A "clustering" technique for directly assessing concept learning^{1,2}

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A convergent paired-associate task (having two or more stimuli per response) can be solved via rote learning or concept learning processes. On the basis of assumptions concerning the operation of these processes within a trial, a "clustering" measure is developed which is purported to tap the contribution of rote and concept learning to performance.

The convergent paired-associate task, which involves the learning of two or more stimuli per response, has been regarded as a paradigm task for concept learning (Goss, 1961). The purpose of this paper is to present an internal measure of the use of conceptual cues in learning. First, however, it will be useful to distinguish between "rote" and "concept" learning.

Consider an eight-pair convergent list consisting of eight stimuli and four responses (four stimulus subsets). How does learning in this task proceed? Three possibilities are as follows: (1) by forming a direct association between each stimulus and its response term, (2) by forming an association between some coded representation common to the subset stimuli and their response term, or (3) by a mixture of both kinds of association.

Learning via direct associations will be referred to as *rote learning*, while learning of the second type (via a mediating event) will be referred to as *concept learning*. A *concept* can thereby be defined generally as a mediational mechanism inferred to be operative when it can be determined that a relationship has been established between the subset stimuli other than that provided by the common task response.

Convergent paired-associate lists may vary in the degree of initial relationship between the subset stimuli. Tasks employing lists in which the degree of stimulus relatedness is initially high are usually called "concept attainment" tasks, whereas "concept formation" tasks are usually those employing lists wherein the subset stimuli are related only arbitrarily. On the view advanced here, the mere fact of completed performance on either kind of task does not *eo ipso* indicate a conceptual solution to the task. Rather, performance in either a concept attainment or a concept formation task can reflect *processes* of either rote learning, concept learning, or a mixture of both in varying degrees. That is, some of the learning may reflect grouping of the subset instances, and some may reflect direct associative connections. The measure to be introduced here is designed to reflect the full continuum from complete rote learning to complete concept learning.

A "Clustering" Measure of Conceptual Behavior

For any given list subset, let A and C be two subset stimuli and let B be the response term. The rationale for the technique given below is that if concept learning takes place, then *intralist positive transfer* should result, such that the learning of an A-B pair facilitates the learning of its corresponding C-B pair (cf., Richardson, 1960). That is, if the A and C stimuli are grouped conceptually, they become psychologically similar to each other, and hence the subset becomes an A-B, A'-B positive transfer situation (where A' is similar to A). On the other hand, if rote learning occurs, then *intralist negative transfer* should result, such that the learning of an A-B pair interferes with the associative learning of its C-B pair (due to the backward B-A association; e.g., see review by Martin, 1965). Hence the two processes of rote and concept learning imply totally different within-list transfer characteristics.

The measure to be described will be called a "clustering" measure, as it is purported to get at the degree to which the stimulus instances are grouped or clustered while the learner is attaching to them a common response term. Specifically, the first assumption is that if A and C are grouped conceptually, then they will enter into association with B *at the same time*. . In other words, presentation of A-B will strengthen not only the A-B association, but also its corresponding C-B association, given that C occurs implicitly in conjunction with A. Thus, on the eight-pair list (two stimuli per response) above, on any given trial (one run through the eight pairs), evidence for positive transfer (clustering) is adduced when, given that an A-B pair is correct, its corresponding C-B pair is likewise correct *on the same trial*. For positive transfer, then, subset members must be simultaneously correct more often than would be expected on a chance basis.

The second assumption is that if A and C are *not* grouped conceptually during learning, they will enter into association with B *at different times*. That is, presentation of A-B, while strengthening the A-B association, will serve also to weaken its corresponding C-B association, by virtue of the increased strength of the interfering backward (B-A) association. Thus, on any given trial of the eight-pair list, evidence for negative transfer (or rote learning) is adduced when, given that A-B is correct, its corresponding C-B pair is *not* correct *on the same trial*. That is, the subset members will be correct together less often than expected by chance.

A *cluster*, then, is defined as the event in which there are at least two correct pairs on a trial, both of which

Table 1. Observed and Expected Clustering Scores on Trials of 3, 4, and 5 Correct Responses on an 8-pair List as a Function of Pattern of Correct Responses

	3		Number Correct			5	
	Pattern		Pattern			Pattern	
Convergent							
List	a	b	a	b	c	a	b
S ₁ -R _a	+	+	+	+	+	+	+
S ₂ -R _a	+	-	+	+	-	+	+
S ₃ -R _b	+	+	+	+	+	+	+
S ₄ -R _b	-	-	+	-	-	+	-
S ₅ -R _c	-	+	-	+	+	+	+
S ₆ -R _c	-	-	-	-	-	-	-
S ₇ -R _d	-	-	-	-	+	-	+
S ₈ -R _d	-	-	-	-	-	-	-
Observed Clustering	2	0	4	2	0	4	2
Expected Clustering	0.86	0.86	1.71	1.71	1.71	2.86	2.86

involve members of the same stimulus subset (and, therefore, share a response term). *Observed clustering* will here be defined for a given S on a given trial as the number of correct responses that occur in clusters. Thus, if a S gets two correct pairs, his observed clustering score will either be zero or two for that trial, depending upon whether or not the two correct pairs possess the same or different responses. Table 1 provides further illustrations showing the possible clustering patterns with 3, 4, and 5 correct responses.

Expected clustering is determined for a specified number of correct responses on any trial by calculating the number of correct responses that would occur in clusters, supposing that this specified number of correct responses were distributed randomly over all pairs within the list. In the eight-pair list, for example, if only two were correct on a particular trial, either two or zero correct responses could be due to clustering; that is, those two correct responses either occurred within one of the four subsets or they did not. However, one must take account of the fact that mere random sampling of two events within the four subsets will yield a cluster 1/7 of the time, or, equivalently, 2/7 correct responses due to clustering will occur by chance. It is clear that a measure of expected clustering (here, the number of correct responses on a trial due to ran-

dom clustering) depends only upon the number of correct responses on that trial, the list length, and the number of stimuli per response. In the case of two stimuli per subset, if n is the number correct on a trial of a task employing N pairs, then the number of correct responses due to random clustering on any trial is given by the following formula:⁴

$$\text{Expected Clustering} = \frac{n(n-1)}{N-1}.$$

Hence the number of correct responses attributed to chance clustering for an eight-pair list with 0, 1, 2, 3, 4, 5, 6, 7, and 8 correct are, respectively, 0.00, 0.00, 0.28, 0.86, 1.71, 2.86, 4.28, 6.00, and 8.00.

For each S, one can compute an observed and an expected clustering score for each trial during training, and an average observed and expected clustering score over training trials. Consistent with the above analysis, performance will be considered to be influenced primarily by concept learning when clustering scores reliably exceed chance expectations, and by rote learning when clustering scores are reliably below chance.

Systematic study of the effects of relevant learning variables on clustering behavior in convergent paired-associate tasks may facilitate our understanding of conceptual processes, and their role in paired-associate learning generally.

References

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Notes

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- Thanks are due Professor Slater E. Newman for a critical reading of the manuscript.
- Now at the University of California, Irvine, California.
- When there are 3 stimuli per response ($S:R = 3:1$), the formula for expected clustering is $[n(n-1)/(N-1)] [(2N-2-n)/(N-2)]$. Tables for $S:R = 2:1, 3:1, \dots 10:1$ of lists up to length 20 are available from the author. When $S:R$ is greater than 2:1, then all sizes of clusters possible are considered in the measure (e.g., when $S:R = 3:1$, clusters of size 2 still contribute to the clustering score).