	12	9	9	9	8
Winter School	11	7	8	9	7	7	7	8	8	8
	12	7	7	6	7	6	10	7	7	6
	13	10	8	8	11	10	6	8	8	8
	14	6	10	8	8	8	8	12	7	8
	15	17	9	9	8	6	9	7	7	8
	16	10	8	8	7	13	8	7	6	8
	17	18	12	10	10	10	7	8	8	10
	18	8	7	7	7	6	7	6	6	7
	19	10	10	9	14	10	7	11	9	8
	20	8	9	7	7	9	8	7	7	6

APPENDIX E

RAW DATA FOR EXPERIMENT IV

GROUP I - TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Serial Position of Words

Subjects

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	19	11	8	14	11	11	8	10	9	11	8	10	15	12	11	9	8	7
2	8	8	19	8	10	10	11	15	11	11	13	10	9	10	7	7	11	11
3	9	10	10	6	6	8	6	7	10	5	7	5	6	6	9	5	6	7
4	15	11	10	15	10	12	9	10	13	10	7	8	9	6	8	9	6	8
5	18	10	8	8	8	9	8	15	8	6	10	5	5	8	5	7	7	6
6	18	18	20	24	9	8	8	10	9	8	8	14	9	8	6	5	7	8
7	29	28	27	26	8	9	25	10	16	11	16	20	22	15	30	19	17	24
8	14	15	11	11	10	16	9	7	10	8	8	8	8	8	9	11	8	14
9	12	7	7	7	6	5	9	8	15	6	7	9	8	9	7	8	7	6
10	21	13	21	17	9	15	11	10	11	9	16	6	11	10	14	12	7	10
11	28	14	18	17	20	21	15	12	12	16	16	10	15	10	13	17	9	12
12	18	16	9	11	15	14	8	9	9	13	14	10	13	11	8	12	8	15
13	13	24	11	19	6	12	8	9	9	9	8	10	11	8	11	14	18	8
14	16	9	22	23	9	12	25	8	7	7	10	10	8	10	7	8	12	7
15	9	21	16	24	21	23	19	22	20	19	21	16	15	9	13	12	12	10
16	18	9	14	14	12	8	9	15	9	13	9	7	9	8	8	10	7	8
17	12	9	11	8	8	8	7	8	8	8	7	8	8	8	7	8	8	6
18	8	10	7	9	7	6	6	8	6	6	7	6	6	6	7	7	6	5
19	11	9	15	11	7	9	12	9	11	11	9	12	8	10	8	7	7	8
20	8	7	7	8	6	8	5	6	6	7	6	7	8	8	7	7	7	5

GROUP II - TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects	Serial Position of Words																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	17	20	18	15	12	17	12	13	12	13	13	12	10	9	9	9	10	9
2	16	20	17	20	14	13	10	11	17	9	14	12	11	14	10	9	15	11
3	18	11	10	10	11	8	9	14	8	8	14	9	12	9	9	8	13	7
4	8	13	7	10	15	8	17	11	14	7	7	9	6	6	8	6	8	6
5	8	8	19	9	7	8	8	7	8	7	8	7	6	6	6	7	6	9
6	20	17	9	8	7	13	9	7	8	10	6	8	8	8	8	6	7	6
7	11	11	8	8	7	17	7	8	9	11	10	15	10	13	9	8	6	7
8	15	8	7	9	15	7	8	6	5	5	9	8	7	7	6	5	6	5
9	14	9	6	16	8	16	10	8	12	8	7	13	9	8	8	10	9	7
10	8	7	9	7	8	6	7	6	7	12	7	6	9	7	8	8	7	7
11	11	15	9	9	11	9	10	8	13	8	13	8	10	9	10	8	8	11
12	17	12	13	11	17	9	9	9	8	13	8	7	13	9	8	11	13	8
13	15	21	16	16	18	15	19	13	8	11	16	16	16	11	16	8	14	8
14	8	13	21	12	14	7	18	8	7	8	12	9	7	7	10	6	7	7
15	15	23	22	25	14	13	9	9	13	8	10	11	6	9	17	10	14	13
16	11	14	12	8	9	7	10	10	7	8	12	7	7	8	8	13	11	8
17	10	8	9	8	8	9	7	9	16	7	7	7	8	7	9	8	6	6
18	10	8	12	7	10	7	13	8	14	8	9	13	7	8	9	9	10	9
19	15	15	11	20	9	15	10	9	14	10	14	11	10	8	11	9	8	10
20	16	8	11	7	7	9	11	9	8	6	7	7	6	7	8	7	10	9

GROUP III - TEST SERIES

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects	Serial Position of Words																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	21	11	11	7	10	7	10	9	8	10	11	10	9	9	9	10	9	7
2	10	10	6	6	6	8	6	6	8	7	7	8	7	5	7	7	6	7
3	13	9	8	8	7	13	10	7	8	7	9	9	7	7	7	8	7	7
4	13	20	10	16	9	11	13	10	9	11	8	9	9	9	9	12	8	9
5	16	11	17	18	15	14	11	14	11	10	12	8	11	17	9	11	15	13
6	13	14	12	9	9	10	11	8	9	8	7	8	7	8	13	9	7	7
7	9	7	10	10	8	11	6	7	10	5	11	7	7	8	8	8	6	6
8	14	9	9	9	7	10	7	10	8	9	8	9	7	7	7	9	7	9
9	17	9	12	8	8	11	10	15	9	11	8	10	8	7	11	8	14	8
10	10	7	8	5	6	9	7	6	7	7	7	7	8	9	8	7	5	7
11	11	9	11	11	12	8	8	8	9	8	8	9	7	6	8	6	6	9
12	8	12	9	8	7	7	10	8	6	7	6	8	7	7	5	7	7	9
13	16	11	16	12	8	8	9	10	10	9	9	8	10	8	9	11	8	7
14	15	13	10	10	9	18	12	12	13	16	9	6	10	11	10	12	10	8
15	13	10	10	14	8	7	10	9	10	6	8	7	7	5	9	7	7	7
16	14	12	8	12	7	8	7	15	6	8	7	8	7	6	7	10	9	7
17	9	14	13	11	15	12	10	10	9	10	10	9	11	7	7	7	10	10
18	15	11	13	11	14	10	14	21	14	8	16	12	8	12	16	12	12	9
19	14	14	8	7	7	7	7	12	6	6	7	5	6	6	8	6	7	6
20	15	11	13	10	8	9	8	9	8	8	8	8	8	7	7	7	9	11

APPENDIX F

RAW DATA FOR EXPERIMENT V

FIXATION GROUP

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects	Serial Position of Words																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	11	16	7	7	11	12	12	11	8	8	7	7	12	7	6	5	9	6
2	9	7	7	7	5	6	9	6	6	5	5	10	6	7	5	5	7	6
3	10	8	8	8	9	7	6	6	7	6	8	5	9	7	6	7	6	8
4	13	7	7	9	6	6	8	8	7	6	8	5	8	6	8	7	5	6
5	8	10	8	8	8	8	7	7	5	10	8	7	7	8	7	8	8	7
6	8	7	16	7	10	6	7	9	7	6	7	11	6	7	8	9	8	8
7	7	6	6	7	6	6	5	5	12	7	5	5	5	5	6	5	7	5
8	10	9	8	9	11	10	11	8	9	8	9	10	7	13	7	9	7	7
9	18	15	13	10	10	14	11	12	9	9	9	11	9	7	8	10	10	9
10	13	6	8	7	6	8	7	6	8	6	9	6	8	6	7	6	5	7

NO FIXATION GROUP

THRESHOLD SCORES IN HUNDREDTH OF A SECOND

Subjects	Serial Position of Words																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	17	10	18	8	10	7	10	6	7	11	10	7	9	12	11	6	7	6
2	21	14	8	9	8	16	7	9	8	10	8	8	10	11	8	8	9	12
3	14	8	11	9	8	11	18	8	8	19	8	8	8	9	8	5	9	10
4	24	14	19	15	17	14	15	9	11	10	9	13	11	12	10	7	7	7
5	19	13	16	11	14	10	11	8	9	13	10	10	16	8	8	7	9	7
6	11	6	8	6	6	6	6	6	7	7	6	7	6	7	5	7	6	8
7	15	9	12	12	11	15	9	9	8	8	12	11	8	6	9	7	8	7
8	14	9	7	9	10	10	7	9	13	7	6	10	8	6	11	7	8	9
9	14	11	10	13	9	14	7	7	8	9	8	9	8	11	10	7	19	11
10	17	14	12	12	17	11	9	11	11	11	9	6	11	10	7	7	9	7