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UNCLASSIFIED

CLUSTERING IN RECALL AS A FUNCTION OF THE NUMBER OF

WORD-CATEGORIES IN STIMULUS-WORD-LISTS

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Clustering in Recall as a Function of the Number of

Word-Categories in Stimulus-Word-Lists

THE PROBLEM

The term clustering is here used to denote the tendency to recall the items of a randomized stimulus-word-list in sequences of related words. Our operations for inducing and measuring clustering involve the following steps: (a) the compiling of sub-lists comprising an equal number of words in each of two or more categories; (b) the randomization of all these words to form a stimulus-word-list; (c) the serial presentation of the words of the stimulus-word-list to subjects for learning; (d) the obtaining of recall on the basis of instructions to subjects to write or speak the words they remember; (e) the statistical analysis of the recalled words to determine the extent to which the subjects exceed chance expectancy in their tendency to produce sequences of words belonging to the same category.

Our earlier studies (1,2) have established positive functional relationships between the extent of clustering and the following two variables: (a) number of reinforcements of the stimulus-word-list; (b) frequencies-of-usage of stimulus-words based on the Thorndike-Lorge (5) tables. These studies have also shown that the clustering tendency varies in a systematic way throughout the course of recall. The broadly defined purpose of these studies has been to investigate a type of organization operating in higher mental processes and to develop a theoretical account based on Hebb's (3) conception of the development of superordinate perceptions. According to Hebb's schema, the repeated perception of related parts results in the growth of a superordinate structure. Such a structure, when activated by one or more of its subordinates, will facilitate the action of the remaining subordinates. In applying this theory to our type of situation we have assumed that the probability of recall of any word depends on a summation of two types of strength which a word possesses as a potential response. One of these is habit strength deriving from the various reinforcements the word has received both before and during the experiment. The second type of strength is termed relatedness increment. This is the increment of strength deriving from the facilitating action of superordinate structures, namely, those corresponding to the word-categories.

Since we have attributed the clustering tendency to the action of hypothetical superordinate structures, it is desirable to extend our assumptions relating to the behavior of these structures. The present study was designed from this point of view and we have chosen to observe the effects of different degrees of massing of reinforcement of superordinate structures on the dependent variable of clustering. How we have done this may be explained as follows. If the number of words in a stimulus-word-list of the type we have described remains constant, the larger the number of categories, the smaller the number of words in each category. Therefore, the larger the number of categories the less the reinforcement given the individual

superordinate structures representing the categories. Since the cluster-ing tendency is attributed to the strengths of superordinate structures, we might infer that the smaller the number of categories the greater the amount of clustering, i.e., the greater the positive deviation of obtained clustering from chance expectancy. On the other hand, a massed type of repeated activation of superordinate systems might result in an impairment of their functional capacity. Should something like this happen on a sufficient scale, it would be necessary to reverse our prediction. In either event we would be successful in broadening our assumptions regarding the properties of superordinate systems.

We shall report the results of two separate experiments designed to determine the influence on clustering of three types of 40-word stimulus-lists, namely, a two, a four, and an eight-category arrangement. We also used 20-category lists but the results were unstable and therefore of ques-tionable value. For such lists, the amount of clustering required in order to exceed chance expectancy is very small and appears to be markedly affect-ed by uncontrolled factors arising in the choice of categories and stimulus-words. For example, the two words whiskey and brandy belonging in a drink category will be clustered by a majority of our college student subjects even though these words are widely separated in a stimulus-word-list.

EXPERIMENT I

Subjects.— The subjects were 150 undergraduate students enrolled in the laboratory sections of the first semester course in introductory psychology at the University of Connecticut. They were divided into three groups of 50 each so as to make a separate group for each type of stimulus-word-list.

Stimulus-word-lists and apparatus.— The three 40-word stimulus-lists were prepared as follows. All words were two-syllable nouns with Thorndike-Lorge frequencies falling within the range of two to 17 per million. The mean frequency for each category was set at eight. List I comprised two categories, namely, 20 male first names and 20 professions. List II com-prised four categories, namely, 10 male first names, 10 professions, 10 animals, and 10 vegetables. List III comprised eight categories, namely, 5 male first names, 5 professions, 5 animals, 5 vegetables, 5 countries, 5 flowers, 5 carpenter's tools, and 5 trees. The words of each list were randomized and copied on glass slides in the randomized order. To expose the words singly and in serial order on a screen, use was made of an over-head projector with a mask containing an opening large enough to expose a single word. The experimenter moved the slides manually and in time with the flash of a small light occurring at three-second intervals. Data sheets, 8½" X 11" in size, were distributed for use by the subjects to write the words they recalled.

Procedure.— The experimenter informed the subjects that they would see a list of words projected one at a time on a screen. Following the projection of the stimulus-word-list they were to write as many words as they could recall in the order in which the words occurred to them. A total of 10 min-utes was allowed for recall. The same procedure was followed for each of

the three stimulus-word-lists.

Results.-- The following steps were taken in preparing the data for analysis. The words on each data sheet were numbered in serial order. Each word was then labelled to indicate its classification. If it belonged to a category represented in the stimulus-list, it received a letter-symbol corresponding to its category. If the word belonged to an appropriate category but did not appear in the stimulus-word-list, it received an additional symbol to indicate that the word was a categorical intrusion. If the word did not belong to a stimulus-category, or was illegible, it received a third type of symbol indicating an irrelevant intrusion. All sequences of words in the same category, including categorical intrusions, were bracketed to indicate clustering.

The data thus prepared were analyzed to provide a group of measures related to clustering. The top half of Table 1 contains a summary of the results of the first phase of our analysis. For the sake of comparisons to be made later, this table also contains results from Experiment II which we may ignore at this point. We shall consider the data under their respective headings. (a) Mean Number of Words Recalled. The data imply a positive relationship between the number of categories and recall. In view of the reversal of this trend in the subsequent experiment, however, we cannot assume the generality of this relationship without theoretical qualifications to be explained later. (b) Mean Number of Intrusions. While the incidence of both categorical and irrelevant intrusions is relatively small, we note that the former are consistently more frequent than the latter. (c) Mean Number of Repetitions. The term repetition refers to the repeating of a category in recall. The number of repetitions in a cluster is equal to the number of words in a cluster minus one. In addition to the data supplied by the subjects, Table 1 also shows the number of repetitions to be expected on the basis of chance. We may observe that the discrepancy between chance and the results for the subjects increases with the number of categories. (d) Mean Ratio of Repetition ($r/N-1$). This is the ratio of the number of repetitions, r, to the number of words recalled minus one, $N-1$. Whereas the number of repetitions is dependent on N, the ratio of repetition is independent of N. The data show, however, that the trends revealed by this index are essentially the same as those for the number of repetitions alone. (e) Percentages of Subjects Showing Clustering Significant at the .01 and .05 Levels. This method for evaluating clustering was developed in order to provide more meaningful comparisons for the use of different types of stimulus-word-lists. The index should be based of both N and r. Furthermore, it should allow direct comparisons regardless of the number of categories in the stimulus-word-lists and the number of words in each category. Our method employed the following steps. On the basis of an artificial experiment involving the drawing of random numbers to represent various numbers of categories and numbers of words in a category, the chance probability, p, of obtaining a repetition was computed for our experimental conditions. These values were sufficiently close to the following equation to enable us to assume its validity for our purposes:

$$p = \frac{W_c - 1}{N - 1}$$

Table 1

ANALYSIS OF RECALL OF RANDOMIZED 40-WORD STIMULUS-LISTS

OF TWO, FOUR, AND EIGHT CATEGORIES

Experiment I

No. Cats.	No. Ss.	Mean No. Words Recalled	Mean No. of Intrusions		Mean No. of Repetitions		Mean r/n		% Ss. Sign. .01	% Ss. Sign. .05
			Cat.	Irrel.	Chance	Ss	Chance	Ss.		
2	50	14.60	.80	.32	7.11	7.40	.49	.55	6	14
4	50	15.62	.86	.22	3.61	5.12	.23	.35	16	30
8	50	17.64	.52	.33	1.82	4.20	.10	.24	38	50

Experiment II

No. Cats.	No. Ss.	Mean No. Words Recalled	Mean No. of Intrusions		Mean No. of Repetitions		Mean r/n		% Ss. Sign. .01	% Ss. Sign. .05
			Cat.	Irrel.	Chance	Ss	Chance	Ss.		
2	72	25.50	1.38	.32	12.42	15.97	.49	.65	35	50
4	35	23.54	.94	.49	5.44	10.91	.23	.47	57	74
8	53	19.71	.66	.55	2.03	6.90	.10	.36	68	85

In this ratio, W_c is the number of words in a category of a stimulus-word-list, and N is the number of words in the list. Having obtained the values which p could assume in our experiment, the binomial $(p \neq q)^N$ was expanded for each p in relation to integral values of N ranging from one to 40. For each value of N the cumulative probabilities of obtaining $0, 1, 2, \ldots r$ repetitions were plotted. It was then simple to determine for each value of N how many repetitions were required to reach the .01 and .05 levels of significance. These values of r, at the given levels of significance, were then plotted against N so that a pair of curves, one for the .01 level and one for the .05 level, were generated for each value of p. Table 1 gives the percentages of subjects showing significant clustering at the two levels. The data show that the amount of significant clustering increases with the number of categories in the stimulus-word-list.

The second phase of our analysis was undertaken as a supplement to the first. It involved the determination of the frequencies of occurrence during recall of variously sized clusters for each type of stimulus-word-list. From these tabulations we then computed the percentages of words occurring in clusters of varying size. These percentages are shown plotted in Figure 1 which also gives the percentages expected on the basis of chance. These chance percentages were derived from the artificial experiment mentioned earlier. The plots for Experiment II, appearing in Figure 1, will be considered later. Returning to Experiment I, it may be noted that Figure 1 does not include the percentages of single, i.e., unclustered items which were as follows: (a) two-category list, 23.7% for subjects and 34.4% for chance; (b) four-category list, 47.2% for subjects and 61.0% for chance; (c) eight-category list, 58.2% for subjects and 81.4% for chance. On the basis of Figure 1 we see that the total clustering of the subjects increasingly deviates from chance in the progression from the two to the eight-category list.

EXPERIMENT II

This experiment was a replication of the first and was undertaken because of our uncertainty regarding the influence on the results of the first experiment of our choices of categories and stimulus-words.

Subjects.-- The subjects were 160 undergraduate students enrolled in the second semester course in introductory psychology. They differed from those of the first experiment in that they were sophisticated in the sense of having previously taken part in another study of clustering. They were presumably naive, however, with respect to the purposes of this experiment and the nature of the analysis of the data. These subjects were divided into four groups as follows: Group I, 41 subjects; Group II, 31 subjects; Group III, 35 subjects; Group IV, 53 subjects.

Stimulus-word-lists and apparatus.-- We used a semi-chance device for the selection of both the categories and stimulus-words. The first step in this undertaking was the construction of a table of 20 different categories and 20 words for each category. The requirements for this table were: (a) the categories should be reasonably definitive; (b) all stimulus-words should
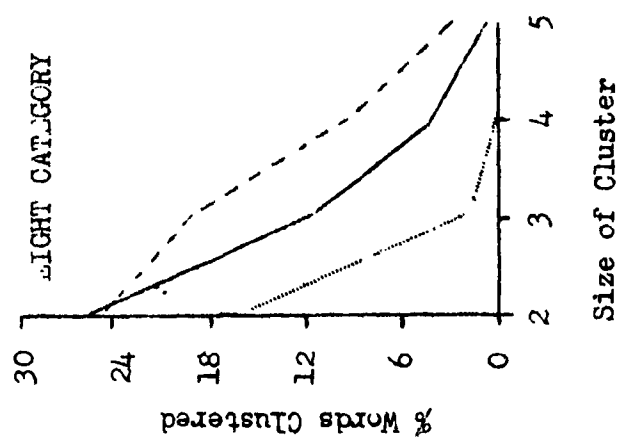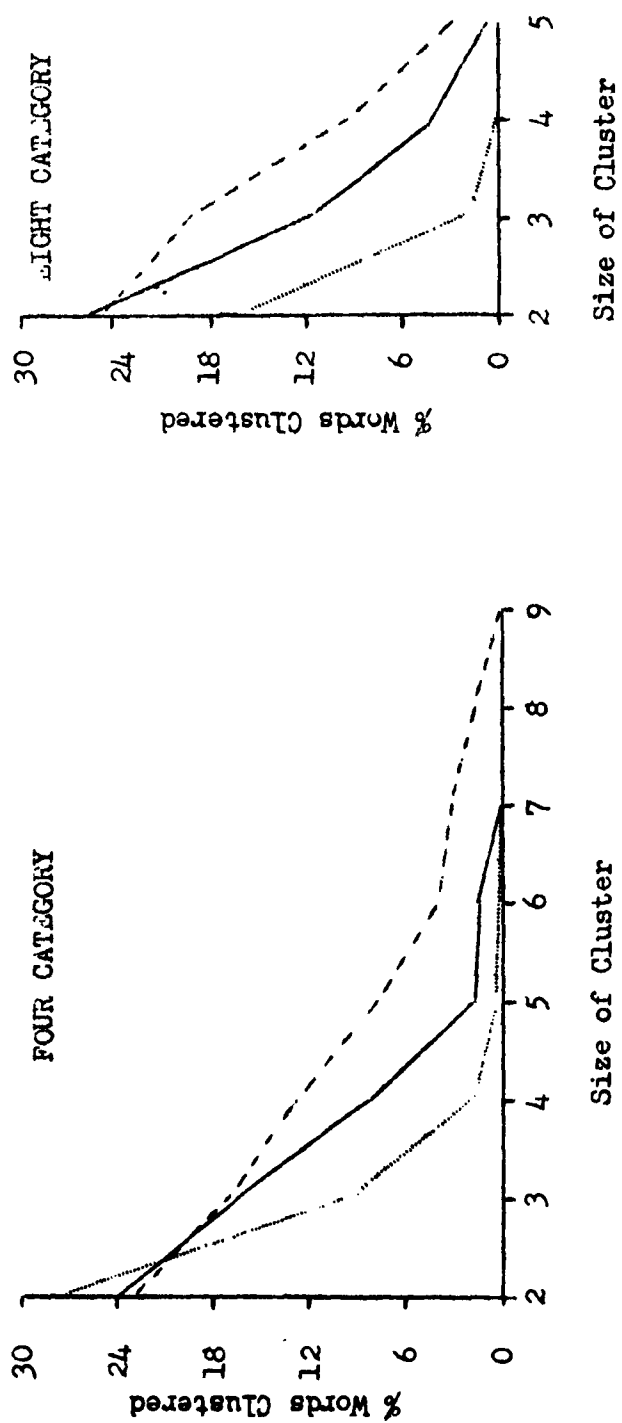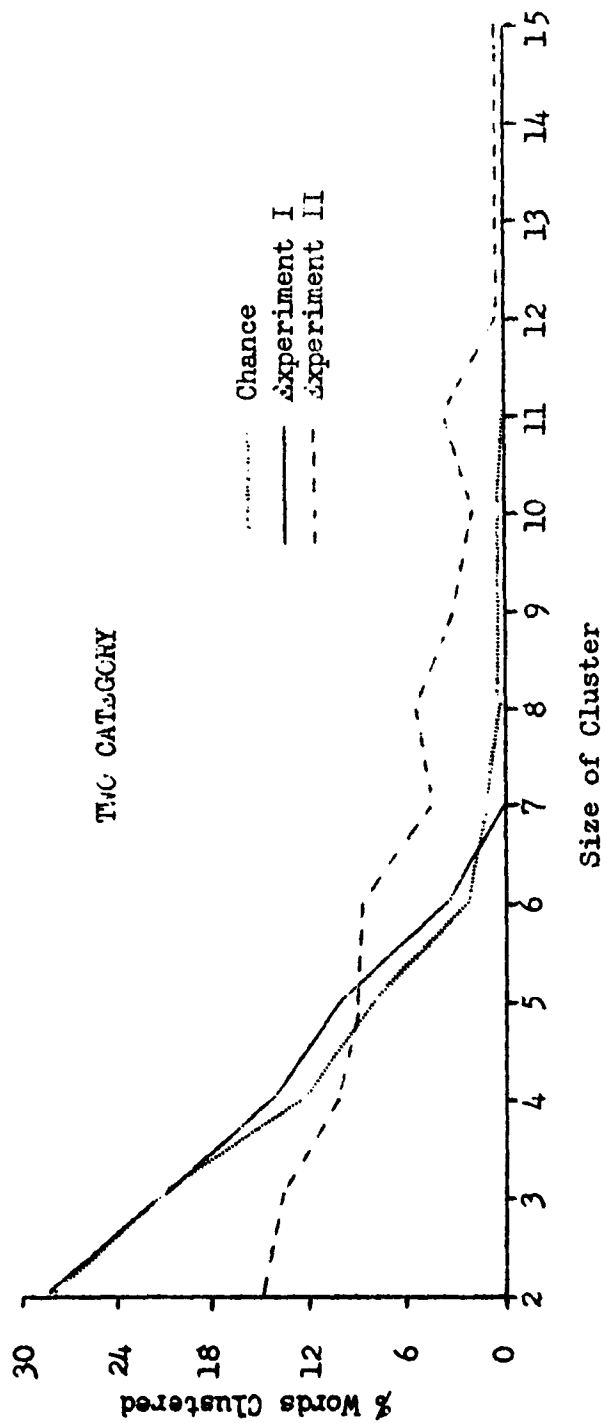
FIGURE 1

PERCENTAGES OF RECALLED WORDS OCCURRING IN
CLUSTERS OF VARYING SIZE

clearly belong to their respective categories; (c) all stimulus-words should have frequencies-of-use given in the Thorndike-Lorge word book. The categories were arranged in the table in the order of the median frequencies-of-use of their corresponding words. These median frequencies ranged from one to 21.5 words per million. The medians were then divided into four consecutive frequency ranges with five categories in each range. Using this table we then randomly selected four categories, one from each frequency range. From lowest to highest frequencies these categories were musical instruments, weapons, animals, and clothing. For each of these four categories we then selected at random 10 words from the corresponding 20-word lists to make up the four-category, 40-word stimulus-list. Two 40-word, two-category lists were then prepared by using all 20 words in each of the categories of the four-category list. List A comprised musical instruments and animals; List B, weapons and clothing. For the eight-category list, we used the four categories already chosen plus four more which were randomly selected, one from each of the four median frequency ranges. These were boats, birds, chemical elements, and countries. The 40 words for these eight categories comprised five selected at random from each of the four 10-word groups of the four-category list, plus five selected at random from each of the 20-word lists corresponding to the four additional categories. The four 40-word lists thus prepared were copied on glass slides. The same projector and data sheets were used as were employed in Experiment I.

Procedure.-- The procedure was similar to that of Experiment I. The subjects in Group I were given the two-category List A; Group II, the two-category List B; Group III, the four-category list; Group IV, the eight-category list.

Results.-- The analysis of the data was similar to that of Experiment I. The results for the two two-category lists showed no significant differences in spite of the fact that different word-categories were used for each list. We therefore combined the data for Groups I and II. Table 1 summarizes the first phase of our analysis. In comparing the two sets of data in Table 1, we may note that as compared with the subjects of the first experiment, those of the second: (a) showed greater recall, but a reverse trend in the relationship between the number of words recalled and the number of categories of the stimulus-lists. (b) showed greater clustering but followed a similar trend in the relationship between clustering and the number of categories of the stimulus-lists. It would thus appear that the trends in clustering are confirmed but not the trends in recall.

Following the same method as was employed in the analysis of the data of Experiment I, we computed the percentages of words occurring in clusters of varying size for each of the three types of stimulus-word-list. These appear in Figure 1. Again, this figure does not show the percentages of unclustered words appearing in recall which were as follows: (a) two-category lists, 16.1%; (b) four-category list, 30.6%; (c) eight-category list, 42.8%. We may suppose that the corresponding percentages to be expected on the basis of chance are the same as were reported for Experiment I. As might be expected from the data of Table 1, the percentages of words falling in clusters of varying size are in general greater for Experiment II

than for Experiment I. Of special interest is the depression below chance for the two-category lists for clusters of two, three, and four items shown by the subjects in Experiment II. The subjects compensated for this depression by giving clusters of larger size.

DISCUSSION

As indicated in the introduction, we have undertaken in the earlier papers (1,2) to develop a theory to account for clustering on the basis of Hebb's conception of the nature of superordinate perceptions. Applying Hebb's schema to our type of situation, we may assume that the superordinate structures corresponding to the categories and the subordinate structures corresponding to the stimulus-words have been developed to a considerable degree prior to the experiment. Both types of structures are reinforced by the presentation of the stimulus-word-lists. An important aspect of this reinforcement is the strengthening of the connections between the superordinates and the particular subordinates which are activated during the learning. The tendency to cluster would thus vary with three factors, namely, the strengths of the superordinate structures, the strengths of the subordinate structures, and the strengths of the connections between the two types of structures. Let us now compare our two-category situation having 20 words in each category with the eight-category situation having five words in each category. The superordinate structures of the former receive considerably more reinforcement, during both learning and recall, than those of the latter. On the basis of this differential in reinforcement we might expect superior clustering for the two-category lists. On the other hand, if a massed type of activation of superordinate structures should result in an impairment of their functions, such an impairment would most likely take place in the case of the two-category lists. If the loss of function is sufficiently extensive, it would be sufficient to account for our results of most significant clustering for the eight-category list and least for the two-category lists. This appears to be the most plausible theoretical explanation of our findings with respect to clustering. We therefore assume that we have obtained evidence for the following hypothesis which we may now state in rather general terms: <u>With</u> <u>sufficient</u> <u>massed</u> <u>activation,</u> <u>a</u> <u>superordinate</u> <u>system</u> <u>tends</u> <u>to</u> <u>show</u> a <u>decrease</u> <u>in</u> <u>its</u> <u>capacity</u> <u>to</u> <u>facilitate</u> <u>the</u> <u>action</u> <u>of</u> <u>its</u> <u>subordinates.</u> The support for this hypothesis derives from the group-trends in both our experiments, showing a positive relationship between total clustering and the number of categories in the stimulus-word-list. It may be noted that in stating our hypothesis we have avoided any specification of the nature of the assumed loss in functional capacity of a superordinate system consequent on massed activation. Various theorists have recognized the consequences of massed activation on habits. Hebb (3) speaks of the possibility of deterioration of the phase sequence and the cell assembly action. Hull (4) has developed the postulate of reactive inhibition. We believe our present data do not provide the cues for such specification.

While the group-trends in clustering are similar, the results of the two experiments differed in several respects. The subjects in the second

experiment, as compared with the first, showed generally superior recall, generally superior clustering, and an inverse relationship between recall and the number of categories in the stimulus-word-lists. Can we give a satisfactory theoretical account of these differences? Our answer to this question is a tentative yes. The subjects of Experiment II had previously been exposed to a study which required the recall of stimulus-words in lists comprising either four or six categories. We can assume that this previous experience resulted in a set in these subjects to look for categories in the stumulus-words. Such a set might be expected to have the effect of a more immediate reinforcement of the superordinate systems. Possibly the set may also have served to some extent to counteract the loss of functional capacity of the superordinate systems resulting from massed activation. As a consequence of one or both of these effects we should expect the subjects of Experiment II to show both generally superior clustering and generally superior recall. Let us now consider the more difficult question of the relationship between recall and the number of categories in the stimulus-word-lists. Our data indicate a positive relationship for Experiment I and a negative relationship for Experiment II. We have attributed the differences in the results of the two experiments to the existence of a type of set in the subjects of Experiment II which was presumably lacking in the subjects of Experiment I. We propose that our data support the important assumption that the potency of set to increase both recall and amount of clustering varies negatively with the number of categories of the stimulus-word-list, i.e., the potency of set varies negatively with the complexity of the categorical structure of the stimulus-word-lists. Thus, because of set, recall for the two-category lists is increased from 14.60 to 25.50 or 75 per cent. For the eight-category list, the increase is from 17.64 to 19.71 or only 12 per cent. These changes are sufficient to account for the reversal in the trends for recall. We also observe that the relative increase in the percentage of significant clustering is greatest for the two-category lists and the least for the eight-category list. The absolute magnitudes of these increases, however, do not alter the similar trends in the relationship between clustering and the number of categories in the stimulus-word-lists for the two experiments.

It is evident that our account of the differences in the results of our two experiments has depended on what appear to us to be plausible assumptions regarding the influences of set. We would submit, however, that these assumptions may be tested by further experimentation.

SUMMARY

This study was designed to investigate the relationship between clustering and the number of categories in 40-word stimulus-lists. Clustering was defined as the tendency to recall the words of a randomized stimulus-word-list in sequences of items belonging to the same category. Two separate experiments were undertaken. A total of 150 subjects served in the first experiment and 160 subjects in the second which was a replication of the first. Three types of stimulus-word-lists were employed. These were a two-category type with 20 words in each category, a four-category type with 10 words in each category, and an eight-category type with five

words in each category. The data of both experiments showed a positive relationship between the extent of clustering beyond chance expectation and the number of categories in the stimulus-word-lists. The following hypothesis was proposed to account for the established relationship between the number of categories and clustering: With sufficient massed activation, a superordinate system tends to show a decrease in its capacity to facilitate the action of its subordinates.

The results are interpreted on the basis of an application of Hebb's account of the development of superordinate perceptions.

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