DOCUMENT RESUME

ED 094 404 CS 201 459

AUTHOR	Ghatala, Elizabeth S.; Levin, Joel R.
TITLE	Children's Discrimination Learning as a Function of Differences in Materials: A Proposed Explanation.
INSTITUTION	Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
REPORT NO	TR-283
PUB DATE	Jan 74
CONTRACT	NE-C-00-3-0065
NOTE	16p.; Report from the Project on Children's Learning and Development
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Cognitive Processes; *Discrimination Learning; *Educational Research; Elementary Education; Grade 6; *Language Development; *Structural Analysis; *Verbal Learning

ABSTRACT

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 subjects (sixth graders) knew the meanings produced apparent frequency measures consistent with superior verbal discrimination learning, while low-frequency words that were known to the children did not. The 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. (Author)

Technical Report No. 283

CHILDREN'S DISCRIMINATION LEARNING AS A FUNCTION OF DIFFERENCES IN MATERIALS: A PROPOSED EXPLANATION

by

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Report from the Project on
Children's Learning and Development

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

January 1974

Published by the Wisconsin Research and Development Center for Cognitive Learning, supported in part as a research and development center by funds from the National Institute of Education, Department of Health, Education, and Welfare. The opinions expressed herein do not necessarily reflect the position or policy of the National Institute of Education and no official endorsement by that agency should be inferred.

Center Contract No. NE-C-00-3-0065

Statement of Focus

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints—financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher student achievement and self-direction in learning and in conduct and also to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

Acknowledgment

We are grateful to Becky Abbott for assistance in data collection.

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Abstract

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.

I
Introduction

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 (1974). 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 pre-experimental (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 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 meaning 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.

II
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 subject 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, four words presented three times and two 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 run individually and slides were shown at a 5-sec. rate by means of a Kodak Carousel slide projector. The Ss were told about 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 they were told that they should pay close attention because they would later 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, 1974), several measures of frequency judgment performance were computed. 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 (item variability) associated with "one"-item judgments; and (C) the total number of correct frequency identifications for the 36 items (accuracy).

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 (a) their respective high-frequency word counterparts (two-tailed t-tests each with $\alpha = .05$), and (b) with each other (one-tailed difference t-tests with $\alpha = .05$).

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, lower variability, and greater accuracy.

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 or Lo-F/Lo-M words (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. 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.

Discussion

The results of Experiment I clearly replicate our previous findings with respect to pictures and high-frequency words--Ss assigned higher average frequencies to pictures and, at the same time, they 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, it 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 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.

III
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, as in Experiment I. 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/Hi-M words was 6.0 occurrences 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 run. 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, 1-item means, 1-item variances, and accuracy measures were computed for each S in each experimental condition. These data (averaged over Ss) are summarized in Table 1. 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"[1] to

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[1] 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

TABLE 1
SUMMARY DATA FOR THE FOUR EXPERIMENTAL CONDITIONS OF EXPERIMENT II

Measure	Condition			
	High-frequency	Lo-F/Hi-M	Lo-F/Lo-M	Nonsense
1-item Means	.93	1.16	1.10	.93
1-item Variances	.26	.19	.48	.60
Accuracy	23.25	25.60	22.45	17.55
Composite	.32	1.85	.02	-2.19

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 (α = .05) for each performance measure. According to this procedure, it was found that relative to Ss in the high-frequency word condition: (1) Lo-F/Hi-M Ss produced significantly higher mean judgments; (2) Lo-F/Lo-M Ss exhibited signficantly higher variances; and (3) Ss in the nonsense word condition exhibited both significantly higher variances and significantly lower accuracy. 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 measure. These were then summed (the variance measure being reflected, since smaller variances are indicative of "superior" frequency judgment performance) to form a composite frequency judgment measure. The mean composites for each of the experimental conditions are presented in Table 1. Dunnett comparisons 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; Lo-F/Lo-M Ss did not differ significantly from high-frequency word Ss; and nonsense word Ss were "inferior."

frequency judgment performance which produces larger means, smaller variances, and greater accuracy as being "superior."

IV
General Discussion

The results of both experiments (especially those of Experiment II) provide support for the hypothesis that pre-experimental 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. As Lovelace (Lovelace, 1969; Lovelace & Pulley, 1972) has suggested, stable encoding of items is necessary before subjective frequency can effectively accrue to those items. The present results suggest that, in particular, semantic encoding of materials may be necessary for effective, subjective frequency accrual. This latter finding may help to account for the fact that word frequency has not been found to be a potent variable in verbal discrimination learning.

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 et al, 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.[2] 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 reduce 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 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 et al. (1974) study cited earlier, in which apparent frequencies

[2]Although this finding is based on a sample of children, it is not unreasonable to suspect similar word norm/word knowledge discrepancies for adults as well, as Allen and Garton's (1968) study would suggest.

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 extra-experimental manipulations. The present study involved an extra-experimental manipulation in the sense that comparisons were made on 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.

GPO 806-044

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