Bulletin of the Psychonomic Society
1991, 29 (6), 549-552

Improving memory for temporal order through extended practice

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Considerable controversy exists as to whether a fundamental memory process can be identified as automatic, particularly as set forth by Hasher and Zacks (1979). This study examined their notion that practice will not improve one's ability for temporal coding. Additionally, the difficulty of the subjects' ability to recognize visually presented test items was manipulated by the introduction of irrelevant distractor words. Four different groups of subjects were administered word lists, each containing 48 items, for 10 trials distributed over a 22-day period. Groups receiving repeated trials were compared to a control group that did not receive any practice. During recall, memory for temporal order was assessed, along with d' scores derived from the subjects' ability to detect words they had been given. The results indicated that memory for temporal order could be improved with practice, in violation of a criterion believed necessary for the establishment of an automatic process. This evidence is consistent with current findings against the automaticity notion for memory of temporal information (Naveh-Benjamin, 1990a).

The level of interest in automatic memory processes has been extensive. In part, this has been due to the ongoing debate as to whether a fundamental encoding operation conforms or does not conform to Hasher and Zacks' (1979) six criteria for identifying an automatic process (McCormack, 1981; Michon & Jackson, 1986; Naveh-Benjamin, 1987; Sanders, Gonzalez, Murphy, Liddle, & Vitina, 1987; Toglia & Kimble, 1976; Zacks, Hasher, Alba, Sanft, & Rose, 1984). As Naveh-Benjamin (1990a) points out, most of the attention has been directed toward three encoding processes: memory for frequency of occurrence, spatial location, and temporal coding.

Although at one time Hasher and Zacks (1979) argued that all of these processes were automatic, and they provided empirical evidence to bolster their claim, a different picture is now emerging. The debate on the degree of automaticity of specific memory processes appears to be narrowing. For the most part, investigators have demonstrated that the three memory processes have violated many of the automaticity criteria (Auday, Sullivan, & Cross, 1988; Michon & Jackson, 1984; Naveh-Benjamin, 1990b; Naveh-Benjamin & Jonides, 1986; Sanders et al., 1987; Zacks et al., 1984).

One of Hasher and Zacks' (1979) original criteria states that additional practice will not improve the performance of an automatic process. Practice effects have been investigated for frequency of occurrence (Hasher & Chromiak, 1977, Experiment 2; Zacks, Hasher, & Sanft, 1982, Experiment 1) and memory for spatial location (Ellis, in press, cited in Ellis, 1991; Naveh-Benjamin, 1987, Experiment 3). The present research specifically addressed the role of practice for temporal-order coding. A literature search revealed that one study has attempted to explore the influence of practice on temporal memory (Zacks et al., 1984). Another study by Naveh-Benjamin (1990a, Experiment 3) did not focus on practice per se but rather encouraged subjects to employ particular training strategies without the opportunity for repeated trials. The Zacks et al. (1984) study visually presented subjects with a 30-item word list across four different trials, whereby each list was unique and categorically related, for example, items associated with clothing. During the first three trials, half the subjects were instructed that a subsequent free-recall test would be administered; the other half were informed that a temporal-order test would be given. On the fourth list, half the subjects who initially received free-recall instructions were now given temporal-order prelist instructions. Zacks et al. (1984) found that practice over four trials increased temporal-order accuracy, as assessed by Pearson product-moment correlations between judged order and true order of test stimuli, but the specific nature of prior training (receiving either free-recall or temporal-order instructions) did not. Because Hasher and Zacks (1979) held that an automatic encoding operation will not benefit from practice, they concluded "that the encoding for temporal memory information does not occur automatically, at least as that concept is defined by Hasher and Zacks" (Zacks et al., 1984, p. 392).

Although it explores the effects of practice on temporal coding, the present investigation is different in many respects from the experiment just discussed. First, the sub-

The authors would like to thank Bert Hodges and Kaye Cook for their insightful comments on an earlier draft of this manuscript. In addition, we wish to acknowledge Kari Johansson for her assistance with the data processing. Henry A. Cross is Professor Emeritus at Colorado State University and is now at Mobile College, Mobile, AL 36606. Correspondence should be addressed to Bryan C. Auday, Department of Psychology, Gordon College, 255 Grapevine Rd., Wenham, MA 01984-1899.

jects received "extended practice," which consisted of 10 individual trials spread out over a 22-day period. This longer period of practice provided a better opportunity to evaluate any learning-how-to-learn effects that may have developed (Harlow, 1949). Second, the present word lists were substantially larger (48 vs. 30 items) and were more difficult because they were not categorically related. Nairne (1990) has shown that serial-order performance dramatically improves when items are taken from the same category. Third, during the temporal-order recall test, the present subjects had to discriminate the 48 test items from 48 distractor words, whereas Zacks et al. (1984) used only 4 distractor words. The fourth, and perhaps the most significant, difference lies in the nature of the four groups that received extended practice. Two groups received the same test words throughout the experiment, whereas the other two were given different test words on each trial. In addition, the distractor words that appeared at the recall phase were manipulated, with two groups receiving the same distractors throughout and the remaining two receiving different distractors on each trial. The present study not only provides a test for one of Hasher and Zacks' (1979) criteria for automatic processes within an extended practice paradigm but, by varying the test items and distractor words, affords insight into the role of the retrieval mechanisms that are involved in memory for temporal order.

METHOD

Subjects

Twenty-four subjects from Colorado State University's research subject pool, most of whom were freshmen or sophomore students, participated. Subjects were both male and female and chose this project to fulfill an introductory psychology course requirement. Data received from 1 subject was not included in the analysis because instructions were not followed properly.

Materials

Words. Word lists made up of 48 words each were constructed from a pool of 960 words chosen from Thorndike and Lorge (1944) on the basis of word frequency.

Temporal-order recall test. After a word list was presented, each subject completed a temporal-order-recall test (TORT). The TORT was two pages in length and listed 96 words in the left-hand margin. Half of the 96 words were identical to the test items just seen by the subject (they will be referred to as "signals") and the other half were made up of distractor words. All 96 words were placed in a random serial order. Next to each signal or distractor word were the numbers 0-48. Subjects were asked to look at each word and then determine if it came from the test list or if it was simply a distractor word. If a word was recognized as a signal, the subjects were then asked to indicate where it occurred positionally within the test list by circling a number from 1 through 48. A word not recognized as a part of the test list was assigned the serial position 0.

Experimental Design and Procedure

The subjects were randomly assigned to one of five conditions. All were given prelist instructions that they would be required to recognize test words, as well as to assign each item a serial position according to where it occurred in the list. Those participating in the first condition were presented a list of 48 words on an Apple IIe computer. Each word appeared, one at a time, for 5 sec in a serial order determined by the computer's randomization function. The interstimulus interval among word presentations was .25 sec. This group served as the control group, since it received no extended practice, and will be referred to as Group C.

The second condition differed from Group C in two important aspects. First, subjects returned for a total of 10 trials spread out over a 22-day period (a Monday, Wednesday, and Friday sequence was used). Second, all 10 trials used 48 different signals, so no test list had any words in common. However, the same 48 distractor words were present throughout the 10 trials. This condition will be referred to as the DS condition (different signals; same distractors). The subjects participating in a third group received the same 48 signals throughout the trials, but 48 different distractors appeared on each of the 10 trials (Group SD: same signals; different distractors). The fourth group received the same signals in addition to the same distractors (Group SS) throughout the 10 trials. Finally, the subjects in a fifth condition received different signals and different distractors on every trial (Group DD).

After each word list was presented, the subjects were asked to complete the TORT. No time constraints were placed on their ability to make temporal judgments. The subjects participating in groups that required extended practice were retested in the same laboratory under similar conditions.

At the end of the experiment, all subjects were thanked and debriefed and given some background information on recent developments within the study of memory for temporal order.

RESULTS

Over the years, a number of procedures have been recommended to analyze temporal-order data similar to the kind that was collected by using the TORT (Block, Nickol, & Brown, 1983; Hintzman & Block, 1971; McCormack, 1982; Toglia & Kimble, 1976). Because the primary interest was in acquiring an overall index of memory for temporal order rather than in using one that is particularly sensitive to individual serial positions within a list, the Pearson product-moment correlation coefficient was used (Michon & Jackson, 1984; Naveh-Benjamin, 1990a).

Borrowing a technique initially used by Hintzman and Block (1971) and later used by Auday et al. (1988), the 48 test words were grouped into 8 blocks of 6 words each. Thus, Block 1 included the first 6 words presented (Items 1-6), Block 2 included the next 6 words (Items 7-12), and so forth. Correlation coefficients for each trial were obtained by correlating the block associated with the subject's positional assignment of each signal with the actual block in which the item had occurred. In addition, since the first trial for the subjects participating in the extended practice groups was the same for Group C (who received one trial), these scores were averaged in with the other scores in Group C.

A one-way between-groups analysis of variance performed on the Pearson *r*s among the five groups revealed significant differences [$F(4, 208) = 6.28, p < .01$]. The mean *r* values for Groups C, DS, SD, SS, and DD were .388, .519, .657, .619, and .521, respectively. A subsequent Student-Newman-Keuls (SNK) showed that Group C subjects performed significantly lower in overall memory for temporal order than subjects in the DS, SD, SS, or DD conditions. The SNK also indicated that SD subjects performed reliably better than both DS and

Table 1
Average Product-Moment Correlations and d' Scores as a Function of Practice Trials for All Extended Practice Groups Combined

	Number of Practice Trials				
	1–2	3–4	5–6	7–8	9–10
Pearson r	.51	.53	.57	.60	.64
d'	1.69	2.19	2.45	2.68	2.69

DD subjects. Additionally, SS subjects did better than DD subjects.

After finding evidence that the accuracy for temporal memory was improved for the subjects receiving extended practice, a test for the presence of a positive linear trend involving Pearson *r*s over the 10 trials was performed. Using scores from groups receiving practice, the slope for the best-fitting line for temporal-memory scores and trials was found to be significantly greater than zero [$t(188) = 3.39, p < .01; r = .24$], providing further support that accuracy can improve with practice, even when large intertrial intervals are employed. Table 1 shows the benefit of practice on average product-moment correlations. Individual inspection of the slopes associated with the groups receiving practice revealed that the subjects in the SD group showed the greatest improvement [$t(38) = 2.56, p < .02; r = .38$]. Although performance for subjects in the DS, SS, and DD conditions showed a positive linear trend that approached significance, they were not reliable to the .05 alpha level.

In addition to the analysis of correlation coefficients, hit and false-alarm rates were extracted to generate d' scores from the TORT. The d' score indicates the level of ease or difficulty a subject had in trying to differentiate the signals from the distractors on each trial. As expected, there were significant differences among the groups [$F(4,208) = 76.07, p < .001$]. The means for the d' scores for Groups C, DS, SD, SS, and DD were 1.49, 1.58, 4.19, 2.51, and 1.63, respectively. The SNK showed that SD subjects performed better than all of the other groups. The SS condition was found to outperform those in Groups C, DS, and DD. Additionally, one can see a general linear trend between d' scores over the number of practice trials (refer to Table 1). To assess the overall relationship between Pearson r scores and d' scores, a correlation was performed and found to be significant ($r = .27, p < .001$). As one might expect, d' scores significantly improved (all r values had *p*s $< .05$) over the 10 trials for all groups except Group DD ($p > .05$).

DISCUSSION

In recent years, we have been witnessing the demise of the notion that a memory process is either exclusively automatic or effortful. The present results show that memory for temporal order can be improved with extended practice, and this stands in opposition to one important criterion for defining an automatic process—namely, that practice should not improve scores (Hasher & Zacks, 1979). Such findings contribute to the growing body of empirical research that suggests that temporal coding should not be defined as an automatic process, at least not according to the Hasher and Zacks' (1979) criteria.

Naveh-Benjamin (1990a) has argued that an all-or-none approach to automaticity should be dropped in favor of a continuum model that allows for degrees of automaticity. The continuum approach can account for some of the discrepancies found in the literature over the last 12 years. It has also been maintained that temporal-coding mechanisms are much more complex than were previously believed. After all, stimulus items need to be encoded, retained, and then retrieved in a manner that is appropriate to the particular test that is employed by the investigator to measure temporal accuracy. Perhaps, as Naveh-Benjamin (1990a) has pointed out, some of these stages are relatively automatic, whereas others require more effort.

The substantial d' differences among the groups reflect a different ability to partition signals from distractors. The SD condition had by far the largest d' scores ($M = 4.19$), as well as the highest average temporal-order score ($r = .66$). The correlation between d' scores and temporal-order scores for this group was statistically significant ($r = .37, p = .01$). This suggests to us that when temporal information needs to be retrieved, at least one of the factors involved is the saliency and/or familiarity of both the signal words and the distractor words.

Perhaps the concept of automaticity should be understood as a memory phenomenon, as advocated by Logan (1988), rather than as a process derived from the attentional single-capacity resource models of the 1970s (e.g., Kahneman, 1973). Our finding of improved temporal accuracy conjoined with increases in d' scores could be viewed within an "automaticity-as- memory" view, in which improvement through practice results from strengthened temporal codes, particularly if the words involved are "predifferentiated" in some way.

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(Manuscript received May 16, 1991.)