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ASSOCIATIVE INTRUSIONS IN SHORT-TERM RECALL [1]

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30 MIT undergraduates listened to a list of 9 letters presented at the rate of 4 letters per second and then attempted to recall the letters in order. Some lists contained repeated letters, and some did not. The letters following repeated letters tended to be substituted for each other in recall, by comparison to the frequency of confusing letters in the same positions of lists without repeated letters. Such substitutions were called "associative intrusions," and the associative-intrusion phenomenon was observed whether the repeated letters occurred at the beginning or the middle of the list, whether 1 or 2 items separated the repeated letters, and whether the items following the repeated items did or did not have a vowel phoneme in common. The results were interpreted as supporting an associative theory of short-term memory.

Evidence for the importance of serial position-to-item associations in short-term serial learning has been obtained by Conrad (1959, 1960), who demonstrated that there is a significant tendency for an intrusion to be the item that occurred in the same position in a prior list.

The most direct evidence for the existence of item-to-item associations in short-term serial learning was an incidental finding of a study comparing memory for lists with and without repeated digits (Wickelgren, 1965b). In lists such as "8 3 9 1 9 5 7 . . . ," that have separated repeated digits, the digits following the repeated digits tend to be substituted for each other in recall. In the example just cited, "1" would tend to be substituted for "5" in recall and vice versa. We shall refer to these types of errors as "associative intrusions."

Associative intrusions are most easily explained by assuming that associations are strengthened between the internal representatives of temporally adjacent items and that there is only one internal representative of an item regardless of how many times it is presented in a list. Competition of A-B and A-C associations accounts for associative intrusions, while items prior to A and serial position serve as differentiating cues that make correct responses much more frequent than associative intrusions.

The primary purpose of the present study is to replicate the associative-intrusion phenomenon in the forward direction and determine if the effect is significant in the backward direction. Associative intrusions in the backward direction are confusions in recall of the items preceding repeated items. If *S*s always recalled in a strict left-to-right order there would be no reason to expect associative intrusions in the backward direction. However, there is no way to guarantee this order of recall by *S*, and in the present experiment no attempt was made to guarantee this order of writing the items on paper. Thus, it would not be surprising to find associative intrusions in the backward direction.

The secondary purpose is to test the generality of the associative-intrusion phenomenon over a variety of experi-

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mental conditions. The conditions are: (*a*) the position of the repeated items in the list (beginning or middle); (*b*) the number of items separating the repeated items (one or two); and (*c*) the phonemic similarity of the items following the repeated items (similar or not similar).

According to the associative-memory explanation of the phenomenon, one would expect to find associative intrusions under all of these conditions and, without a quantitative model, one could not predict that the effect would be greater under one of these conditions than under another. On the other hand, if the effect depends on strategies connected with the recognition of repetition, then the phenomenon should be stronger for repeated items at the beginning, rather than the middle, of the list and stronger for repeated items separated by one, rather than two, items. The reason for this is that the recognition of repetition appears to be poorer in the middle of the list and poorer the more items separate the repeated items (Wickelgren, 1965b).

Finally, it has been repeatedly demonstrated that intrusions in short-term recall tend to have a phoneme in common with the correct item. It may be necessary for the items following repeated items to have a common phoneme in order to obtain above-chance substitution of one for the other. If this were so, then the explanation of the effect in terms of association to a common item would not be so plausible. Rather one would prefer an explanation in terms of the tendency to make a similar error, which combines with the presence of a nearby similar item, to greatly enhance the probability of the nearby item intruding in recall. The previous study was not systematically confounded by this factor. Also, digits show virtually no systematic substitution errors in recall (Conrad, 1959; Wickelgren, 1965a). Nevertheless, digits do have common phonemes, slight similarity effects could summate in a very nonlinear fashion with the presence of a nearby item, and the previous findings were based on a relatively small number of different lists. Thus, it would be interesting to compare the magnitude of the effects for phonemically different items following the repeated items. This is best achieved, not with digits, but with letters, where large phonemic similarity effects on intrusions are obtained (Conrad, 1964; Wickelgren, 1965a).

Method

Procedure.—The *S*s listened to a list of nine letters presented at the rate of approximately four letters per second and then had 15 sec. in which to attempt to recall the letters in the correct order by filling in nine boxes on their answer sheet. The next trial followed immediately after the 15-sec. recall period. Each list contained two /ē/ letters (B, C, D, E, G, P, T, V, Z), two /ĕ/ letters (F, L, M, N, S, X), two /ā/ letters (A, H, J, K), two /ū/ letters (U, Q, W), and one /ī/ letter (I, Y). The experiment was recorded on tape and lasted about 40 min.

Design.—There were nine different types of lists, eight types with repeated items and one type with no repeated items. The eight types with repeated items were all the combinations of two places for the repeated items (beginning or middle of the list), two degrees of separation of the two occurrences of the repeated item (one or two intervening items), and two types of items following the two occurrences of the repeated item (phonemically similar or dissimilar items). Phonemically similar items were letters with a common vowel phoneme, /ē/, /ĕ/, /ā/, or /ū/. When the repeated items were in the middle of the list and separated by one item, the repeated items were in Positions 4 and 6 of the list. When the repeated items were in the middle of the list and separated by two items, the repeated items were in Positions 3 and 6. When an item was repeated, it used up both occurrences of its voweltype of letter, i.e., if the repeated letter was "B," there was no other /ē/ letter in the list. The nine different types of lists, with a brief

TABLE 1

Repetition Patterns of Lists Used in Experiment

Name	Description	Example
AD	All-different lists (no repeated letters)	BLVKNUIQH
$(iji\tilde{j})_B$	Repeated letters separated by one at beginning of list phonemically similar letters following repeated letters	DHDKQYMSW
$(ijik)_B$	Repeated letters separated by one at beginning of list phonemically different letters following repeated letters	SQSAVWJBI
$(iji\tilde{j})_M$	Repeated letters separated by one in middle of list phonemically similar letters following repeated letters	VUWASAFIT
$(ijik)_M$	Repeated letters separated by one in middle of list phonemically different letters following repeated letters	HNWCSCAIU
$(ijli\tilde{j})_B$	Repeated letters separated by two at beginning of list phonemically similar letters following repeated letters	JSVJFGYQU
$(ijlik)_B$	Repeated letters separated by two at beginning of list phonemically different letters following repeated letters	KPWKLXQIT
$(ijli\tilde{j})_M$	Repeated letters separated by two in middle of list phonemically similar letters following repeated letters	WQFKGFHIP
$(ijlik)_M$	Repeated letters separated by two in middle of list phonemically different letters following repeated letters	NQTHUTSJY

Note.—Sim = $(iji\tilde{j})_B + (iji\tilde{j})_M + (ijli\tilde{j})_B + (ijli\tilde{j})_M$; Diff = $(ijik)_B + (ijik)_M + (ijlik)_B + (ijlik)_M$; B Sim = $(iji\tilde{j})_B + (ijli\tilde{j})_B$; B Diff = $(ijik)_B + (ijlik)_B$; M Sim = $(iji\tilde{j})_M + (ijli\tilde{j})_M$; M Diff = $(ijik)_M + (ijlik)_M$; 1 Sim = $(iji\tilde{j})_B + (iji\tilde{j})_M$; 1 Diff = $(ijik)_B + (ijik)_M$; 2 Sim = $(ijli\tilde{j})_B + (ijli\tilde{j})_M$; 2 Diff = $(ijlik)_B + (ijlik)_M$. M 1 = $(iji\tilde{j})_M + (ijik)_M$; M 2 = $(ijli\tilde{j})_M + (ijlik)_M$.

name for each and an example of each, are shown in Table 1. Table 1 gives names for various combinations of these list types.

The eight types of lists with repeated items occurred three times each in a block of 30 trials (once with the repeated letter being an /ē/ letter, once being an /ĕ/ letter, and once being an /ā/ letter). Lists without repeated items, all-different lists, occurred six times in a block of 30 lists. There were four blocks of 30 lists in the session, or 120 trials altogether. The 120 trials followed one after another with no extra time between blocks, so *S*s had no knowledge of the block structure of the experiment.

Subjects.—The *S*s were 30 Massachusetts Institute of Technology undergraduates taking psychology courses. They participated in the experiment as part of their course requirements.

Results

Associative intrusions are only predicted following or preceding correctly recalled repeated items. Thus, only cases where the repeated item was correctly recalled were scored for intrusions in the following or preceding position. The frequency with which these intrusions were associative, as opposed to nonassociative (some other incorrect letter), is shown in Table 2. For example, slightly over 23% of the 115 intrusions occurring after (correctly recalled) repeated letters in $(iji\tilde{j})_B$ were associative intrusions. That is, 23% of the intrusions were $\tilde{j}$ for j in the second position or j for $\tilde{j}$ in the fourth position.

To establish the associative intrusion phenomenon, we need to determine whether the frequency of associative intrusions is greater than would be expected because of the presence of

TABLE 2

Relative Frequency of Associative vs. Nonassociative Forward and Backward Intrusions

List Type	Associative Intrusions (%)	N	All-Different Control Intrusions (%)	N	Difference
Forward Instrusions					
$(iji\bar{j})_B$	23+	115	23	47	+0
$(ijik)_B$	16	134	8	226	+8
$(iji\bar{j})_M$	24	111	5	43	+19*
$(ijik)_M$	24	115	13	126	+11*
$(ijli\bar{j})_B$	33	118	24	38	+9
$(ijlik)_B$	23	106	6	183	+17***
$(ijli\bar{j})_M$	16	91	6	18	+10
$(ijlik)_M$	9	99	7	212	+2
Sim	25	435	16	146	+9**
Diff	18	454	8	747	+10**
B Sim	28	233	24	85	+4
B Diff	19	240	7	409	+12**
M Sim	21	202	5	61	+16*
M Diff	17	214	9	338	+8
1 Sim	24	226	14	90	+10**
1 Diff	20	249	10	352	+10*
2 Sim	26	209	18	56	+8
2 Diff	16	205	7	395	+9**
Backward Intrusions					
M 1	16	147	11	114	+5
M 2	17	99	7	125	+10*

* $p < .05$.
** $p < .01$.
*** $p < .001$.

the two letters in close proximity in the same list. To do this, it is necessary to compare the frequency of associative intrusions to the frequency of confusing letters in the same positions of lists containing no repeated letters (all-different lists). The frequency of such intrusions in the control all-different lists (following correctly recalled prior or subsequent letters) is also shown in Table 2. The control frequency for each type of list and each type of associative intrusion (forward or backward) is obtained by scoring the all-different lists exactly as the list-type containing the repeated letters was scored. Also, in lists where the repeated letters were followed by phonemically similar letters, only those control all-different lists were scored where the comparable intrusion errors were phonemically similar. When the associative intrusions were phonemically different, only those control all-different lists were scored where the comparable intrusions were phonemically different.

In the backward direction no attempt was made to manipulate similarity systematically, so cases where the prior items were similar or different are lumped together. "Similar" and "different" are always kept separate in the totals in Table 2 for intrusions in the forward direction because intrusions tend to be similar to the correct item, and the frequency with which similar items followed repeated items was greater than the frequency with which similar items appeared in the same positions of all-different lists. This was not true in the backward direction.

The relative frequencies of associative and control intrusions were determined for each *S*, and the significance level of the differences in relative frequency between associative and control intrusions was determined by the Wilcoxon matched-pairs signed-ranks test. Since the direction of the difference was definitely expected in advance and all differences were in the expected (positive) direction, one-tailed tests were used. These significance levels are shown in Table 2 next to the difference in the average relative frequencies of associative and control intrusions for lists of each type.

In the forward direction, all eight list-types show a greater frequency of associative intrusions than comparable confusions in all-different lists, and three of the differences are significant. In the backward direction, both list-types show a greater frequency of associative intrusions than comparable confusions in all-different lists, and one of these differences is significant.

When the total number of intrusions is increased by combining conditions in the totals shown in Table 2, 7 out of 10 comparisons are significant and all are in the expected direction. The closest it is possible to come to an overall test of statistical significance is provided by the total Sim and the total Diff, both significant at beyond the .01 level.

There do not appear to be any consistent differences in the magnitude of the associative intrusion phenomenon over the different conditions. Furthermore, there is no practice effect on the relative frequency of associative intrusions as measured by computing the difference between associative intrusions and controls for similar and different conditions (Total Sim and Total Diff) separately for each of the four blocks in the experiment. For Blocks 1–4, respectively, the differences in percent for Total Sim are: −1, +5, +5, +21 and for Total Diff are: +13, +16, +2, +9.

Discussion

The associative intrusion phenomenon has been replicated, and it appears to hold under all of the conditions of the present experiment. These results are completely consistent with the theory that short-term associations are formed (more properly, strengthened) between adjacent items in a serial list. This associative theory of short-term memory is illustrated in Fig. 1, which shows the internal representatives of items as labeled circles and the internal representatives of temporal order as arrows standing for the direct forward associations between the internal representatives of items. Notice that although "9" is presented twice, there is only one internal representative of "9," which is simply activated twice and which has, therefore, two direct forward associates. Remote associations and serial position-to-item associations have been omitted from Fig. 1. Thus, it is not correct to conclude that associative intrusions should be as frequent as correct responses following correct recall of "9." However, because of the repetition of "9," there should be a greater frequency of substituting "1" for "5" and "5" for "1" in this list than in a list where there was no repeated item.

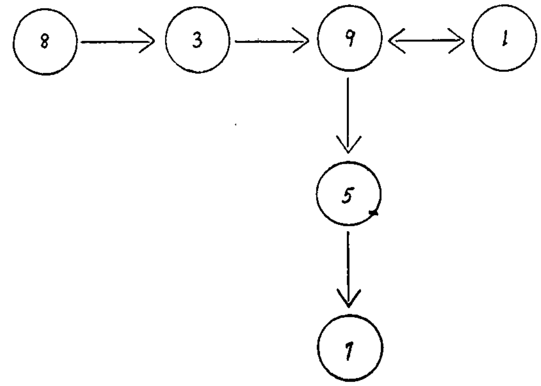

FIG. 1. Illustration of associative theory of memory for 8 3 9 1 9 5 7.

A nonassociative memory is one in which successive items are stored in an ordered set of cells (boxes, locations, registers, etc.) and an item can be stored in more than one cell. Such a nonassociative memory is illustrated in Fig. 2. The internal representative of an item is a pattern stored in a cell. The internal representative of temporal order is the *fixed* ordering of cells. It is particularly important to note that, since any item can be stored in the "first" cell or the "second" cell, etc., a repeated item can be stored in more than one cell. In retrieval *S* reads out the contents of each cell, starting with the "first" cell and proceeding in order to the end of the list. Errors are due to decay of the pattern in each cell and to errors in the order of storing in or reading out of cells. So long as the errors in storage or retrieval

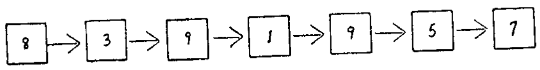

FIG. 2. Illustration of nonassociative theory of memory for 8 3 9 1 9 5 7.

ordering of cells do not depend upon the contents of a cell, there is no reason to expect associative intrusions with such a nonassociative short-term memory. Finding associative intrusions is rather strong evidence against such a nonassociative theory of short-term memory.

Nevertheless, it is logically possible for a nonassociative memory to produce associative intrusions, provided we make a number of additional assumptions, many of which have no plausibility on other grounds. For example, assume that read-out is nondestructive, that is, the pattern in a cell is not destroyed when its contents are scanned in recall. Second, assume that the act of writing the item on paper requires the scanning mechanism to lose the information as to which cell ("first," "second," etc.) was last scanned. Third, assume that the information as to the contents of the cell last scanned is not lost, but is available to the scanning mechanism as it tries to find the next cell to scan. What the system might do under these circumstances is to look for a cell with the same contents as the one last scanned, then scan the "next" cell in the fixed order. Such a system will produce associative intrusions, though additional ad hoc assumptions are required in order to explain why the system does not make associative intrusions as often as correct responses following repeated items.

All in all, the nonassociative explanations of associative intrusions are extremely inelegant, while the associative explanation is simple and plausible. Thus, it seems likely that the prior item is an important cue in short-term memory for serial lists and that there is only one internal representative of an item no matter how many times it is presented.

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