Transfer of serial information from short-term memory to long-term memory: Toward the locus of the repetition effect*

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Using a modification of Hebb's paradigm, a series of 12 digits recurred on every third trial with previously recalled digits and previously missed digits either repeated or changed. The results implied that the transfer of serial information from short-term memory to long-term memory is all-or-none rather than continuous: Changing vs repeating previously missed digits had no effect; the repetition of previously recalled digits was necessary and sufficient to increase recall.

Current models of human memory (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965) emphasize the transfer of information from short-term memory (STM) to long-term memory (LTM). Theoretically, the beneficial effect of repetition upon learning is directly related to the process of STM-LTM transfer. The present study focused on the nature of this STM-LTM transfer: Is it continuous (analogous to a television camera copying information) or all-or-none (analogous to a snapshot camera copying information)?

Hebb's (1961) paradigm, a variation of the basic test for the span of immediate memory, concentrates on the STM-LTM transfer of serial information. A string of digits is presented, and the S immediately serially recalls as many digits as he can. Then a new digit string is presented, the S recalls it, and so on. However, undisclosed to the S, every third digit string (i.e., third, sixth, ninth, . . .) is the same—this recurring string is designated the "critical" string—while the remaining "filler" strings comprise new random orders of digits. Hebb's results showed that the recall of the critical string increased significantly over trials.

Previous research on STM has shown that (1) items are forgotten from STM within 30 sec after rehearsal ceases (Peterson & Peterson, 1959), and (2) forgetting from STM is all-or-none rather than decremental (Nelson & Batchelder, 1969). Since a filled interval in excess of the 30-sec limit—presentation and recall of two filler strings—intervenes between successive repetitions of the critical string, the increased recall in Hebb's paradigm cannot be coming from STM. Instead, information from the critical string presumably transfers from STM to LTM during each repetition of that string; benefits accrue because information about the critical string accumulates in LTM. Thus, the increased recall is a joint function of the information building up in LTM and the relatively constant amount of information in STM (cf. Atkinson & Shiffrin, 1968). Within this framework, the question about continuous vs all-or-none STM-LTM transfer can be examined by rephrasing it as follows: When an item has entered STM and will shortly thereafter be forgotten, does partial information about that item transfer into LTM—leaving some traces in LTM that are below the recall threshold but capable of being built upon—or does information from STM transfer into LTM either completely (remembered items) or not at all (forgotten items)? If STM-LTM transfer is continuous, then repetition benefits should accrue from *both* forgotten items and remembered items. If STM-LTM transfer is all-or-none, then only remembered items should produce repetition benefits. Notice that the "all" in "all-or-none" concerns the amount of information in STM which could be transferred into LTM rather than to the much greater amount of information about the item that LTM could potentially hold. That is, according to an all-or-none theory of STM-LTM transfer, the overlearning of a single item is assumed to be the result of multiple complete traces, each of which transferred in toto from STM to LTM (cf. Bower, 1967).

Prior research (Nelson & Batchelder, 1969) has shown that the level of analysis is important when the continuous vs all-or-none issue is examined. One could potentially analyze the Hebb paradigm either at the component level (examining individual digits) or at the multicomponent level (examining entire digit strings). However, even if the underlying process of an individual component were all-or-none, an analysis at the multicomponent level would not yield all-or-none results because the multiple all-or-none component processes would average together. Therefore, the present study investigated the STM-LTM transfer process at the level of the individual digit rather than at the level of the entire digit string.

METHOD

Four groups of University of Illinois undergraduates (39 Ss per group) differed in terms of the digit string that recurred on critical trials. There were two between-Ss factors in the design. Digits recalled successfully (s) on the previous critical trial were either repeated (R) or changed (C) prior to presentation on the next critical trial; digits missed (m) on the previous critical trial were either repeated (R) or changed (C) prior to presentation on the next critical trial (cf. Rock, 1957). This yielded the following four groups: RsRm, RsCm, CsRm, and CsCm, where the first uppercase letter indicates whether successfully recalled digits from Critical Trial N were repeated or changed on Critical Trial N + 1; the second uppercase letter indicates whether missed digits from Critical Trial N were repeated or changed on Critical Trial N + 1. For example, suppose that on Critical Trial N the four-digit string "4791" is presented and the response is "4733" (first two digits are successfully recalled; last two are missed). Then the string presented to each group on Critical Trial N + 1 might be: "4791" for RsRm; "4726" for RsCm; "8591" for CsRm; "8526" for CsCm. If STM-LTM transfer occurs in all-or-none snapshot fashion, then the expectation in terms of digits correctly recalled over all critical trials is (1) RsRm = RsCm, and (2) CsRm = CsCm (i.e., repeating vs changing previously missed digits has no effect). If STM-LTM transfer is continuous so that forgotten digits leave partial traces in LTM, then the expectation is (1) RsRm > RsCm, and (2) CsRm > CsCm (i.e., repeating previously missed digits is superior to changing them). In either case, the overall expectation is (RsRm + RsCm) > (CsRm + CsCm)—repeating previously recalled digits is superior to changing them.

The stimuli were 12-digit strings generated randomly from the pool of Digits 1-9 with the following restrictions: No digit appeared twice in succession and no two digits appeared in their natural order (e.g., "582" but

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Table 1
Mean Number of Correct Responses on All Critical Trials as a Function of Repeating or Changing on Trial N + 1 Those Digits Successfully Recalled or Missed on Trial N

Successfully Recalled on Trial N	Missed on Trial N: Repeated on Trial N + 1	Missed on Trial N: Changed on Trial N + 1	Mean
Repeated on Trial N + 1	72.38[a]	68.85[b]	70.62
Changed on Trial N + 1	53.54[c]	55.59[d]	54.56
Mean	62.96	62.22	

Note—MSE = 432.6
[a]RsRm, [b]RsCm, [c]CsRm, [d]CsCm

not "589"). Each S saw and recalled 36 12-digit strings of which every third string, beginning with String 3, was a critical string. Digits were presented one at a time at a rate of 1/sec on a computer-programmed television screen (University of Illinois PLATO system). Then a series of 12 empty boxes appeared, and S typed his responses onto a keyboard connected to the computer; each response appeared in its corresponding box, and typing errors could be erased and changed. The S was told that his score would be determined by the number of digits recalled in the correct location, and he could either guess or leave blank those positions that he could not remember. The recall interval lasted for 24 sec or until all 12 boxes were filled, whichever came first. There was no feedback to indicate the correctness of the S's recall.

RESULTS

The dependent variable of interest is the number of digits correctly recalled during the critical trials. The mean number of correct recalls for each group during all critical trials is shown in Table 1. Rather than employing a standard 2 by 2 analysis of variance, three planned orthogonal comparisons were carried out because the latter seemed more appropriate than the former to test the predictions mentioned above. The first comparison was RsRm vs RsCm—a test of the simple effect of the two entries in the first row in Table 1—and the difference was not significant ($F < 1$). The second comparison was CsRm vs CsCm—a test of the simple effect of the two entries in the second row of Table 1—and this difference also was not significant ($F < 1$). The results of both comparisons show that repeating previously missed digits is no better than changing them, which supports the notion that STM-LTM transfer is all-or-none rather than continuous. The third comparison was (RsRm + RsCm) vs (CsRm + CsCm)—a comparison of the row marginals in Table 1—and the difference was highly significant, $F(1,152) = 23.2$, $p < .001$, percentage of total variance accounted for $(\omega^2) \doteq 11\%$; as expected, repeating previously recalled digits was superior to changing them.

DISCUSSION

The major finding was that the transfer of serial information from STM into LTM is all-or-none rather than continuous. This result is in accord with other studies using the traditional serial-learning paradigm (Bolles, 1959; Jensen, 1962), where only the middle portion of the serial list was manipulated.

In addition to being consistent with the view that STM-LTM transfer is all-or-none, the present findings also help delimit the process by which repetition benefits the serial acquisition of multicomponent information. Given fixed-capacity STM processing and a supraspan amount of information to be serially acquired, the critical variable for "learning via repetition" does not seem to be repetition per se but rather *repetition of remembered information.* When information is forgotten during the previous critical trial, no residual is transferred to LTM that can facilitate recall during the next critical trial. Rather, "learning" occurs because the number of to-be-acquired components is reduced when remembered components are repeated; this, in turn, increases the likelihood that a given nontransferred component will be acquired.

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