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Automatic Encoding of Event Frequency: Further Findings

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The three experiments reported in this article examined the process by which frequency of occurrence information is registered in memory. Based on the hypothesis that this information is encoded automatically, performance on a frequency discrimination task was predicted to be insensitive to a variety of manipulations expected to influence free recall, a task requiring considerable effortful processing and therefore used as a counterpoint to the frequency task in two of the experiments. These expectations were confirmed. Frequency performance did not increase with practice, was unaffected by appropriateness of practice, was not influenced by accuracy of test expectations, and was not hindered by competing demands. Also, no stable individual differences were obtained in discriminating relative frequency, and strategy effects were small. These results conform to criteria of automatic processing. They are also in striking contrast to the free-recall findings. Free-recall performance increased with practice, was affected by appropriateness of practice and accuracy of test expectations, and was hindered by competing demands. Also, stable individual differences were obtained in free recall.

A number of studies have found that people possess considerable knowledge of the relative frequency with which explicit environmental events occur. This is true of event types ranging from individual letters (Attneave, 1953) to diseases (Lichtenstein, Slovic, Fischhoff, Layman, & Combs, 1978). People also appear to have knowledge of the relative frequency with which implicitly referenced events occur (for example, superordinate categories when only exemplars are presented; Alba, Chromiak, Hasher, & Attig, 1980).

The central concern of this article is the *process* by which event-frequency information gets stored in memory. In particular, we hope to bolster an earlier suggestion (see Hasher & Zacks, 1979) that occurrence-rate information is one of a small number of event attributes (which also include temporal and spatial location information) that are encoded automatically. By our definition, automatic encoding operations are ones

> that drain minimal energy from our limited-capacity attentional mechanism . . . [that do] not interfere with other ongoing cognitive activit[ies] . . . [that] function at a constant level under all circumstances . . . [that] occur without intention and [that] do not benefit from practice. (Hasher & Zacks, 1979, p. 356)

This description of automatic or obligatory encoding operations has several empirical implications that, *taken together*, serve as a set of converging operations or joint criteria to establish that a particular encoding operation is automatic.

With regard to frequency of occurrence information, existing evidence already confirms a number of the proposed empirical criteria for automaticity (see Hasher & Zacks, 1979, Table 1, p. 368). There is considerable evidence that frequency data are acquired without intention, and that the addition of intention does not improve performance (e.g., Flexser & Bower, 1975; Howell, 1973). There is some evidence that the accuracy with which occurrence-rate information is encoded does not improve with small amounts of practice (Hasher & Chromiak, 1977). Accuracy is also unaf-

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fected by alterations in mood state (depressed vs. not depressed) or by other alterations that are otherwise associated with reductions in cognitive functioning (Hasher & Zacks, 1979).

We have further proposed that the encoding of event frequency is an automatic operation for which people may be genetically prepared. By this we mean that this operation belongs to the category identified by Flavell (1977) as "basic" memory processes. According to Flavell, these processes are the basic "hardware" of the memory system. As such, they show limited developmental trends that are completed at an early age (by 1½–2 yr.), and development is largely a function of maturation. If the encoding of event frequency is such a process, then maximal proficiency in registering frequency should be attained early in life and should continue unchanged into old age. There is now considerable evidence for the expected age invariance: Kindergartners perform as well as third graders on a test of frequency knowledge (Hasher & Zacks, 1979, Experiment 1); second graders do as well as college students (Hasher & Chromiak, 1977, Experiment 1); college-aged, middle-aged, and elderly adults all do equally well (Attig & Hasher, 1980; Hasher & Zacks, 1979, Experiment 3; Kausler & Puckett, 1980).

Another aspect of the proposition of preparedness for event frequency encoding has to do with individual differences. Many abilities with strong genetic components do show individual differences, but the degrees of such differences appear to vary widely. In this vein, we suggest that the capacity to encode frequency data is more like the capacity for bipedal gait or for everyday linguistic communication than it is like the capacity for gymnastics or for writing poetry (cf. Lenneberg, 1964). That is, the ability to encode frequency information should be widely shared among people and should show minimal individual differences. Factors such as culture, education, socioeconomic status, and intelligence should have little influence on the quality of encoding of event frequency. To our knowledge, there is only one study that has provided data relevant to this proposition. That study compared learning-disabled with normal school children and found no differences in their sensitivity to frequency (Goldstein, Kosteski, Golding, & Hasher, Note 1).

The three experiments reported here evaluated a number of the empirical criteria for automaticity, including ones proposed for a prepared automatic operation. The first two experiments were an attempt to evaluate the role of fairly extensive practice in extracting frequency information. These experiments also enabled us to evaluate the degree of systematic individual differences in encoding frequency information. The third experiment evaluated three criteria: individual differences, intention, and, for the first time, the impact of competing demands on the extraction of frequency information. In both Experiments 1 and 3, performance on a forced-choice frequency discrimination task was compared to performance on a free-recall task. Free recall was chosen to counterpoint the performance on the automatically mediated frequency discrimination task because the former is a task influenced by the use of effortful encoding strategies (e.g., organization, imagery) that are under voluntary control, show strong developmental trends (Flavell, 1977), and are subject to capacity limitations (see Hasher & Zacks, 1979). Thus, although a variety of variables were expected to influence recall, they were expected to have no effect on frequency processing.

Experiment 1

This experiment compared practice effects on a single-trial free-recall task with those on a forced-choice frequency task. Free-recall performance was expected to improve over lists because of the considerable amount of effortful processing recall requires. This expectation is in accordance with the consistent finding of multiple-trial free-recall studies that performance improves over trials (e.g., Postman, Burns, & Hasher, 1970). The improvement has been attributed to increased efficiency in the use of conscious strategies, including subjective organization of list items (cf. Postman et al., 1970). Effortful processing should also in-

crease in efficiency over lists in single-trial free recall, due to "learning-to-learn" effects. Although, to our surprise, none of the many studies that used single-trial free recall included in the published reports information on list-to-list changes in performance, an increase in performance over lists should be observed when the data are examined for it. In contrast, no improvement was anticipated in the frequency task. This outcome would be in agreement with earlier findings (Hasher & Chromiak, 1977, Experiment 2). However, Hasher and Chromiak's subjects were given only two successive lists, and these may not have been enough to allow the benefits of practice effects to reveal themselves. In the present experiment, two groups of subjects were tested on four successive lists, either for recall or for frequency. Two other groups of subjects switched from one memory task to the other after three lists at a given task. Thus, on the fourth list performance could be compared between test-appropriate practice conditions and test-inappropriate practice conditions. On a free-recall test, appropriate training was expected to yield higher recall than inappropriate training. Type of prior training was expected to have no influence on the frequency test.

The possible use of encoding strategies in the frequency task was evaluated by a post-experimental questionnaire. Because frequency processing is thought to be optimal when automatically driven, the use of any strategy should have no influence on performance.

The use of multiple lists enabled us to assess individual differences in performance on both frequency and recall tasks. We expected to see stable performance patterns (as assessed by intertrial correlations) for subjects given practice at recall; free recall requires substantial effort, and so individual differences in motivation, intelligence, and familiarity with effective strategies will influence performance. For reasons noted earlier, the encoding of frequency was not expected to show stable individual differences. An additional reason is that, since minimal capacity is required for an automatic operation, differences in effort expended in relation to motivation level should not influence acquisition of frequency information. Thus, significant intertrial correlations were not anticipated on the frequency task.

Method

Design. The experiment included four groups of subjects who were exposed to four lists of words. Each list received a single presentation and a single test trial. Half the subjects had three trials on a forced-choice frequency discrimination task (F), and the other half had three trials on a free recall task (R). For the fourth list, half of the subjects who had been tested with each memory test continued with the same memory test (groups F-F and R-R), and the other half were switched to the alternative test (groups F-R and R-F; the first letter denotes the test given on the first three trials and the second letter the test on the fourth trial).

Materials. The experimental materials consisted of four unique lists of 30 words each. Each list contained words belonging to one of the following categories: things associated with eating, things associated with clothing, places or locations, and small things (items culled from Battig & Montague, 1969). For each of the four lists, the 30 words were used to construct two versions of a 90-slot presentation list. Within each presentation list, words occurred 0 to 7 times. Words were randomly assigned to particular frequency levels, with the constraint that no word could appear at the same frequency level in the two versions of the list. Four words occurred once, 5 occurred twice, 6 three times, 6 four times, 3 five times, 2 six times, and 1 seven times. Repeated words were placed randomly in segments of the list whose size was determined by the number of repetitions (i.e., twice-presented words occurred once in the first half and once in the second half, and so on). A repeated word thus never succeeded itself. Eight different orders for sequencing the different lists were used in order to counterbalance the lists across stages of practice.

For each presentation list, a different 15-pair forced-choice frequency test was generated. All test lists were based on the same format: Across the 15 pairs, three levels of absolute difference in presentation frequency (1, 2, and 3) were combined with five levels of frequency of the less-frequent pair member, or base frequency (0, 1, 2, 3, and 4). Three words appeared only on the test list.

Procedure. One to three subjects were tested simultaneously. Subjects were fully informed about the nature of the memory test prior to the first list and were reminded before each successive list. Subjects who switched tasks for the fourth list were informed of the change prior to its presentation. Each list was preceded by its category name and then the words were presented at a 2-sec rate by a tape recorder. The memory test immediately followed list presentation. On the free-recall test, subjects wrote down any words they recalled in any order. For the frequency test, subjects circled the more frequent member of each pair. Test sheets for all trials were stapled together with blank sheets in between. After each test subjects were told to turn their test booklets face down.

Following all four lists, an informal interview was conducted with subjects in Group F-F. They were asked

if there were any particular strategies they used to remember how often a word occurred on a list, whether they believed such strategies were helpful, and, if appropriate, when any strategy change had taken place.

Subjects. Ninety-six introductory psychology students participated to fulfill a course requirement. There were 24 subjects in each group.

Results

Free recall. Table 1 presents the mean proportion of words recalled on each list for the first three lists of Groups R-R and R-F and for the fourth list of Groups R-R and F-R. As expected, practice at a recall task resulted in a small but consistent increase in performance, $F(2, 92) = 5.48$, $p < .01$. Significant improvement was seen between the first and second list, but not thereafter (Newman-Keuls test). Also as expected, fourth-list performance was influenced by prior training, with subjects having appropriate training (recall) showing a significant advantage over those having inappropriate (frequency) training, $t(46) = 2.56$, $p < .01$.

Frequency discrimination. The results for the frequency task are also shown in Table 1. Performance on this task was very good, with an overall mean of 78% (11.7 out of 15) correct choices. Performance did not improve with practice; in fact, it unexpectedly dropped slightly. Across the first three lists, the drop-off in performance was significant, $F(2, 92) = 10.66$, $p < .01$. This effect was accounted for by the drop between the first and second lists (Newman-Keuls test). Because of a borderline significant interaction between groups (F-F vs. F-R, a dummy variable) and lists, $F(2, 92) = 2.37$, $p \approx .10$, separate list effects were studied for the two groups. The drop-off on List 2 was significant for Group F-F, $t(23) = 2.15$, $p < .05$, but not for Group F-R, $t(23) = 1.22$, $p > .10$. Thus, the negative practice effect may not be a robust finding. Still, it was investigated further in the second experiment.

The data of Experiment 1 were also explored to determine whether the negative practice effect was limited to specific frequency discriminations defined in terms of the test pair's base frequency, the absolute difference in frequency, or the particular combination of these two variables. Other investigators (e.g., Attig & Hasher, 1980;

Table 1
Mean Proportion of Words Recalled and Mean Proportion of Correct Frequency Choices in Experiments 1 and 2

Group	List 1	List 2	List 3	List 4
	Experiment 1, Recall (n = 24)			
R-R	.58 (.12)	.61 (.14)	.60 (.11)	.66 (.11)
R-F	.54 (.09)	.59 (.10)	.60 (.12)	—
M	.56	.60	.60	—
F-R	—	—	—	.55 (.10)
	Experiment 1, Frequency (n = 24)			
F-F	.83 (.09)	.76 (.14)	.76 (.14)	.74 (.14)
F-R	.84 (.09)	.80 (.10)	.73 (.11)	—
M	.83	.78	.74	—
R-F	—	—	—	.76 (.12)
	Experiment 2, Frequency (n = 16)			
Instructed	.81 (.13)	.83 (.08)	.79 (.10)	.80 (.13)
Uninstructed	.78 (.09)	.76 (.09)	.73 (.16)	.77 (.14)

Note. Standard deviations appear in parentheses. The maximum possible score on the recall test was 27 and on the frequency test was 15. R = free recall task; F = forced-choice frequency discrimination task; the first letter denotes the test given on the first three trials, the second on the fourth trial.

Underwood & Freund, 1970) have found that frequency discrimination displays a "Weber effect." This was also observed in our data. For example, an analysis was carried out on the first and second list data of Groups F-F and F-R. Errors increased as the base frequency increased, $F(4, 56) = 4.20$, $p < .01$, and they decreased as the absolute difference increased, $F(2, 28) = 4.91$, $p < .05$. These two variables interacted, with the effects of base frequency being less at higher absolute difference levels, $F(8, 112) = 6.10$, $p < .01$. There were, however, no interactions with lists, thus indicating that the drop in performance from List 1 to List 2 was not localized in a particular set of frequency discriminations.[1]

On List 4, performance was expected to show little effect of type of prior experience on frequency coding. The small difference (in the wrong direction) between a group with appropriate experience (frequency) and one with inappropriate experience (recall) was not significant, $t(46) = .20$.

Interlist correlations. Interlist correlations were used to examine the stability of individual differences in performance (see Table 2). Do subjects who do well on one list tend to do well on others? The answer depends, as expected, on the nature of the test task. The between-list correlations for recall were uniformly positive and significant, indicating stable individual differences. The correlations for cases in which frequency was tested provide a stark contrast. None of these correlations was significant. Also, direct comparison of the recall test correlations with the frequency test correlations indicates that the former were generally significantly higher than the latter (e.g., .495 vs. .146). For Groups R-R and R-F combined versus Groups F-F and F-R combined, the Fisher Z values for Lists 1 and 2, Lists 1 and 3, and Lists 2 and 3 were 1.88, 1.87, and 1.84, respectively ($p \approx .03$, one-tailed test); the Lists 3 and 4 correlation of Group R-R was not significantly higher than that of Group F-F, $Z = .97$. (The Lists 3 and 4 correlations of Groups R-F and F-R were not included in these analyses because in these cases different memory tests were used on the two lists.) Thus, individual differences appear fairly stable for recall tests but not for frequency tests.

Table 2
Between-List Pearson Product-Moment Correlations for Experiment 1

Group(s)	N	Lists	r
R-R and R-F	48	1 and 2	.495*
R-R and R-F	48	1 and 3	.351*
R-R and R-F	48	2 and 3	.554*
R-R	24	3 and 4	.531*
F-F and F-R	48	1 and 2	.146
F-F and F-R	48	1 and 3	−.029
F-F and F-R	48	2 and 3	.234
F-F	24	3 and 4	.283
R-F	24	3 and 4	.329
F-R	24	3 and 4	.240

Note. R = free recall task; F = forced-choice frequency discrimination task; the first letter denotes the task given on the first three trials, the second on the fourth trial.
* $p < .01$

Postexperimental questionnaire. Following the fourth test list, subjects in Group F-F were questioned about their strategy use. Their responses were examined to determine whether any consistent strategies were used. Reports were categorized into three classes: no strategy (9 subjects), a counting strategy (8 subjects), and a miscellaneous category (imagery, repetition, etc.; 7 subjects). Performance of each of these subgroups of subjects was evaluated to determine the benefits of the reported strategies.

For the no-strategy, counting, and miscellaneous subgroups, the mean proportions of correct choices per list were .76, .80, and .75, respectively. Although a counting strategy seemed to provide a small benefit, a comparison of the three groups revealed no significant differences, $F(2, 21) = 1.08$.

The strategy reports were also examined for clues about the possible causes of the negative practice effect. The 24 subjects were divided into two subgroups: those whose

[1] To perform this analysis macrosubjects were created by collapsing data across groups of three subjects who had received the same list sequence. This was done because each combination of Base Frequency × Absolute Difference occurred only once on each test list; individual subjects' data for each trial were therefore dichotomous. Similar analyses were performed on the data of Experiments 2 and 3. Since the results in the latter cases were fully consistent with those just described, the Weber effect data are not discussed further.

performance remained stable or improved across the four lists ($n = 10$), and those whose performance declined. The criterion for a decline was at least three fewer correct responses on any later list than on the first list. The strategy reports did not seem to differentiate between the two subgroups; for the subjects with stable performance, the distribution was 4 no-strategy, 4 counting, and 2 miscellaneous-strategy reports. For the subjects whose performance declined, the distribution across the strategy classes was 5, 4, and 5, respectively. However, there was a hint that the subjects showing a decline in performance were less persistent across lists in their use of a counting strategy than were the stable subjects. Only two of the four declining subjects persisted in using a counting strategy for all lists. All of the four stable subjects continued to use such a strategy throughout the experiment.

Discussion

As predicted, the results for the free-recall task contrasted with those for the frequency task. Recall performance showed (a) a positive practice effect, (b) a benefit from appropriate practice, and (c) reliable individual differences. In contrast, frequency performance showed (a) a drop in performance with practice, (b) no differential effect of appropriate versus inappropriate training, and (c) no consistent individual differences in performance. Also, performance varied minimally as a function of reported strategy. With one exception, all of these findings were predicted and so conform to the hypothesis that the encoding operations involved in free recall are effortful but those that register frequency data are automatic. In the case of the unexpected finding—namely, the negative practice effect in the frequency task—separate analyses for Groups F-F and F-R indicated that this result may not be replicable, and in fact Hasher and Chromiak (1977) found no change in performance in a frequency judgment task over two lists. Experiment 2 followed up on this issue.

Experiment 2

This experiment was conducted for two purposes: (a) to determine the reliability of the negative practice effect for frequency discrimination seen for at least one group in the first experiment, and (b) to follow up on the suggestion from the interviews that subjects who consistently use a counting strategy are better able to discriminate frequency than those who do not. To these ends, two groups of subjects were tested for frequency discrimination on each of four successive lists. Both groups were informed about the nature of the test task. One group, in addition, received explicit instructions about the use of a counting strategy.

Method

The procedure and materials from Experiment 1 were used again with the sole exception that the counting-strategy instructions were given to half of the 32 subjects. The strategy group was told to try to keep a running track of the number of times each item appeared. They were reminded to do so before each of the four lists. At the end of the experiment each subject was informally interviewed about strategy use.

Results

The results are shown in Table 1. Again, performance was high, with an overall mean of 78% correct. Although there was a slight drop in performance over lists, the drop was not significant in Experiment 2, $F(3, 90) = .573$. The small advantage that instructed subjects (81%) had over uninstructed subjects (76%) was significant, $F(1, 30) = 5.89$, $p < .05$.

Systematic individual differences were investigated by using between-list correlations (Table 3). As in Experiment 1, these correlations were small and for the most part unreliable. Also, despite the differences in overall performance, the patterns shown by the instructed and uninstructed subjects do not appear to be different (no Fisher Z comparisons were significant.)

Postexperimental interview results for the uninstructed group were similar to those seen in Experiment 1. The distributions of subjects across the no-strategy, counting-strategy, and miscellaneous-strategy categories were 5, 5, and 6 subjects, respectively. Mean proportions of correct choices per list were .70, .80, and .77 for these subgroups, respectively. Again, the subjects reporting a counting strategy had the highest average

Table 3
Between-List Pearson Product-Moment Correlations for Experiment 2

Group	Lists	r
Uninstructed	1 and 2	−.080
	1 and 3	.169
	1 and 4	.172
	2 and 3	.040
	2 and 4	−.540*
	3 and 4	.379
Instructed	1 and 2	−.401
	1 and 3	−.304
	1 and 4	−.037
	2 and 3	.290
	2 and 4	−.250
	3 and 4	.048

* $p < .05$.

performance, and this time the differences were significant, $F(2, 13) = 4.22$, $p < .05$. However, an analysis that combined these data with the data for Group F-F of Experiment 1 yielded a nonsignificant effect of strategy subgroup, $F(2, 36) = 2.07$, $p > .10$.

Our instructions to the instructed group seem to have been effective in that all but 2 of the 16 subjects reported using a counting strategy at some time during the experiment. Two subjects reported they ceased using the strategy after the first or second list. The remaining subjects used the strategy throughout.

Discussion

Practice effects were not reliable in Experiment 2, but again there was some tendency for performance to drop over lists. Further research is needed to establish whether the negative practice effect is consistently found in frequency-discrimination tasks, and if so, the precise circumstances under which it occurs. However, even if this effect is reliable, it probably will not require any alteration in our basic claim that frequency data are encoded by an automatic process. Quite possibly the experience of multiple lists in the same situation results in the build-up of proactive interference. The exact nature of such proactive interference effects is unclear; perhaps the retrieval of the relevant frequency information becomes more difficult over lists, or perhaps the similarities across lists make the frequency discriminations harder. In any case, similar proactive interference effects are likely to occur in the free-recall task as well. If so, this means that the performance gains in free recall seen in Experiment 1 are an underestimate of the "true" learning-to-learn effect.

An aspect of the data of Experiment 2 that is somewhat more troubling than possible negative practice effects is that a counting strategy seems to have benefited performance. In one analysis, strategy subgroups differed significantly, with the counting subgroup showing the best performance. More important, subjects instructed to use a counting strategy outperformed those not so instructed. Taken together, our results suggest that counting has a consistent effect on frequency discrimination, but it is a small one; the overall difference between the instructed and uninstructed groups was 5%, or .73 items out of 15. This small difference can probably be accounted for if subjects count as few as two items accurately (Hintzman, Note 2). In view of some data from an earlier study (Alba et al., 1980), a larger benefit from counting seems unlikely. In that study, subjects asked to judge the frequency of different categories after being shown a list containing only category instances did not benefit from a presentation condition that should have increased the ease of counting, that is, blocked presentation of category exemplars. This was true even for groups studying the list under intentional instructions. Further, subjects specifically instructed to provide a running tally of category size found the task very difficult; none was able to do this for a complete list in which items from different categories were randomly interspersed. Our belief about strategy effects on encoding of frequency information is that an effortful counting strategy probably adds something to the amount that is automatically encoded. The additional information is, however, small in amount and is undoubtedly gained at the expense of reducing capacity for other effortful processing.

Our belief about practice effects on the encoding of frequency information is that

the extraction of frequency data does not improve with practice. People are good at this task the first time they are asked to do it and they get no better at it, even under the advantageous circumstances of the present studies in which the subject is free to concentrate his or her entire attention on extracting this information, and in which the identical frequency pattern is repeated across successive lists. Performance may sometimes drop slightly due to the build-up of proactive interference.

Experiment 3

In this experiment, subjects were presented with a single list of words and were tested either by free recall or on a forced-choice frequency discrimination task. Three variables were explored, each of which was expected to influence recall but not frequency performance: (a) accuracy of expectations about the memory test, (b) competing demands for capacity, and (c) individual differences.

In previous work on the effect of intentionality on the encoding of frequency information, comparisons have been made between prepresentation instructions that accurately described the frequency task and instructions that gave vague indications or no indication about a forthcoming memory task. These studies all reported no intentional–incidental difference in performance (e.g., Flexser & Bower, 1975; Hasher & Chromiak, 1977; Howell, 1973). In this experiment, we took a different approach to the issue of intentionality and looked at the effects of accurate information about the forthcoming test versus misleading information. To this end, one third of the subjects were informed about a forthcoming frequency test, one third were informed about a forthcoming recall test, and one third were informed about both a frequency and a recall test. Each of these three groups was then divided in half, with one group receiving a frequency test and one a recall test.

The groups instructed for both tests were included as a way to place competing demands on subjects. Preparation for a recall test is thought to require considerable capacity, especially if subjects are using mnemonics. Preparation for a frequency test may also require some capacity; as interview data from Experiments 1 and 2 show, approximately two thirds of the subjects forewarned about a frequency test adopt some strategy. Regardless of the small amount of benefit from such activities, they require capacity and so will take attention away from other concurrent activity. Competing demands (induced here by instructing subjects to prepare for two tests), assuming these are sufficiently high, should reduce performance for effortful tasks (here, recall) but should have no impact on automatic tasks (here, frequency discrimination).

Individual differences were examined by comparing the performance of students from two very different universities: University A was a small, highly select, private institution; University B was a state university with more liberal admission standards. An idea of the differences between student populations at the two schools can be gained by a comparison of the median Scholastic Aptitude Test scores of incoming freshmen; at University A they were 610 Verbal and 630 Mathematical, and at University B they were 471 Verbal and 495 Mathematical (data are from *Barron's Profiles of American Colleges*; Barron's Educational Series, Inc., 1979).[2] Whatever differences in motivation to perform well, systematic use of mnemonic strategies, and intelligence that these scores may reflect should undoubtedly favor students at University A. Such differences were expected to influence recall performance but not frequency performance.

Method

The experiment had a 2 × 3 × 2 between-groups factorial design. The variables were type of memory test (free recall vs. a forced-choice frequency task), instructional condition (instructed for free recall, for the frequency task, or for both), and university attended by the subjects (A vs. B). A single list of 30 unrelated high-frequency words was used to generate four different presentation sequences, each of which had the same

[2] The inclusion of this variable was fortuitous. At one point, we were having trouble getting enough subjects to complete the experiment at University A, whereas University B had a large subject pool available to us. We started testing at University B as well, intending to pool all the data. When we saw the interesting trends emerging, we ran more subjects at both places.

structure as the Experiment 1 presentation lists. Assignment of a specific word to a particular frequency level was made on a random basis with the constraint that no word could appear more than once at the same frequency level across the four versions of the list. The details of presentation and test list construction followed those for Experiment 1.

Subjects were tested in groups with a maximum size of nine. Prepresentation instructions and memory test instructions and forms were all contained in booklets so that a variety of conditions was represented in each group. The word lists were presented by slide projector at a 4-sec rate.

The number of subjects in each of the 12 groups ranged from 24 to 32. At both universities, subjects participated to fulfill course requirements.

Results and Discussion

Free recall. The data for the recall groups are shown in Figure 1. It can be seen that both university and instructions influenced performance on the free-recall task. In a 2×3 unweighted means analysis of variance, significant effects were obtained for university, $F(1, 171) = 11.56$, $p < .01$; for instructions, $F(2, 171) = 11.61$, $p < .01$; and for their interaction, $F(2, 171) = 6.54$, $p < .01$. Looking first at the interaction, it is apparent that University A subjects recalled more than University B subjects in the two conditions in which a recall test was expected, $Fs(1, 171) \geq 10.89$, $p < .01$. However, when a frequency test was expected, students at University A no longer performed better than those at University B; in fact, performance was equivalent, $F < 1$.

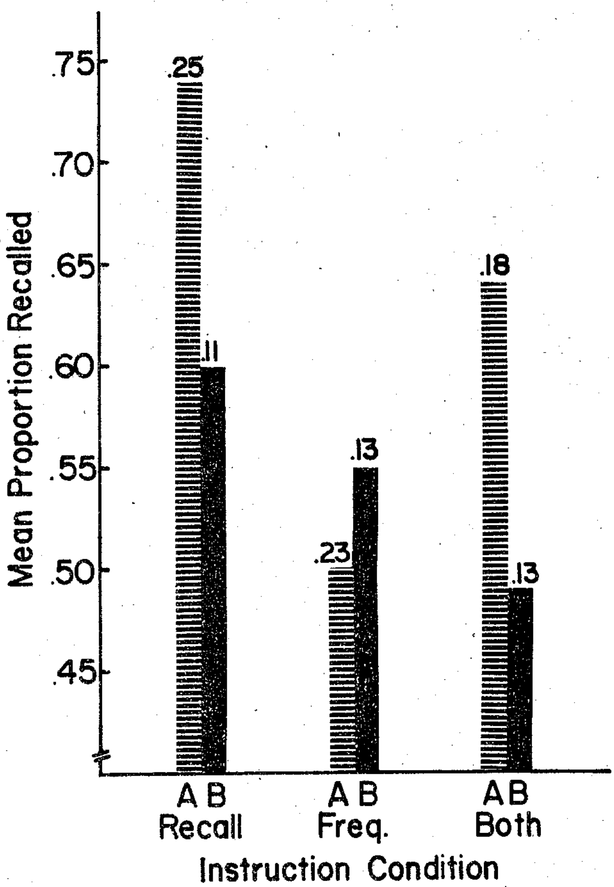

Figure 1. Mean proportion recalled for the recall groups of Experiment 3. (The bars labeled A and B represent the data for University A and B subjects, respectively. The number above each bar is the standard deviation for that group.)

For University A subjects, performance was best in the recall-instructed condition, intermediate in the recall–frequency condition (possibly because some capacity was expended on a minimally beneficial but effortful strategy of preparing for a frequency test), and poorest in the frequency-instructed condition (Newman-Keuls test). Apparently, University A students were capable of engaging in effortful strategies that benefit free recall, but these strategies occurred in reduced amounts or not at all in the absence of specific intentions (the frequency-instructed condition) or in the presence of competing demands (the recall–frequency instructed condition).

The pattern of performance for University B subjects was quite different from that for University A subjects: University B subjects benefited less from correct expectations of a recall test, and their poorest performance occurred under conditions of competing demands (the recall–frequency instructed condition). Thus it seems that, compared to University A subjects, University B students were less capable of (or less willing to) increase free recall through effortful processing and experienced greater disruption under competing demands. Whatever the functional variables that distinguish students admitted to University A from those admitted to University B, it is clear that individual differences are important in free-recall performance.

Frequency discrimination. Figure 2 shows the average proportion of correct choices for each of the frequency groups. Once more the high level of performance, 85% correct, is notable: People have quite accurate knowledge of the frequency of occurrence of events

even when they are not expecting to be tested for it. This accuracy appears to be invariant across all of the instructional conditions as well as across the two different populations of subjects, largest $F(2, 165) = 2.54$, $p > .05$. Neither test expectations, competing demands, nor individual differences influenced the encoding of frequency information. These results contrast completely with those for free recall, in which all three variables influenced performance.

General Discussion

The results of these experiments provide clear demonstrations that variables that influence free recall do not influence, or influence only slightly, the encoding of frequency information. For the free-recall task, we found that performance varied with the extent of practice, with the appropriateness of the practice, with the existence of competing demands, with the accuracy of test expectations, and finally with individual differences. The free-recall results are consistent with the contention (Hasher & Zacks, 1979) that good free-recall performance requires effortful encoding operations that use up considerable capacity and occur only with intention.

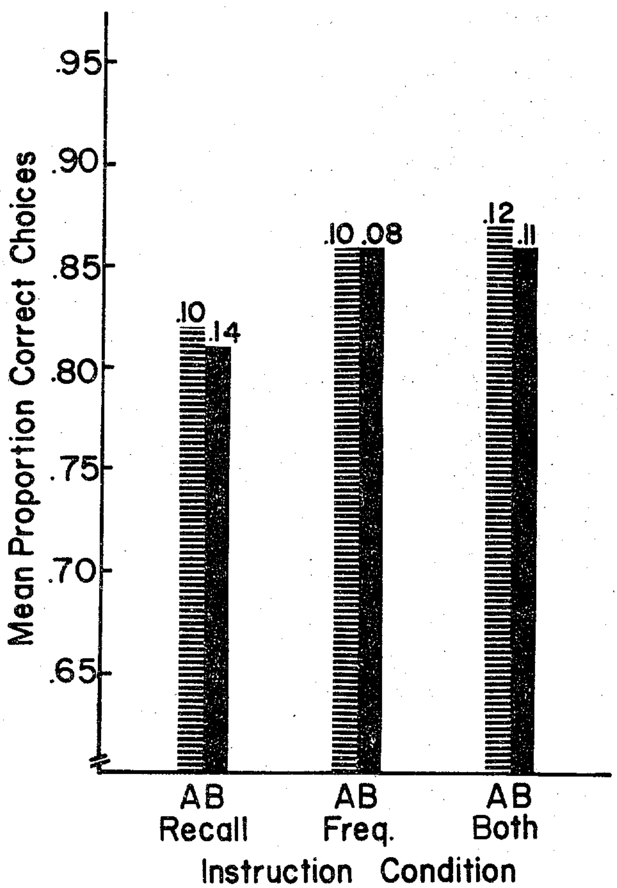

Figure 2. Mean proportion correct choices for the frequency groups of Experiment 3. (The bars labeled A and B represent the data for University A and B subjects, respectively. The number above each bar is the standard deviation for that group.)

In marked contrast to these findings are those from the frequency task. The storage of occurrence-rate data was affected minimally or not at all by the extent of practice, the appropriateness of that practice, individual differences, competing demands, and the accuracy of test expectations. Variability in frequency performance among individuals appears to be due to mainly random factors. These results conform to the hypothesis (Hasher & Zacks, 1979) that event frequency is encoded by an automatic process requiring minimal attentional capacity and occurring at optimal levels without intention. Only the small benefit from use of a counting strategy is at odds with this hypothesis.

For the most part, then, the present series of experiments expands on the considerable findings that confirm the proposition that frequency of occurrence is processed automatically. As noted earlier, other findings include a lack of effect of intentionality or of mood state, a striking age invariance, and no deficit in learning-disabled children. All of the criteria of automatic encoding proposed by Hasher and Zacks (1979) have now been tested for frequency information, some of them several times. These tests have almost always yielded results consistent with automatic processing.

Automatically encoded frequency information is now known or speculated to be critical for a wide variety of behaviors in humans. For example, frequency information at least partially underlies the ability to distinguish old objects from new ones (e.g., Underwood, 1971); it is involved in the development of knowledge about categories (Alba et al., 1980; Rosch, 1978); it is involved in sex-role-appropriate imitation behavior (Perry & Bussey, 1979); and it is involved in decisions about the truth or validity of statements about people, facts, and events (Hasher, Goldstein, & Toppino, 1977). Al-

though the issue of how frequency is represented in memory remains to be resolved (e.g., Hintzman & Stern, 1978; Whitlow & Estes, 1979), the unusual nature of the process by which such information is encoded is becoming more clear, along with the importance of this information to human, and perhaps even animal, (see Sih, 1980) behavior.

Reference Notes

1. Goldstein, D., Kosteski, D., Golding, J., & Hasher, L. *Memory processes in learning disabled and nondisabled children.* Manuscript submitted for publication, 1981.
2. Hintzman, D. Personal communication, June 1981.

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