Discrimination learning as a function of differences in materials: A proposed explanation*

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The present study affords an explanation for the consistent, but not always statistically significant, pattern showing superior verbal discrimination learning performance for low- as compared to high-frequency words. In a frequency judgment task, it was found that relative to high-frequency words, low-frequency words for which Ss (sixth graders) knew the meanings produced apparent frequency measures consistent with superior verbal discrimination learning, while low-frequency words that were unknown to the children did not. These results, taken together with those based on comparisons of pictures and high-frequency words, lend themselves to a modified Weber's law interpretation of stimulus material differences in discrimination learning.

There is substantial evidence that in the verbal discrimination learning paradigm, picture pairs are easier to discriminate than word pairs (Rowe, 1972; Rowe & Paivio, 1971a; Wilder & Levin, 1973). The results of a recent study by Ghatala, Levin, and Wilder (1973) suggest that picture-word differences in this task might be explained in terms of frequency theory (Ekstrand, Wallace, & Underwood, 1966). In an absolute frequency judgment task with sixth graders, it was found that: (1) Ss judged pictures (line drawings of common objects) to be higher in situational frequency than their verbal labels even though the actual presentation frequency of the two were the same; (2) Ss were less variable in their judgments of pictures than in their judgments of words; and (3) though not reported by Ghatala et al (1973), Ss' accuracy (in estimating exactly the presentation frequencies of items) was higher for pictures than for words. These results have essentially been replicated by the present authors in other published (Ghatala & Levin, 1973) and unpublished work.

Given the Ghatala et al (1973) results, it follows from frequency theory that pictures should be more easily learned than words in a discrimination task, since the basis for successful performance on this task is presumed to reside in *frequency* discriminations. Thus, if pictures produce apparent frequency "units" which are larger (cf.

the first finding cited above) and more stable (cf. the second and third findings above) than those of words, frequency discriminations should be easier with pictures (as discussed at length by Ghatala et al, 1973).

The above reasoning utilizes one empirical finding (i.e., apparent frequency differences between pictures and words) plus the tenets of frequency theory to "explain" another empirical result (i.e., picture-word differences in discrimination learning). This explanation is less than satisfying, however, unless: (a) it can be demonstrated that apparent frequency differences among stimulus materials (here, between pictures and words) are directly related to discrimination learning performance; and (b) one can also explain *why* stimulus materials differ in apparent frequency.

With regard to the initial requisite above, support has recently been obtained by Levin, Ghatala, and Wilder (in press). When pictures and words were equated on the basis of mean or variance apparent frequency measures obtained from the Ghatala et al (1973) study, the usual picture-word differences in discrimination learning disappeared. Concerning the second requisite above, the purpose of the present experiments was to test the hypothesis that apparent frequency differences among stimulus materials may be due to differences in preexperimental (or "background") frequency.

In most experiments in which pictures and words are compared, the pictures used as stimuli typically represent common objects that are undoubtedly familiar to Ss, but which consist of line drawings that the Ss have never actually seen before. Thus, the *particular* pictures employed possess low (in fact, zero) background frequencies in comparison to their most readily elicited verbal labels (the word stimuli). Generalizing Weber's law to this situation, an item low in background

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frequency should be judged higher in apparent frequency than an item high in background frequency. Moreover, discrimination of experimentally induced frequency differences for low background frequency items should be better than for high background frequency items.

If background frequency is indeed the crucial construct underlying picture-word differences in apparent frequency, then the finding should not be unique to picture-word comparisons; rather, apparent frequency differences should be detected with any materials which differ in background frequency. In the first experiment, this notion was investigated by obtaining situational frequency judgments for pictures, for high-frequency labels of the pictures, and for low-frequency labels of the pictures. In line with previous results (Ghatala & Levin, 1973; Ghatala et al, 1973), the apparent frequencies of pictures were expected to be larger (reflected by higher mean judgments) and more stable (reflected by lower variability and greater accuracy of judgments) than their high-frequency labels. Moreover, comparisons of low-frequency labels with high-frequency labels were expected to produce the same pattern of results as the comparison between pictures and high-frequency words.

However, a review of verbal discrimination learning studies in which high- and low-frequency words have been compared leads to a qualification of the above predictions. Some studies have shown better performance with low-frequency than with high-frequency words (e.g., Underwood, Broder, & Zimmerman, 1973). Other studies have shown little or no difference between high- and low-frequency words (e.g., Paivio & Rowe, 1970). A study by Allen and Garton (1968) suggests a possible reason for this discrepancy. These authors found that recognition memory for low-frequency words is better when Ss know the meanings of the words than when they do not—indicating that apparent frequency of low-frequency words may be influenced by Ss' semantic knowledge of the words. Thus, any low- vs high-frequency word comparisons in a frequency judgment or verbal discrimination learning task might be moderated by the meaningfulness of the low-frequency materials: with meaningful low-frequency materials, the predictions stemming from Weber's law should hold; with meaningless materials they might not.

EXPERIMENT I

Method

Materials. One set of pictures and two sets of words were prepared for use in an absolute frequency judgment task. The pictures were 36 line drawings of common objects (e.g., *cup*, *box*) randomly selected from a pool of over 200 drawings. The high-frequency words consisted of 36 labels for the pictures (e.g., "cup," "box") for which the Thorndike-Lorge (1944) values were all in the AA or A range. The low-frequency words were also labels for the pictures (e.g., "tankard," "carton"). The average Thorndike-Lorge value for the 36 low-frequency words

was 9.6 occurrences per million. Half of the low-frequency words were selected because they had little meaning for the Ss; meanings of the other 18 low-frequency words were known by the Ss.

Selection of the two types of low-frequency words was based on the results of a pilot study. Twenty Ss from the same S population used in the main experiment were presented with approximately 60 low-frequency synonyms for the high-frequency labels. Each word was presented on a card and S was required to pronounce and then give a definition for each word. The 18 low-frequency/high-meaning (Lo-F/Hi-M) words were those which at least 80% of the Ss pronounced correctly and defined (any sort of definition was taken to indicate that the word had meaning for the S). The 18 low-frequency/low-meaning (Lo-F/Lo-M) words were those which at least 80% of the Ss pronounced correctly, but which no more than 20% of the Ss defined in any manner (i.e., at least 80% of the Ss said "I don't know" when asked to give a meaning to the word). The average Thorndike-Lorge values were 11.8 and 7.4 occurrences per million for the Lo-F/Hi-M and Lo-F/Lo-M words, respectively.

Of the 18 Lo-F/Hi-M and 18 Lo-F/Lo-M words selected for use in the absolute judgment task, 13 apiece were randomly distributed among the four presentation frequency categories represented in the study list. The study list consisted of 10 words (5 Lo-F/Hi-M and 5 Lo-F/Lo-M) presented once, 10 words presented twice, 4 words presented three times, and 2 words presented four times, thereby making a total of 50 study presentations. The remaining 10 words were used as filler (or zero-frequency) items on the test list. The order of the low-frequency words on the study list was random subject to the restriction that words of multiple occurrences were distributed equally in each equal-sized section, with the number of sections being determined by the frequency. That is, a word presented twice occurred once in each half of the list, a word presented three times occurred once in each third of the list, and so on. This arrangement also insured that Lo-F/Hi-M and Lo-F/Lo-M words occurred equally often in each equal-sized section of the list.

The test list for the low-frequency words consisted of the 26 words presented for study plus 10 words which had not been presented. The order of the low-frequency words on the test trial was random.

The assignment of the pictures and the high-frequency words to the four frequency categories for presentation was determined by the assignment of the corresponding low-frequency labels to frequency categories. In addition, across the three conditions, the picture, the high-frequency label for the picture, and the low-frequency label for the picture occurred in the same positions on the study and test trials.

The line drawings were photographed and mounted one to a slide; the words were typed one on a card in primary type, photographed, and mounted on slides.

Procedure. The pictures, high-frequency words, and low-frequency words were presented for study to independent groups of Ss. In all conditions, Ss were tested individually and slides were shown at a 5-sec rate by means of a Kodak Carousel slide projector. The Ss were informed as to the type of items they would be shown (i.e., "pictures of common objects," "words you know," "words, some of which you know and some of which you may not know"). All Ss were told that some of the items would occur more than once and that they should pay close attention because later they would be asked questions about the items.

After presentation of the study list, Ss were immediately given the appropriate test list at a 5-sec rate. The Ss were instructed to respond to each item, guessing if uncertain, by saying the number of times that item had been presented for study.

Subjects. The Ss were 80 sixth-grade children from an elementary school located in a middle-income area in Ogden, Utah. Twenty Ss were randomly selected for the pilot study. The

remaining 60 Ss were assigned to the three conditions (pictures, high-frequency words, and low-frequency words) by means of a block-randomized schedule.

Results

In accordance with the procedure adopted in our previous experiments (Ghatala & Levin, 1973; Ghatala et al, 1973; Wilder, Levin, Ghatala, & McNabb, in press), several measures of frequency judgment performance were computed for each S. Since many of the measures are highly correlated, however, the data from only three of these are reported here: (a) *mean* judgments associated with items presented once during study; (b) the intra-S *variability* associated with "one"-item judgments, as defined by S's mean squared deviation (about his or her "one"-item mean); and (c) the total number of correct frequency identifications for the 36 items (*accuracy*).

The averages of each experimental condition on these three measures are reported in Table 1. Due to the mixed-list format of the low-frequency list, it was not possible to perform a straightforward analysis of variance on these measures. Rather, an *a priori* conceptualization of the research questions resulted in the following comparisons: (1) a comparison of picture and high-frequency word measures (one-tailed *t* tests with $\alpha = .05$) to provide continuity with our previous research; and (2) comparisons of the two types of low-frequency words with their respective high-frequency word counterparts (two-tailed *t* tests each with $\alpha = .05$) and with each other (one-tailed difference *t* tests with $\alpha = .05$). (Since the low-frequency words were compared with selected high-frequency counterparts, the exact results of these statistical analyses are not retrievable solely from the data in Table 1.)

Consistent with the Ghatala et al (1973) findings, the first set of analyses detected picture-word differences on all three frequency judgment measures: pictures exhibited higher mean judgments ($t = 2.41$, $df = 38$, $p < .025$), lower variability ($t = 2.08$, $df = 38$, $p < .025$), and greater accuracy ($t = 3.45$, $df = 38$, $p < .001$).

The results of the second set of analyses provided support for the present predictions on the mean, but not on the variability or accuracy, measure. For mean judgments, Lo-F/Hi-M words were judged significantly higher than either high-frequency words ($t = 3.04$, $df = 38$, $p < .01$) or Lo-F/Lo-M words ($t = 2.00$, $df = 19$, $p < .05$), the latter two not differing significantly. However, high-frequency words tended to produce lower variability and greater accuracy than both low-frequency word types, although they were statistically different only from Lo-F/Lo-M words on the variance measure ($t = 2.15$, $df = 38$, $p < .05$). While Lo-F/Hi-M words resulted in slightly lower variability and greater accuracy than Lo-F/Lo-M words, neither difference was statistically significant ($0 < |t| < 1$ for each).

Table 1
Summary Data for the Conditions of Experiment I

Measure	Condition			
	Pictures	High-Frequency Words	Lo-F/Hi-M	Lo-F/Lo-M
One-Item Means	1.10 (.055)	.95 (.073)	1.30 (.120)	.99 (.116)
One-Item Variances	.15 (.045)	.26 (.058)	.36 (.050)	.42 (.059)
Accuracy	75%	62.5%	59%	56%

Note—Standard errors are in parentheses. Since the low-frequency words were compared with their high-frequency counterparts and since the Lo-F/Hi-M comparisons with Lo-F/Lo-M were based on within-S (correlated) differences, the exact results of the statistical analyses are not retrievable from the means and standard errors reported here. Also, since the mixed-list Lo-F conditions each contained half the number of items as the two other conditions, accuracy is reported as a percentage.

Discussion

The results of Experiment I clearly replicate our previous findings with respect to pictures and high-frequency words—Ss assigned pictures higher average frequencies and, at the same time, were less variable and more accurate in their judgments of pictures than of high-frequency words.

The results with respect to comparisons of high-frequency words with the two types of low-frequency words were equivocal. The measure of mean frequencies gave results in accordance with predictions. However, the results for the variability and accuracy measures were not in accordance with predictions.

It should be recalled that while the pictures and high-frequency words were each presented in homogeneous lists, the low-frequency list contained both Hi-M and Lo-M items. Thus, it is possible that the low-frequency word list may have produced a contrast effect resulting in selective attentional and rehearsal strategies, or may have simply confused the Ss.

In order to eliminate this possible mixed-list effect, a second experiment was conducted utilizing homogeneous Lo-F/Hi-M and Lo-F/Lo-M lists. Because the apparent frequency differences between pictures and high-frequency words have now been replicated numerous times, it was felt that in the interest of economy the picture condition could be eliminated in Experiment II. Thus, in the second experiment, frequency judgments were obtained for homogeneous lists of high-frequency words, Lo-F/Hi-M words, and Lo-F/Lo-M words. In addition, judgments were obtained for "nonsense" items in order to assess the extremes of the meaningfulness dimension.

The nonsense items were transformations of the Lo-F/Lo-M words which were expected to have even less

Table 2
Summary Data for the Conditions of Experiment II

Measure	Condition			
	High-Frequency	Lo-F/Hi-M	Lo-F/Lo-M	Nonsense
One-Item Means	.93 (.080)	1.16 (.108)	1.10 (.067)	.93 (.115)
One-Item Variances	.26 (.051)	.19 (.056)	.48 (.090)	.60 (.098)
Accuracy	23.25 (.736)	25.60 (.807)	22.45 (.947)	17.55 (.642)
Composite	.32 (.330)	1.85 (.204)	.02 (.420)	-2.19 (.360)

Note—Standard errors are in parentheses.

meaning for Ss than the Lo-F/Lo-M words. By this is meant that even though the Lo-F/Lo-M words provided little or no realized semantic content for Ss (as was determined from the pilot ratings), their possible closer resemblance to known English words in terms of linguistic structure and pronunciability might afford more meaning and/or associations for the Ss than would nonsense words. Accordingly, we speculated that the nonsense words would result in even lower mean judgments, larger variability, and less accuracy (relative to high-frequency words) than Lo-F/Lo-M words.

EXPERIMENT II

Method

Materials. The 36 high-frequency words from the first experiment were used again. The 18 Lo-F/Hi-M and the 18 Lo-F/Lo-M words were also retained from the first experiment. In order to obtain two sets of 36 low-frequency words, one consisting entirely of low-meaning words and the other of high-meaning words, 18 new Lo-F/Hi-M words and 18 new Lo-F/Lo-M words were generated on the basis of a pilot study conducted in the same fashion as the pilot study in the first experiment.

Twenty Ss were asked to pronounce and define approximately 65 low-frequency nouns. The 18 Lo-F/Hi-M words selected were those which at least 80% of the Ss could both pronounce and define. The 18 Lo-F/Lo-M words were those which at least 80% of the Ss could pronounce but no more than 20% could define. The average Thorndike-Lorge value for the set of 36 Lo-F/Hi-M words was 8.2 occurrences per million; the value for the 36 Lo-F/Lo-M words was 6.0 per million.

The high-frequency words were presented and tested in the same order as in Experiment I. The two low-frequency word lists were ordered such that each old low-frequency word maintained its same ordinal position on the study and test trials as in Experiment I. The new Lo-F/Hi-M items replaced the old Lo-F/Lo-M items, resulting in a homogeneous Lo-F/Hi-M list. A homogeneous Lo-F/Lo-M list was similarly obtained.

The items for the nonsense condition were created as follows. Each Lo-F/Lo-M word was transformed according to the rule: Replace each consonant with the next consonant in the alphabet and retain the same vowels (e.g., tankard was transformed into vaplasf). This rule produced nonsense items having the same length and consonant/vowel structure as the Lo-F/Lo-M words. Also, the interitem similarity for the two sets of items in terms of number of repeated letters was the same. Each nonsense item occurred with the same presentation frequency and in the same

ordinal positions on study and test trials as the Lo-F/Lo-M word from which it was derived.

Procedure. The procedure was exactly the same as in the first experiment.

Subjects. The Ss were 100 sixth-grade children from an Ogden elementary school quite similar to the one in which the first experiment was conducted. Twenty Ss were randomly selected for the pilot study. The remaining 80 Ss were randomly assigned in equal numbers to the four conditions of the experiment (high-frequency words, Lo-F/Hi-M words, Lo-F/Lo-M words, and nonsense items).

Results

As in Experiment I, one-item means, one-item variances, and accuracy measures were computed for each S in each experimental condition. These data (averaged over Ss) are summarized in Table 2. Previous research findings and the predictions derived from them (outlined in the introduction) dictated an efficient set of statistical comparisons. In particular, since it was predicted that low-frequency words would be "superior" to high-frequency words as long as they had meaning for the Ss, each of the two low-frequency word conditions and the nonsense word condition were compared with the high-frequency word condition by means of Dunnett tests for each performance measure. (Since superior discrimination learning is assumed to be characterized by larger and more stable frequency "units," as outlined in the introduction of this paper, we will refer to frequency judgment performance which produces larger means, smaller variances, and greater accuracy as being "superior.")

According to this procedure (using a critical Dunnett value of 2.40, based on $\alpha = .05$ and $df = 76$), it was found that relative to Ss in the high-frequency word condition: (1) Lo-F/Hi-M Ss produced significantly higher mean judgments ($t = 2.43$); (2) Lo-F/Lo-M Ss exhibited significantly higher variances ($t = 2.87$); and (3) Ss in the nonsense word condition exhibited both significantly higher variances ($t = 4.44$) and significantly lower accuracy ($t = -5.12$). No other Dunnett comparisons were statistically significant.

Considered jointly, this set of outcomes is consistent with the predicted ordering of conditions with regard to frequency judgment performance. However, in order to get a more parsimonious representation of performance, the three measures were combined in the following manner. Across experimental conditions, Z scores were computed for each S on each measure. A simple linear combination of these yielded:

$$Z_C = Z_M + (-Z_V) + Z_A$$

where Z_M , Z_V , and Z_A represent a given S's Z scores on the mean, variance, and accuracy measures, respectively. Note that in this composite, Z_C , S's variance measure, Z_V , received a negative weight since smaller variances are indicative of "superior" frequency judgment performance. Thus, a S whose judgments produced high means, low variances, and high accuracy would obtain a

positive "frequency judgment performance composite," while a S with low means, high variances, and low accuracy would obtain a negative one. The mean composites for each of the experimental conditions are presented in Table 2. Dunnett comparisons ($\alpha = .05$, $df = 76$, $t_c = 2.40$) on these data yielded statistical decisions completely in support of the predictions: Lo-F/Hi-M Ss were "superior" to Ss in the high-frequency word condition ($t = 3.23$); Lo-F/Lo-M Ss did not differ significantly from high-frequency word Ss ($t = -.62$); and nonsense word Ss were "inferior" ($t = -5.28$).

DISCUSSION

The results of both experiments (especially those of Experiment II) provide support for the hypothesis that preexperimental or background frequency differences in materials account for apparent frequency differences. The results also substantiate our notion that Weber's law (as applied to the frequency judgment situation) holds only for materials which have meaning for Ss, which in turn help to account for the fact that word frequency has not been found to be a potent variable in verbal discrimination learning (see also Lovelace, 1969, and Lovelace & Pulley, 1972, for a similar interpretation).

In particular, although it has occasionally been found that low-frequency word pairs are learned significantly better than high-frequency word pairs (e.g., Rowe & Paivio, 1971b, Experiments I and IV; Underwood, Broder, & Zimmerman, 1973), this is not always the case (e.g., Ingison & Ekstrand, 1970; Paivio & Rowe, 1970; Rowe & Paivio, 1971b, Experiments II and III). While there are probably many differences among the studies (such as range of frequency employed, mixed vs homogeneous lists, etc.) which could account for the discrepant results, the present study suggests that the meaningfulness of the low-frequency words employed may be a crucial factor. As we found from our pilot studies, words within the low-frequency range in the Thorndike-Lorge (1944) norms differ with respect to their meaning value for Ss. [Although this finding is based on a sample of children, it is not unreasonable to expect similar word norm/word knowledge discrepancies for adults as well, as Allen & Garton's (1968) study would suggest.] Thus, it is likely that the meaning value of the low-frequency words (as defined by the operations in the present study) may have varied both within studies (which would tend to lessen differences between high- and low-frequency words) and across studies (which would account for some studies finding the effect and others not). Research is needed contrasting high- and low-frequency words in verbal discrimination learning when the Ss' knowledge of the meanings of the low-frequency words is assessed and controlled.

What we have demonstrated here may be summarized as follows: With materials which have meaning for Ss,

predictions from Weber's law are supported. Materials low in background frequency produce "superior" frequency judgment performance in comparison to materials high in background frequency. Note that with our proposed frequency/meaningfulness explanation there is no theoretical reason to deal separately with words and pictures. Rather, as long as the words are low in frequency *and* have meaning for Ss, they should behave more like pictures than like high-frequency words. By the same token, implicit in this argument is the assumption that the pictures utilized also have meaning for the Ss. Were this not the case (say, if low-meaningful pictures or nonsense shapes were employed), the "superior" performance of pictures relative to high-frequency words would be expected to diminish, just as it did for low-frequency, low-meaningful words in the present study.

With respect to the relationship between apparent frequency and discrimination learning, it has been suggested by us and by others (as outlined in the introduction) that because materials which are low in background frequency produce larger frequency "units" and/or more stable "units," they are more easily discriminated in discrimination tasks. The Levin, Ghatala, and Wilder (in press) study cited earlier in which apparent frequencies of pictures and words were manipulated experimentally may be taken as affirmative evidence.

Finally, the background frequency explanation of apparent frequency and discrimination learning differences can be tested either by experimental or extraexperimental manipulations. The present study involved an extraexperimental manipulation in the sense that comparisons were made among items which differed on normative (Thorndike-Lorge) frequency. However, experimental manipulations intended to modify the background frequencies of different types of materials may also prove fruitful, as some preliminary results (DeRose, 1974) indicate.

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