but the proportion of intrusion errors was significantly greater for the imagery group at the 5-week recall ($p < .001$). These data indicate a difference in retrieval processes between the two conditions. Failures in recall in the control group were basically omissions. This also occurred at the 1-week recall for the imagery group, but at the 5-week recall the proportion of intrusion errors and omission errors was about the same for the imagery group. Further, the type of intrusion errors in the imagery group was similar to the semantic errors reported by Brown & McNeill (1966). Of the 16 intrusion errors that occurred at the 5-week recall in the imagery condition, 9 were classified as related to the correct word on a semantic basis by two judges, for example, "dollar-money" and "troop-army." Only one of nine errors at the 5-week recall showed this relationship in the control group.

Table 2
Type of Errors in Total List Recall After 1 and 5 Weeks

	1-Week Recall		5-Week Recall	
Condition	Intrusions	Omissions	Intrusions	Omissions
Imagery	4	23	16	19
Control	8	115	9	169

DISCUSSION

The present experiment shows that the method of loci facilitates the accessibility and the ordering of high image-evoking items in comparison to the control group. Although there was no significant difference in the number of items available between groups, as measured with the recognition memory test, the ceiling effect, created by the extremely high recognition of items in both groups, prevents a firm conclusion with regard to the question of imagery techniques making traces available over longer time periods than conventional techniques.

There appears to be two reasonable explanations for the difference in the accessibility of items between the two learning techniques. The first is simply that learning concrete words by forming compound images with prior learned cue images or "conceptual pegs," as Paivio (1969) calls them, is very efficient in terms of encoding and decoding. Another possibility is that the imposition of learning by order in both conditions placed a more serious constraint on the control group. The particular arrangement of response words should be of little importance with the method of loci, since the words are being learned in relation to their cue images, not in relation to each other. The control group, however, basically learned the words by grouping them together. In this situation the words themselves had to serve as cues for the recall of further words. However, the imposition of order in learning the words prevented the Ss from forming the type of subjective categories which has been shown to be a very effective method of recalling large numbers of words (Mandler, 1967) and left them with groups of words to recall, most of which probably were not meaningfully interrelated. The effect of this may have been to leave the control Ss with no efficient means to search for all the items which were still in store, as shown by the recognition memory task.

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Clustering in free recall following verbal-discrimination learning*

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Clustering in free recall following verbal-discrimination learning was assessed for two possible classifications: pairs vs right-wrong functions. There was considerable pairwise clustering in free recall in two different studies. This outcome does not follow directly from frequency theory or other explanations of verbal-discrimination learning which assume acquired equivalence by function; it may, however, indicate the effect of an intrapair association on the subsequent free recall organization.

The verbal-discrimination (VD) task typically presents the S with several pairs of items, and the S's task is to learn to recognize which member of each pair is correct. A recent explanation of how VD learning occurs has assumed that the subjective frequency of experience for each member of each pair eventually becomes different (Ekstrand, Wallace, & Underwood, 1966). Frequency theory assumes that the S's rehearsal of the R terms (right terms) during feedback eventually provides the S with a cue to distinguish the R terms from W terms (wrong terms). Since the R terms will have been more frequently experienced due to

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rehearsal, the S need only use a "rule" to be correct: choose the most frequently experienced word in each pair. The frequency discrimination thus provides the S with a consistent cue for the recognition of the R terms. Typical tests have involved intralist word associations (e.g., Eberlein & Raskin, 1968), interlist transfer of associations (e.g., Raskin et al, 1968), or the number of alternatives (e.g., Radtke & Foxman, 1969). While many tests have been favorable toward frequency theory, some have not (e.g., Eschenbrenner, 1969; Kausler & Boka, 1968).

The present experiment is to examine an implication of frequency theory with regard to the particular "memory unit" which develops during VD acquisition. Transfer from paired associates to free recall (FR) has provided useful information about the mechanisms involved in paired-associate acquisition (e.g., Runquist, 1970; Wood, 1969). Transfer to FR would yield clustering measures which also seem quite pertinent to a complete understanding of VD learning, although specific predictions are not found in the statement of frequency theory (Ekstrand et al, 1966). Elsewhere, Paul (1970) has proposed that Ss are engaged in a classification task in VD learning, with the items acquiring one of two common labels by function. The labels of "is right" and "is wrong" become attached to the words and provide facilitating links in transfer tests. This explanation might expect a great deal of clustering on the basis of right-wrong categories in a subsequent FR task and very little organization based on pairs. Since frequency theory also implies a specific dichotomy between R and W terms, more so than between pairs perhaps, then the same expectation seems to follow.

One other mechanism has also been considered in the explanation of VD performance, namely, the development of an intrapair association. While the generality and operation of this association during VD acquisition remains to be firmly established, it is known that it can serve as the functional stimulus in situations where frequency cannot, e.g., the double-function list (Kausler & Boka, 1968). To the extent that association is involved, that mechanism would indicate that the pairs are the higher order memory units and not the grouping by R and W terms suggested by frequency theory and Paul (1970).

The present study is a simple test of these somewhat opposing views, with the magnitude of clustering in alternative scorings of the same data as the crucial dependent variable. Tentative evidence on this issue was found as an incidental outcome in a recent study involving taxonomic categories in the VD-list words (Kausler, Erber, & Olson, 1970), although the present study will emphasize "unrelated" words.

SUBJECTS

Sixteen introductory psychology students served as Ss in partial fulfillment of course requirements. None had previously participated in human learning experiments.

MATERIALS

The 16-pair VD list was constructed from 32 unrelated words chosen from the control list of Ekstrand et al (p. 572). The pairs were arranged in four different orders for VD presentation, with the R terms at the top and bottom of the slides twice over the four trials and at the top and bottom equally within each trial.

PROCEDURE

The Ss were tested as a single group, with four VD trials followed by four FR trials. For the four VD trials, the pairs were shown on a large screen at a 2-sec rate for study. At the end of each study phase, the Ss were directed to booklets on their desks where the 16 pairs were listed. The Ss were allowed 45 sec to circle the R term in each pair and were encouraged to guess. The pairs were arranged in four different orderings on the sheets, so that each word appeared on the left in each pair twice and in a different upper or lower position each time. These four sheets were balanced across Ss as the first through fourth sheets. While this procedure is somewhat atypical for VD, evidence will be offered that the same phenomena result with more conventional VD procedures.

Immediately following the fourth VD trial, the Ss were told to turn to the first lined page in their booklets and to write as many of the 32 words as they could remember, in any order. The Ss were allowed 90 sec for this phase, which will be referred to as the first FR trial.

Trials 2-4 of FR involved the presentation of the 32 words singly at a 2-sec rate, followed by 90 sec of written recall. The words were arranged in three different orders of presentation for these trials, subject to the restrictions that R and W terms alternate throughout and members of a VD pair be separated by at least three other words.

Since the present VD procedure was somewhat atypical, the data from another experiment were reanalyzed, and brief details about that method must be noted. Fulkerson & Kausler (1969) considered three different types of lists, with 12 pairs each and 20 Ss per list. Their unrelated list was comparable to the present list, except for length and method of presentation. Their "intrapair" list involved associated words as pair members, e.g., table-chair as a pair. Their third list involved "interpair" associates, with one member correct and its associate wrong in another pair.

Thus, the essential differences were that their Ss learned to two consecutive perfect trials by anticipation, instead of the group study-test method for a fixed number of trials, and there was only a single unpaced FR trial, instead of repeated paced FR trials. Except for pacing, the present first FR trial is most comparable to their data. Further details may be obtained from their report.

RESULTS AND DISCUSSION

The FR protocols were scored in two ways, with the R and W terms considered as two categories once (16 or 12 instances of each) and with the pairs classified as the categories once (2 instances for each of 16 or 12 categories). Each S's deviation from chance clustering was divided by the standard deviation, as suggested by Hudson & Dunn (1969). Such a transformation to standard scores is desirable when lists of different lengths are to be compared or when lists of the same length which differ in the number of categories are to be compared. Since different studies are compared here and since the lists in all cases were physically the same for the two scorings, the transformation seemed advisable.

The two clustering scores are shown by trial for the data from the present study in Table 1. Related t tests comparing these two scores by trial revealed that there was a significant difference between the amount of the two clustering scores, $ts(15) > 5.4$, with more clustering by pairs than by R-W functioning and with no apparent change in this trend over the four trials.

Because these results may be specific to the present methods, the data from Fulkerson & Kausler (1969) are shown in Table 2 for similar scorings. The list with no associates revealed the same trends, with pairwise clustering most apparent. It should be noted that the intrapair associate group would yield the pairwise clustering anyhow, and it did show the most. The interpair associate group might be expected to show little of either type of clustering, with the associates interfering with both pairwise and function clustering. This was not the case, with this group showing as much pairwise clustering as the unrelated group, demonstrating that the pairwise presentation was effective even in the presence of other

Table 1
The Clustering Score for Right-Wrong Categorization and Pairwise Categorization for Each Free Recall Trial

	Trials			
Measure	1	2	3	4
Right-Wrong	—0.1	—0.3	—0.3	—0.3
Pairwise	1.0	0.9	1.0	0.8

possible schemes for organization. A 3 by 2 (groups, cluster scoring) mixed analysis of variance revealed that both main effects were significant, Fs = 29.49 and 199.29, dfs = 2/57 and 1/57, as was the interaction, F = 22.34, df = 2/57, all ps < .001.

Considering the numerous procedural differences, these data indicate that VD learning produces higher order memory units based on the pairs rather than differences in frequency or acquired equivalence by function. If the intrapair association is involved in such organization, the association should be somewhat a function of the degree of VD learning, with a resultant effect upon the extent of pairwise clustering. The correlation coefficients between the various combinations of VD and FR acquisition (number correct) and the clustering scores are shown in Table 3. Performance in VD was only slightly correlated with right-wrong (RW) clustering in both studies. While the degree of positive correlation for VD performance and pairwise (P) clustering varied between the two studies, it was substantial for the present data. The difference in magnitude for this correlation may seem to reflect degree-of-learning differences which result for fixed trials vs learning to a criterion, with the result that pairwise clustering was inversely related to degree of VD learning. Since the trials to criterion were available for the Fulkerson-Kausler study, further correlations were run between VD trials to criterion and the FR measures, but this likewise failed to reveal a correlation with degree of learning (rs < .11).

Any conclusion on this latter problem must be tentative because the unlimited time for recall in the Fulkerson-Kausler study may have allowed their Ss to apply quite different retrieval schemes. Moreover, the lack of an apparent influence on FR performance as a function of VD practice is not new and need not deny the operation of the association as the basis for pairwise clustering. Zechmeister & Underwood (1969) found no effect for degree of VD learning on subsequent FR, although there was an increase in associative matching with more VD practice, to suggest that the degree of VD learning may strengthen the R-W association without that change being manifest in the molar FR performance. While neither clustering nor FR varied here as a function of a variable which generally influences associative strength, association of R terms with W terms seems the most likely mechanism.

The present data indicate that whether or not frequency was used as the cue during VD learning and whether or not the Ss were tagging R terms with one label and W terms with another label, those processes seemed not to affect subsequent FR clustering in the manner which might be expected by extrapolation of those views. Instead, the pairwise presentation in VD learning seemed to be the most potent determinant of FR organization and proficiency.

Table 2
Clustering Scores by Intralist Associative Condition for the Data from Fulkerson & Kausler (1969)

	Associative Condition		
Scoring	Unrelated	Intrapair	Interpair
Right-Wrong	—0.13	—0.42	—0.35
Pairwise	0.57	1.57	0.57

Table 3
Correlations Between Verbal Discrimination and Free Recall Performance and the Free Recall Clustering Scores

	Trials in Present Study				Fulkerson and Kausler Groups		
Measures	One	Two	Three	Four	Unrelated	Intrapair	Interpair
VD-FR	0.36	0.49*	0.63*	0.43*	0.07	—0.10	0.01
VD-RW	—0.08	—0.14	—0.08	0.05	0.06	—0.33	—0.15
VD-P	0.37	0.54*	0.35	0.42*	0.14	—0.28	—0.14
FR-RW	0.12	—0.12	—0.24	—0.21	—0.42*	—0.84*	—0.48*
FR-P	0.78*	0.25	0.48*	0.15	0.82*	0.21	0.35

*$p < .05$.

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