The tachistoscopic presentation of words has been used in attempts to detect the role of personality variables in perception. In general, the procedure has been to present printed words, drawn from various relevant "meaning" classes, for very short periods of exposure; the S's task is to identify the words. Recognition thresholds are determined by increasing either the duration of exposure or the intensity of illumination. These thresholds have been considered to be an index of perceptual sensitivity or ease of recognition for the stimuli. The thresholds have also been interpreted as measures of the amount of "stimulus material" necessary for elicitation of the correct response.

The results of such experiments have lent some support to the view that personality variables may be significant determiners of perceptual sensitivity to visually presented verbal stimuli. The demonstrable effects of such factors are not large in absolute terms but often appear to be internally consistent and statistically reliable. Evidence has been presented for the selective effects of personal values and needs on perceptual sensitivity as measured in the tachistoscopic situation (6, 7, 11, 12, 16). It has also been suggested that words which may arouse anxiety because of their emotional connotations have significantly higher thresholds than neutral words (8). There is, however, some evidence that anxiety arousing stimuli may have lower thresholds than words to which S is indifferent (2, 5).

It is important to ask to what extent the apparent effects of complex personality factors reduce to the operation of basic psychological variables of wider generality. In a related series of experiments (3, 12, 13, 14) an attempt has been made to explore systematically some of the variables whose contribution must be taken into account in analyzing the effect of personality factors on recognition thresholds. Since the tachistoscopic studies of word recognition involve the presentation of verbal stimuli and the elicitation of verbal responses, these experiments concentrated on variables which have been shown to be extremely important in the psychology of verbal learning. Specifically, they have considered the effects of frequency and recency on the probability of occurrence of verbal responses in the presence of tachistoscopically exposed verbal stimuli. Howes and Solomon (3) have shown that when word length, word structure, and practice effects are roughly controlled or held constant, a very powerful correlate of the visual recognition thresholds for words is the relative frequency with which a word is used in the English language. Using the Thorndike-Lorge word counts (15) as an index of relative frequency of occurrence, these Es found that visual duration thresholds for tachistoscopically presented word stimuli seem to approximate a linear, inverse function of the logarithm of frequency of usage. The correlations between the thresholds and relative frequency of occurrence of words were found to range from .60 to .90, dependent upon the attendant experimental conditions.

The variable of word frequency had not been taken into account in previous experiments re-
ating recognition thresholds to such factors as personal value (11). Solomon and Howes (14) showed that a very considerable amount of the variance attributed to personal value could be accounted for in terms of the frequency variable. Postman and Schneider (12) confirmed these findings. The question is still open whether the residual effects of value, interest, and so forth, can be reduced to individual S's deviations from the frequency of word usage in the general population.

Howes and Solomon (4) applied a similar critical analysis to McGinnies' evidence for "perceptual defense" against taboo words (8). His taboo words had a low frequency of occurrence in the English language when compared to his neutral words, and higher thresholds for taboo words should, therefore, be expected on the basis of relative frequency of usage. McGinnies (9), in rebuttal, argued that the Thorndike-Lorge word counts are derived from literature, not verbal usage in everyday living, and so are not representative. This point is, however, quite inappropriate when it is realized that tachistoscopic presentation of words is very much like a reading situation; and, if laws of stimulus generalization are at all valid, frequency of occurrence of words in literature may be expected to predict visual duration thresholds for word stimuli at least as well as will some index of actual verbal response frequency in conversation. This problem remains to be explored.

In addition to the studies which have related frequency of usage to visual recognition thresholds, an experiment of Postman and Solomon (13) has shown that, when relative word frequencies are equated, the recency of word usage is significantly correlated with duration thresholds for verbal stimuli. Other things being equal, the more recently a word has been exposed to S, the lower will be the recognition threshold for that word stimulus. The variables of frequency and recency are not, of course, entirely independent. The more often a word occurs relative to all other words, the more likely it is to have occurred more recently than other words, either in literature read by the S or in words uttered by the S.

There is one fundamental weakness in the studies which have demonstrated the importance of frequency and recency in the determination of recognition thresholds for words. The index of frequency of word usage which these studies employed—the Thorndike-Lorge word counts—is a population index and allows us to estimate in only very rough ways the relative frequency of word usage for individual Ss. This method, of course, represents a lack of adequate control over the word frequency variable. In all probability, the relationship between the relative frequency of word usage and recognition thresholds has been underestimated owing to this imprecision. Experimental control of relative word frequencies will make a more precise statement of the relationship possible. Once this frequency variable has been experimentally controlled and its effect on recognition thresholds measured, we shall have an important baseline for the evaluation of emotional, valutative, and need-related variables.

With this point in mind, and with a view to the inadequacy of previous indices of word frequency, two experiments were carried out. In both these experiments, relative frequency of word usage was "built in" experimentally and then related to the recognition thresholds for the words.

**Procedure**

**Experiment 1.**—Five undergraduates at Harvard University participated in this experiment. The Ss were misled as to the purpose of the experiment. When S entered the experimental room, he was given the following instruction:

This is an experiment concerning the effectiveness of repetition in learning to pronounce strange words correctly. It has a direct bearing on the problem of reading words in a foreign language, as compared to hearing the words spoken. In addition, we are interested in knowing whether the relative effectiveness of the two kinds of learning methods depends on general reading ability.

We are going to give you a deck of cards. On each card is printed a strange word. We would like you to look at each card carefully and then pronounce the word in the way it would be pronounced if it were a word in the English language. Proceed steadily from card to card, turning over each one after you have finished with it. Go right through the deck and then stop unless you have serious doubts about your pronunciations.
The E then handed S a pack of 100 cards. The pack consisted of a series of pronounceable nonsense words, seven letters each, typed in capitals across the middle of each card. The 100 cards contained 24 different nonsense words, repeated with varying frequencies. There were two words replicated 25 times, two words replicated 10 times, two words replicated five times, two words replicated 2 times, and 14 words appearing only once.

The pack of 100 cards was shuffled thoroughly before S went through it, card by card, reading and pronouncing each nonsense word. The nonsense words, selected from a Turkish-English dictionary, are presented in Table 1. The first ten words of the list were the core-words; they were used later, in the tachistoscopic presentation. The other 14 words were “padding” to the deck, and they appeared one time each in the deck of cards. Each of the core-words was varied in its frequency of appearance in the pack from S to S, in such a way that a Latin-square experimental design was completed. This design was used in order to try to control for inherent differences among words in memorability and structural variations. Thus, each of the five Ss was exposed to the same 24 words (ten core-words plus 14 padding words), but each S received different frequencies of exposure to the different core-words. Two core-words were used at each frequency, in order to replicate for words per S.

After the Ss had read the 100 cards, they were given an irrelevant task in order to cover up the purpose of the experiment. Ss were handed a book and given the following instructions: Now, we would like you to read the passage marked off in this book. We want you to read as clearly and distinctly as possible without faltering, in order that we may get a general index of your reading ability.

The S then read a page from a section on ethics in a randomly chosen textbook in philosophy. After this, E ushered S into another room for the tachistoscopic phase of the experiment and read these instructions:

We are going to present to you, one at a time, some words. If you look in the eyepiece in this box, you will be able to see two lines. The words we will show you will appear directly between those lines. Each word will be presented to you for very short intervals of time, and at first you will not be able to tell what the words are. However, after each presentation we would like you to make a guess as to what the word was. Each word will be presented to you several times until you have correctly recognized it. I will say “Ready” before each exposure of the word, and I will tell you when you have correctly recognized the word and when a new word is going to be presented to you.

The words used in the tachistoscopic procedure contained the core-words of the pack of cards. These words were “buried,” in random sequence, among 20 other words in the list of words for tachistoscopic presentation. These 20 words contained ten English words, varying in frequency over a large range in the Thorndike-Lorge counts, plus ten pronounceable nonsense words that previously had never been exposed to S. Thus, the total number of words to be exposed was 30. They were (a) the ten core-words; (b) English words (welfare, surmise, testify, titular, example, promise, machete, venture, deserve, balance); and (c) nonsense words never exposed before (afranaf, ekrimen, peyarey, awahad, bilogo, akliyat, pizirik, nobetiki, levahik, fedakar).

In addition to these 30 words, four practice words were given at the start of the tachistoscopic session (Harvard, teacher, university, professor). The words in the tachistoscope were typed in the same capitals used on the cards of the deck described above. The ascending method of limits was used to determine the duration threshold (to the nearest .01 sec.) for each of the 30 words. The duration threshold was defined as the flash duration just necessary for correct recognition. For details of apparatus and procedure, the reader is referred to previous experiments (3, 11).

Experiment II.—The purpose and design of the second experiment were similar to those of the first experiment with the following exceptions: (a) The second experiment was run as a group experiment. (b) The Ss—30 undergraduate and graduate students at the University of California—were instructed to pronounce the words subvocally after E had read them. (c) Because this was a group experiment, there was, of course, no possibility of counterbalancing the words, and, therefore, different frequencies were assigned to different words arbitrarily. This
procedure confounded frequencies and whatever effects stemmed from word structure. (d) Tachistoscopic exposure was by means of a projector equipped with a shutter which was set at a constant exposure duration of .01 sec. Each word was exposed 18 times with the illumination intensity increasing from exposure to exposure by an amount equivalent to a change of 2.5 v. (e) The number of trials required for the first correct recognition of the exposed word was used as a measure of the recognition threshold.

RESULTS

Experiment I.—The average duration thresholds, in seconds, for all core-words are given in Table 2 and plotted in Fig. 1. The control words to which Ss had not been previously exposed, are listed as having a frequency of zero. Clearly, thresholds vary inversely with frequency of prior usage. Before evaluating the differences among the thresholds, we must take account of practice effects. The core-words were scattered through the tachistoscopic list randomly, but the same order of presentation was given to each S. In order to adjust for practice effects, the list was divided into thirds, and separate standard scores were computed for each third of the list. The standard scores for the three thirds were then comparable to each other, and further analysis could then be made on the assumption that practice effects could not differentially affect thresholds for different core-words. The average standard scores for words with different frequencies of usage are listed in Table 2.

An analysis of variance was performed on the standardized threshold data (for core-words only). The main experimental variable—frequency—was found to be a significant source of variance \((F = 4.75, df = 4 \text{ and } 25, p < .01)\). Differences among sets of words fell short of significance \((F = 1.51, df = 4 \text{ and } 25)\). Finally, individual differences among Ss were significant \((F = 23.44, df = 4 \text{ and } 25, p < .01)\).

Experiment II.—The average duration thresholds, in number of trials required for recognition, are listed in Table 2 and presented graphically in Fig. 1. Table 2 also shows the average duration thresholds in standard score form. Analysis of variance again showed frequency to be a highly significant source of variance \((F = 45.60, df = 5 \text{ and } 145, p < .01)\). In the case of Exp. II, individual differences among Ss were not significant \((F = .32)\).

Although the general trend of the thresholds as a function of frequency is the same as in Exp. I, the reversal between words having two and five presentations must be noted. It will be remembered that in Exp. II the core-words could not be counterbal-

<p>| TABLE 2 |
|-----------------|-----------------|
| <strong>AVERAGE RECOGNITION THRESHOLDS FOR CORE-WORDS OF DIFFERENT FREQUENCIES</strong> |</p>
<table>
<thead>
<tr>
<th>Core-Word Frequency</th>
<th>Experiment I</th>
<th>Experiment II</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.96</td>
<td>+.52</td>
</tr>
<tr>
<td>1</td>
<td>.49</td>
<td>+.16</td>
</tr>
<tr>
<td>2</td>
<td>.27</td>
<td>+.29</td>
</tr>
<tr>
<td>5</td>
<td>.26</td>
<td>-.02</td>
</tr>
<tr>
<td>10</td>
<td>.20</td>
<td>-.27</td>
</tr>
<tr>
<td>25</td>
<td>.12</td>
<td>-.48</td>
</tr>
</tbody>
</table>
anced among the various frequencies. It is probable that the particular structural characteristics of the words given two and five presentations outweigh the differential effect of frequency. When the Thorndike-Lorge word counts are used, the structural characteristics of particular words probably obscure the effects of frequency in a similar manner. In the absence of control for word structure, the general resemblance of the curves obtained in Exp. I and II is striking evidence for the importance of frequency of usage as a determiner of recognition thresholds.

DISCUSSION

The data presented in Fig. 1 indicate quite clearly that visual recognition thresholds for words are a negatively accelerated decay function of frequency of prior exposure to a given word. In the previous work of Howes and Solomon (3), using the Thorndike-Lorge count as a word-frequency estimate, recognition thresholds have appeared to be an inverse linear function of the logarithm of frequency of word usage. A logarithmic transformation is not, however, appropriate to the present data. Whereas Howes and Solomon never had occasion to assign a frequency of zero to any English words, there is a true zero frequency point in the present function. The logarithm of zero frequency is relatively meaningless for our purposes without some sort of correction. The shape of the functions in Fig. 1, moreover, does not yield a linear plot when transformed logarithmically.

It is interesting to note, however, that the mean thresholds for frequencies of word usage varying from 1 to 25 (omitting the zero frequency) do yield a very good fit to an inverse linear logarithmic function. Therefore, there is some reason to suspect that, when a word has been exercised at least once, or has been encountered at least once, its recognition threshold will be roughly an inverse function of log frequency of prior exposure or usage.

The results shown in Fig. 1 provide a theoretical bridge between learning theory and perception theory. Let us assume that, by differentially exercising pronounceable nonsense words in this experiment, we have established associations of differential strength between the visually presented verbal stimulus and the response of reading or saying the word. The strength of this association is measured by the duration or intensity of the stimulus exposure necessary for a correct verbal report.

Given a population of associations, the one which has been exercised most frequently will have the greatest probability of being elicited relative to other, like associations. How will this fact influence S's responses in a tachistoscopic situation? When a stimulus pattern is presented at short durations or at low illumination intensities, only fragments of the total word stimulus are "effective." Such a stimulus fragment may be considered to represent a point on the generalization dimension of stimulus patterns capable of eliciting the correct verbal response. A given stimulus fragment may, of course, be located on several generalization dimensions, each involving a different word. Which verbal response will be given depends on the relative strengths of association which have been established, through generalization, between the particular stimulus fragment and the different response words. If the visually presented stimulus word has had a greater fre-

1 For purposes of the present analysis it probably makes very little difference whether we think of these associations in terms of S-R connections or S-S patterns (hypotheses).
quency of prior usage than any of the competing response words, a correct response is highly probable.

Words of lower prior exercise frequency will be interfered with by words of higher exercise frequency. This interference will manifest itself in the tendency for S's "guesses" to be high frequency words. If the actual stimulus word is a low frequency word, effective stimulus fragments will elicit erroneous "guesses" until the amount of effective stimulation becomes great enough on successive exposures to reduce the number of competing word responses. One may describe the increase in effective stimulation as limiting the range of competing "hypotheses" (1, 10) or one may speak of a restriction of stimulus generalization. In this connection it is interesting to point to the parallel between overt intrusions in retroaction and proaction experiments and wrong pre-recognition responses in the tachistoscopic situation. In both cases, a strong competing response temporarily replaces the correct response.

Frequency or prior occurrence used as an independent variable contains two aspects: (a) frequency of prior stimulation; and (b) frequency of prior response. When the Thorndike-Lorge word counts are used as a frequency index, these two aspects of environmental history are confused. Such is also the case in the experiments reported in this paper. When the pronounceable nonsense words were exposed to the Ss, and they were asked to read them, either aloud or subvocally, a frequency index was being established into which the effects of exposure and response enter to unknown degrees. At present, we do not know whether frequency of prior exposure or frequency of prior response is the more important determinant of visual duration thresholds to words.

A series of experiments aimed at this problem would have considerable bearing on the relative strengths and weaknesses of cognitive learning theory as compared with S-R learning theory in handling the facts of word-recognition experiments.

Our experiments point to frequency of prior usage as an important determinant of recognition thresholds but leave open the question of the process mediating the effect of frequency. The interaction of motivational factors with frequency has just begun to be explored (12, 14). Frequency of one type of sequence need not be equivalent to another type. The functions shown in Fig. 1 were obtained with verbal sequences which had no important motivational consequences for the Ss. To what degree consequences of a high motivational nature will alter these functions is a question to be answered experimentally.

One final methodological note. Using operations typical of perception experiments (determination of thresholds), we have attacked our problem in terms of concepts derived from verbal learning. The phenomena of word recognition can play a strategic role in the rapprochement of theories of perception and verbal learning. The fact that many perceptual experiments concerned with nonverbal stimuli use verbal reports as their basic data makes it highly desirable to explore further the relations between the laws of verbal behavior and the laws of perception.

SUMMARY

This experiment was concerned with the relationship between tachistoscopic recognition thresholds for words and frequency of prior usage of the words.

Pronounceable nonsense words were used as stimuli. Frequency of usage was controlled experimentally by requiring Ss to read and pronounce different nonsense words with frequencies ranging from 1 to 25. Later, Ss' tachistoscopic recognition thresholds for these words were determined as well as for control words which had zero frequency of prior usage. Recognition thresholds were found to vary inversely with frequency of prior usage.
The discussion stresses the close relationship between Ss' responses in a tachistoscopic recognition situation and responses measured in experiments on verbal learning. Frequency of past usage is a determiner of response strength in both types of situation. The importance of controlling such variables as frequency of usage in experiments relating perceptual sensitivity to personality variables is pointed out.

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REFERENCES


