Journal of Experimental Psychology:
Learning, Memory, and Cognition
1987, Vol. 13, No. 2, 251–258

0278-7393/87/$00.75

Is Event Frequency Encoded Automatically? The Case of Alcohol Intoxication

Isabel M. Birnbaum and Thomas H. Taylor
University of California, Irvine

Marcia K. Johnson
Princeton University

Carol L. Raye
AT&T Information Systems, Summit, New Jersey

The four experiments reported show that sensitivity to event frequency is diminished by alcohol intoxication. In two experiments on confusion between presented and generated words, the function relating estimated to actual frequency was steeper for sober than intoxicated subjects. In two experiments on word-frequency estimates after a word-pronunciation task, the influence of alcohol intoxication was identified at the input as opposed to the test stage. We conclude that these findings are inconsistent with the idea that frequency-of-occurrence information is automatically encoded.

It has been well established that healthy, sober adults confuse memories of real events with memories of imagined events (Johnson & Raye, 1981; Johnson, Raye, Wang, & Taylor, 1979; Johnson, Taylor, & Raye, 1977; Raye, Johnson, & Taylor, 1980). The ability to identify the origin of an event (i.e., "I said that word" versus "I saw that word") has been labeled *reality monitoring* (Johnson & Raye, 1981).

The present studies began as an investigation of the effects of alcohol intoxication on reality monitoring (Johnson, 1977). It seemed to us extremely likely that alcohol would impair memory for the origin of events, given the abundant evidence that alcohol impairs human memory (Birnbaum & Parker, 1977) and folklore such as the story of the drunkard who cannot even distinguish his current mental creations (e.g., the proverbial pink elephants) from present events, let alone distinguish between prior imagined and real events. Besides the intrinsic interest of alcohol's effect on reality monitoring, Johnson (1977) also suggested that disrupted reality monitoring might help explain recognition deficits from alcohol intoxication. Intoxicated subjects might have special difficulty rejecting distractors which had been covert intrusions during acquisition.

Experiments 1 and 2 reported here used the frequency-judgment paradigm introduced by Johnson et al. (1977) to measure differences in degree of reality monitoring when subjects were either sober or intoxicated. Although we found some evidence for greater confusion between perceived and imagined events when subjects were intoxicated than when they were sober, the effect was limited to judgments of frequency of occurrence of external events (Experiment 1). In Experiment 2, where judgments of frequency of occurrence of self-generated events were made, the amount of confusion between real and imagined events was the same for sober and intoxicated subjects. The level of alcohol intoxication we used was one that reliably produces memory losses on a variety of tasks. It is possible that the reality-monitoring task that we used was not demanding enough to reveal the effects of intoxication on judgments of both types of events; or perhaps the loss of memory for origin of events is not as simply related to intoxication as we presumed. In any case, the experiments did not provide unequivocal support for the idea that alcohol-induced reality-monitoring deficits might, in part, account for alcohol-induced recognition deficits. We did, however, observe a more robust alcohol-related deficit that is relevant to the interpretation of recognition deficits as well as to an evaluation of the proposal that frequency information is encoded automatically (Hasher & Zacks, 1984).

Hasher and Zacks (1984) summarized compelling evidence that supports the assumption that encoding of event frequency is automatic. To recapitulate their points, sensitivity to frequency is the same regardless of the intention of the learner, amount of training, or explicit feedback; subjects who differ in age, motivation, or intelligence differ little in the processing of event frequency; and disruptions due to reductions in capacity such as stress, arousal, or depression have little impact on frequency judgments. In our studies of reality monitoring, we found a diminished sensitivity to event frequency when subjects were intoxicated. Assuming alcohol intoxication falls into the class of tasks that produce disruptions because of reductions in capacity (e.g., Craik, 1977), our results are relevant to the question of automaticity of encoding of event frequency.

Given the importance of the effect of alcohol on frequency judgments to a theory that proposes automaticity, our next step was to examine alcohol's impact on memory in a traditional task. In Experiments 3 and 4, words in a list occurred different numbers of times and sober or intoxicated subjects were later asked to make frequency estimates. The drinks were adminis-

This research was supported in part by National Alcohol Research Center Grant AA03506 from the National Institute of Alcohol Abuse and Alcoholism.

We thank Rosemary Boyd, Doris Margolis, Karen Schenk, Sherry Tackett, and Sherry Wexler for their valuable assistance throughout the project. We also wish to thank Rheem F. Jarrett and Susan C. Weller for their special help.

Correspondence concerning this article should be addressed to Isabel M. Birnbaum, School of Social Sciences, University of California, Irvine, California 92717.

tered either before word presentation and testing (Experiment 3), or only before testing (Experiment 4). With these manipulations, we intended to determine whether diminished sensitivity to event frequency was the result of alcohol's impact on ways of using a numerical scale rather than the result of a process that occurred during the input stage.

Experiments 1 and 2

In both experiments, each of 18 target words was shown to the subject 1, 3, or 5 times and was also generated by the subject 1, 3, or 5 times. Target words were instances of category names. On presentation trials, each target word was shown along with the category name. On generation trials, the target word was cued by the presence of the category name alone. The first generation trial of a specific target word was always preceded by at least one presentation trial of the pair consisting of a category name and the target word. Subjects were asked later, and without warning, to estimate either the frequency of presentation of each target word (Experiment 1) or the frequency of generation of each target word (Experiment 2). We expected intoxicated subjects to show more confusion than sober subjects between instances of presentation and generation. In other words, generating a word should inflate the estimate of its presentation frequency more for intoxicated than for sober subjects, and presenting a word should inflate the estimate of its generation frequency more for intoxicated than for sober subjects.

Experiment 1: Method

Design and subjects. A $2 \times 3 \times 3$ factorial design was used with group (sober or intoxicated) as a between-subjects factor and presentation frequency and generation frequency as within-subjects factors.

The subjects were 48 male, paid volunteers recruited on the campus of the University of California at Irvine. They ranged in age from 21 to 34 years. They were light to moderate drinkers who were screened for physical and psychological disorders. The subjects were asked to avoid drugs, including alcohol, for 24 hr before the test session. In addition, they were asked to eat nothing but a prescribed breakfast at least 3 hr before coming to the laboratory. Seven subjects were replaced for either procedural problems (5 subjects) or failure to follow instructions (2 subjects).

Materials. For each of 18 items, a category name served as the cue, and one of the three most popular instances of the category served as the target word (Battig & Montague, 1969). Our goal was to minimize the difficulty of generating the target word, given the cue. Two assignments of the 18 items to the nine combinations of presentation and generation frequency were made. Across assignments a particular item was not used more than once for the same presentation or generation frequency. Each assignment was used half of the time for sober and for intoxicated subjects.

Items were prepared on slides, and each slide was a trial. Each presentation-trial slide showed a category name (cue) in lowercase letters and the category member (target) in uppercase letters centered below the cue. Each generation-trial slide showed the category name alone in the same position it occupied on the presentation slide. Considering all repetitions of all items, there were 54 presentation trials and an equal number of generation trials. Trials of each type were divided into six blocks of 9 trials each. Blocks of presentation trials and generation trials were shown in simple alternation without an intervening signal. Several restrictions applied: A subject was not asked to generate a word before it had been presented, no item occurred more than once in a block, and at least 4 trials separated a successive presentation and generation of a particular word. The distribution of lags between successive repetitions (ignoring type of trial) of the two items assigned to particular combinations of presentation and generation frequency was approximately the same.

A third type of slide was prepared for the frequency-judgment task. Each slide showed a target word (category member) in uppercase letters in the same position as on the presentation slides. For sober and for intoxicated subjects, two different test orders were used equally often for each assignment of items.

Procedure. Each subject was tested individually and was assigned randomly to the sober or intoxicated group. Upon arrival at the laboratory, the subject was weighed, was administered a breath test, and was given instructions about the tasks that would occur after the drinks were ingested. During the session, breath tests occurred 20 min after the last drink was consumed and immediately after the frequency-judgment task. A Mark IV Gas Chromatographic Intoximeter was used to measure the amount of alcohol in a sample of alveolar air; blood alcohol level is estimated from this measure assuming an approximate ratio of 2100:1 (alcohol in alveolar air to alcohol in blood; Mason & Dubowski, 1976). For the tasks described here, the subject was told that his ability to form and remember associations would be tested. The format of presentation and generation slides was described. It was made clear that on the presentation trials, the subject was to read aloud the category name and then the category member and to try to remember that the two went together; on the generation trials he was to read aloud the category name and then try to call out the missing category member. The subject was also told that he might study and be tested on some items several times; no mention was made of the frequency-judgment task. These instructions were given while all subjects were in the sober state.

After these instructions subjects received two drinks that were consumed slowly over two consecutive 20-min periods. Subjects in the intoxicated group received a total dose of 1.00 ml of absolute alcohol for each kilogram of body weight, distributed equally in two drinks. An appropriate volume of 80-proof vodka was mixed with an equal volume of peppermint-flavored masking solution to form each drink. Subjects in the sober group received an appropriate volume of water in place of vodka, mixed with masking solution. The rims of the cups were swabbed with a miniscule amount of vodka.

Before the slides were presented the subject was briefly reminded of his task. Each subject proceeded through the material at his own pace. The experimenter encouraged the subject to guess if he took more than a few seconds to say a category member on generation trials. After the last trial, instructions were given for the frequency-judgment task. It was emphasized that the subject was to judge how many times each category member had appeared along with the category name, and not how many times he had produced it when tested. To ensure that the subject understood these instructions he was asked to paraphrase them and was corrected as necessary. Testing was paced by the subject.

Experiment 1: Results

The mean blood alcohol concentration for the intoxicated group was .07 g/100 ml just before the task began and about 12 min after the task had ended (*SD*s $< .02$). For the sober group, the mean blood-alcohol concentration was zero throughout.

There was no evidence for differences between sober and intoxicated subjects in amount of time to read or to generate words, in accuracy of generated words, or in time to produce frequency judgments. Specifically, the average time to complete a block of presentation or generation trials ranged from 27.2 to 28.3 s and there were no significant differences between groups, $Fs < 1.00$. The mean number of appropriate category members

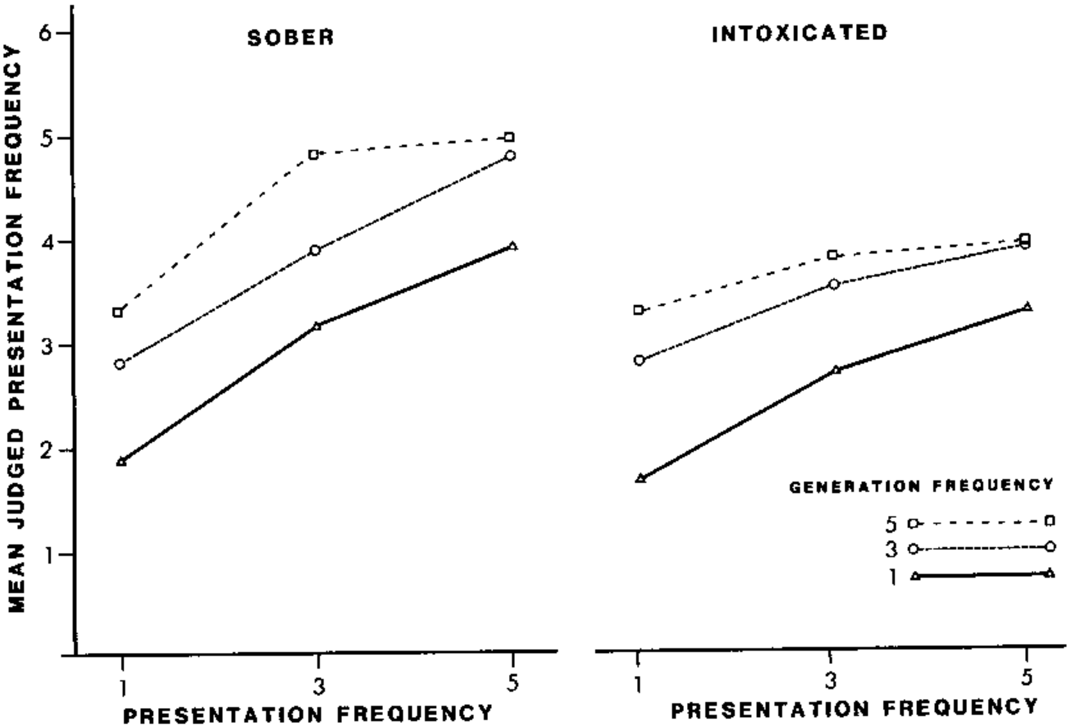

Figure 1. Mean judged presentation frequency as a function of actual presentation frequency for sober subjects (left panel) and intoxicated subjects (right panel): Experiment 1.

produced on generation trials was close to perfect (*M*s = 0.95, 2.94, and 4.95 for generation frequencies of 1, 3, and 5, respectively), and no effects involving alcohol approached significance (*p*s > .14). The sober and intoxicated groups completed the frequency-judgment task in an average of 87.9 and 82.6 s, respectively, $F < 1.00$.

Figure 1 shows the average estimates of presentation frequency given by sober subjects (left panel) and intoxicated subjects (right panel). Each panel shows judged presentation frequency as a function of actual presentation frequency, with generation frequency as a parameter. A 3-way analysis of variance (ANOVA) (Group × Presentation Frequency × Generation Frequency) was performed on these judgments. Not surprisingly, the estimates of presentation frequency increased with actual presentation frequency, $F(2, 92) = 81.36$, $MS_e = 1.06$, $p < .001$. Furthermore, the rate of increase was less for the intoxicated than the sober group, $F(2, 92) = 5.82$, $p < .001$, for the interaction between group and presentation frequency; thus, by using slope as an index of sensitivity to frequency, we see that intoxicated subjects were less sensitive to increases in event frequency than were sober subjects. Also, despite the appearance of Figure 1, there was no significant effect of group, $F(1, 46) = 2.67$, $p > .10$. For each subject, the correlation between estimated and actual presentation frequency was also determined (Flexser & Bower, 1975). Sober and intoxicated groups differed significantly on this measure of sensitivity, $r = .77$ and .57, respectively, $F(1, 46) = 6.34$, $MS_e = .23$, $p < .02$; there was a significantly higher correlation with low than with high generation frequency, $F(2, 92) = 7.09$, $MS_e = .21$, $p < .001$, and there was no significant interaction of Group × Generation Frequency, $F(2, 92) = 1.19$, $p > .25$.

In agreement with previous findings (e.g., Johnson et al., 1977), saying a word systematically increased the apparent frequency of having seen the word: Estimated presentation frequency increased with generation frequency for both groups, $F(2, 92) = 41.57$, $MS_e = 1.39$, $p < .001$. There was no indication that the degree of confusion differed for sober and intoxicated subjects, $F < 1.00$. The only other significant effect in the three-way ANOVA of judged presentation frequency was the interaction of Presentation Frequency × Generation Frequency, indicating that generating a word had a significantly smaller effect on estimated frequency as actual presentation frequency increased, $F(4, 184) = 2.72$, $MS_e = 0.58$, $p < .05$.

Another measure of confusion between real and imagined events yields a different outcome from the preceding analysis. We assessed the amount of confusion between presentation and generation frequency by looking at the extent to which each variable contributed to the variance in judgments of presentation frequency (Experiment 1) and generation frequency (Experiment 2).[1] The proportion of variance among judgment means accounted for by linear trend in presentation frequency and generation frequency is shown in Table 1. As can be seen in Table 1, in Experiment 1 the relevant variable accounted for a greater proportion of variance than did the irrelevant variable (.63 vs. .31) for sober subjects, whereas judgments made by in-

[1] We wish to thank Douglas L. Hintzman for suggesting this analysis.

Table 1
Proportion of Variance Accounted for by Linear Trend in Judged Presentation Frequency and Judged Generation Frequency

	Dependent variable	
Independent variable	Judged presentation frequency (Experiment 1)	Judged generation frequency (Experiment 2)
Sober subjects		
Presentation frequency	.63	.06
Generation frequency	.31	.85
Intoxicated subjects		
Presentation frequency	.43	.06
Generation frequency	.45	.82

toxicated subjects were affected about equally by both variables (.43 vs. .45). The relatively greater influence of the relevant than the irrelevant variable on judgments of presentation frequency by sober subjects indicates that they were better able to discriminate presentation from generation frequency than were intoxicated subjects, that is, reality monitoring was superior for sober subjects by this measure of confusion.

In summary, the results of Experiment 1 showed that sober and intoxicated subjects were similar in speed and accuracy of doing the tasks. According to the ANOVA of judged presentation frequency, the amount of confusion between saying and seeing a word was equivalent for sober and intoxicated subjects; according to the measure of proportion of variance explained, however, sober subjects were better able than intoxicated subjects to discriminate between real and imagined events. Increases in word frequency had a greater impact on frequency judgments of sober than intoxicated subjects as shown by differences in the slope of the function relating judged and actual frequency as well as by differences in the correlation between estimated and actual frequency.

Experiment 2: Method

Experiment 2 differed from Experiment 1 only in that different subjects were used and different instructions were given prior to the frequency-judgment task, that is, subjects were asked to estimate the number of times they had generated each word. The details of subject selection, materials, and procedure were otherwise the same. Again, 48 male, paid volunteers served as subjects. They ranged in age from 21 to 29 years old. One subject was replaced because he did not follow instructions.

Experiment 2: Results

The mean blood alcohol concentration was .07 g/100 ml just before and just after the task (*SD*s = .01). The blood alcohol concentration for the sober group was zero on both occasions.

Again, there were no significant differences between sober and intoxicated subjects in amount of time to read or to generate words, or in number of accurately generated words. Specifically, the average time to complete a block of presentation or generation trials ranged from 26.8 to 28.2 s, $Fs < 1.00$. The mean number of accurate generations was again high: 0.97, 2.92, and 4.98 for generation frequencies of 1, 3, and 5, respectively ($p < .001$); no effects involving alcohol approached significance, $ps > .33$. The frequency-judgment task was completed significantly more slowly by sober than intoxicated subjects, $Ms = 94.3$ and 80.3 s, respectively, $F(1, 45) = 4.49$, $MS_e = 516.71$, $p < .05$.

Figure 2 shows the mean estimated generation frequencies given by sober subjects (left panel) and intoxicated subjects (right panel). Each panel shows judged generation frequency as a function of actual generation frequency, with presentation frequency as a parameter. The three-way ANOVA (Group × Presentation Frequency × Generation Frequency) showed a significant main effect of generation frequency, $F(2, 92) = 330.19$, $MS_e = 0.53$, $p < .001$, and a significant interaction of Group × Generation Frequency, $F(2, 92) = 10.55$, $p < .001$. Intoxicated subjects showed less sensitivity to increases in generation frequency than sober subjects, a finding that parallels the phenomenon of reduced sensitivity to presentation frequency found in Experiment 1. The correlation between estimated and actual generation frequency also differed between sober and intoxicated groups, $r = .88$ and .76, respectively, $F(1, 46) = 5.43$, $MS_e = .09$, $p < .02$.

There was again some evidence for confusion between memories of seeing and saying a word: There was a significant main effect of presentation frequency on judged generation frequency, $F(2, 92) = 22.05$, $MS_e = 0.52$, $p < .001$. There was no evidence for a difference between sober and intoxicated subjects in degree of confusion ($p > .33$). As we found in Experiment 1, there was a significant interaction of Presentation Frequency × Generation Frequency, $F(4, 184) = 14.71$, $MS_e = 0.44$, $p < .001$. Presenting a word had a smaller effect on judged generation frequency as actual generation frequency increased. As can be seen in Table 1, the contributions of the relevant and irrelevant variables to variance in judged generation frequency are about the same for sober and intoxicated subjects. The analyses based on judged generation frequency and on proportion of variance explained, therefore, yield the same conclusion regarding intoxication and reality monitoring: Intoxication has no effect on reality monitoring in this case.

In summary, sober and intoxicated subjects were similar in speed and accuracy during the presentation and generation task; sober subjects were slower than intoxicated subjects when making estimates of generation frequency. Intoxication had no effect on reality monitoring, but it decreased the effect of generating a word on estimates of generation frequency.

Experiment 3

Our goal in Experiments 3 and 4 was to examine the generality of the earlier findings regarding diminished sensitivity to event frequency under alcohol intoxication. Will similar results be found in a situation that does not involve explicit confusion between perceived and generated events? In addition, we hoped to separate the effect of alcohol during study from its effect during testing. In Experiment 3, words were read aloud by sober or intoxicated subjects, ostensibly for our assessment of enunciation under different conditions. Subjects were not warned of the frequency-judgment task. In Experiment 4, by delaying the

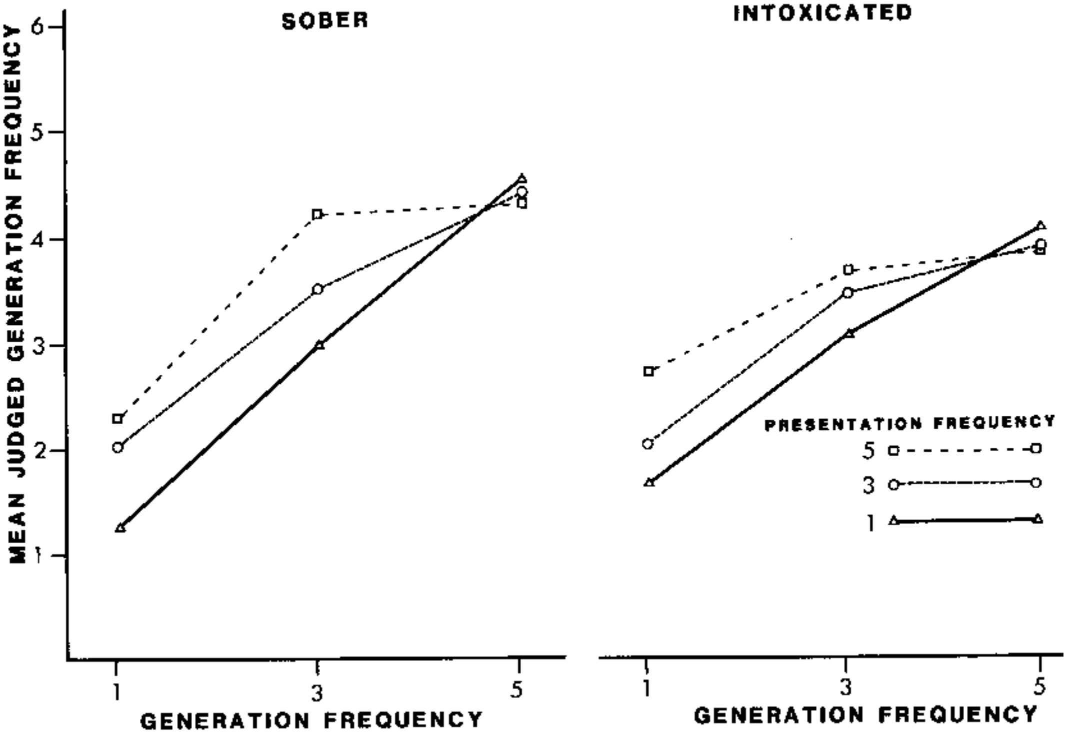

Figure 2. Mean judged generation frequency as a function of actual generation frequency for sober subjects (left panel) and intoxicated subjects (right panel): Experiment 2.

point at which drinks were consumed, we assessed possible effects of alcohol on ways subjects use a numerical scale. The two experiments were run at different times of the year, and are reported separately. The time between study and testing was longer in Experiment 4 and included the ingestion of drinks.

Method

Design and subjects. The design was a 2 × 3 factorial with group (sober vs. intoxicated) as a between-subjects factor and presentation frequency (1, 3, or 5) as a within-subjects factor.

The subjects were 48 male, paid volunteers between the ages of 21 and 35. The details of recruitment and preliminary screening were the same as in Experiments 1 and 2. Four subjects were replaced because of procedural errors.

Materials. Two different word lists were constructed, each containing 12 target words and 12 buffer words. The target words were nouns of A or AA normative frequency (Thorndike & Lorge, 1944) with imagery ratings of 6.00 or higher (Paivio, Yuille, & Madigan, 1968). Buffer words of the same frequency with imagery ratings of at least 5.00 occupied the first and last six serial positions in each list. Four different target words were assigned randomly to each list and presentation frequency. Within each list the order of target words was random with some restrictions. Repeated occurrences of a particular word were distributed approximately equally across the list, as were the 4 words that occurred only one time.

Procedure. Preparation for the session was the same as in the preceding experiments. Following the preliminary procedures the experimenter described the tasks that would occur later in the session (after the drinks were administered). For the word-reading task described here, the subject was told that he should read each word aloud in a natural way and that his responses would be tape-recorded. The frequency-judgment task that would follow was not mentioned.

The administration of drinks was the same as in the previous experiments. The word-reading task began about 40 min after the end of the second drinking period (a sentence-recognition task and free recall intervened between the drinking period and the word-reading task). The subject was reminded briefly of the procedure and then the words were presented on slides, one at a time, at a 3-s rate. After the last word had been read aloud, the experimenter explained the frequency-judgment task; then each word was shown and the subject estimated the number of times he had read the word aloud. The test was paced by the subject and two different orders of testing were used equally often.

Results

The mean blood alcohol concentration measured immediately before and immediately after the word-reading task was .07 g/100 ml for the intoxicated group (SD = .01) and zero for the sober group.

Figure 3 shows mean judged presentation frequency as a function of actual presentation frequency for the sober and intoxicated groups. The well-established sensitivity of subjects to event frequency is evident; there was a significant main effect of presentation frequency, $F(2, 92) = 308.58$, $MS_e = 0.50$, $p < .001$. The apparently greater sensitivity of sober than intoxicated subjects to presentation frequency in Figure 3 is borne out by the significant interaction of Group × Presentation Frequency, $F(2, 92) = 9.39$, $p < .001$. There was also a significant main effect of group, $F(1, 46) = 9.37$, $MS_e = 1.60$, $p < .001$. The results are consistent with the differences between sober and intoxicated subjects in sensitivity to event frequency seen in Experiments 1 and 2.

Experiment 4

All three of the previous experiments support the notion that event occurrence has a smaller impact on intoxicated than on sober subjects. This conclusion rests on the assumption that subjects' estimates of event frequency reflect the cumulative registration of the effects of that event. Another possibility is that intoxicated subjects use the scale of numbers differently than do sober subjects in this situation. That is, the subjective quantification of mnemonic information rather than the accumulation of information that permits recurrence judgments may be influenced by alcohol intoxication. The previous results can be explained by differences in registration, differences in the use of numbers to make judgments, or both. Experiment 4 was designed to assess the effect of intoxication on scaling independent of its effect on registration.

Method

The design and materials of Experiments 3 and 4 were identical; the procedures differed in the following ways: In Experiment 4 the drinks were administered after rather than before the words were read aloud (all subjects therefore were sober during word presentation), and there was a longer delay (1.4 hr vs. 1 min) between the presentation of the word list and the frequency-judgment task. Two 20-min drinking periods and free-recall learning of a categorized list filled the interval. Just prior to the frequency-judgment task, the subject was reminded of the list of words that he had read aloud earlier in the session. Instructions for the task were then given as in Experiment 3. The 48 subjects who served in this experiment ranged in age from 21 to 31 years and one subject was replaced because he could not tolerate the dose of alcohol.

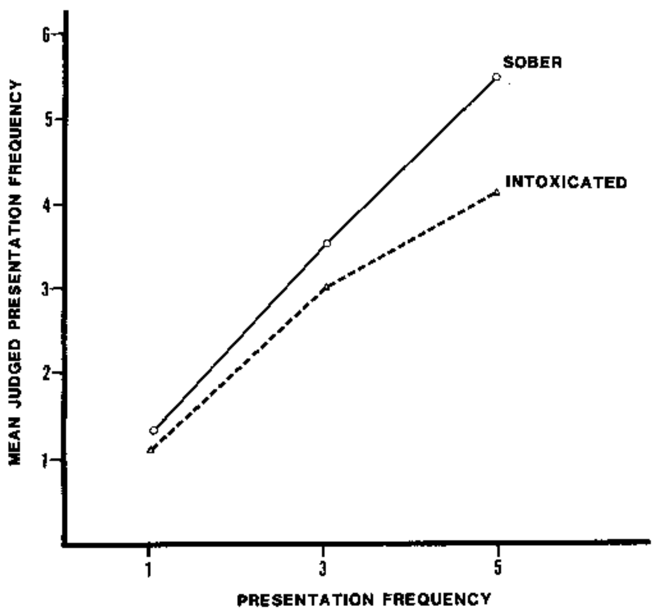

Figure 3. Mean judged presentation frequency as a function of actual presentation frequency: Experiment 3.

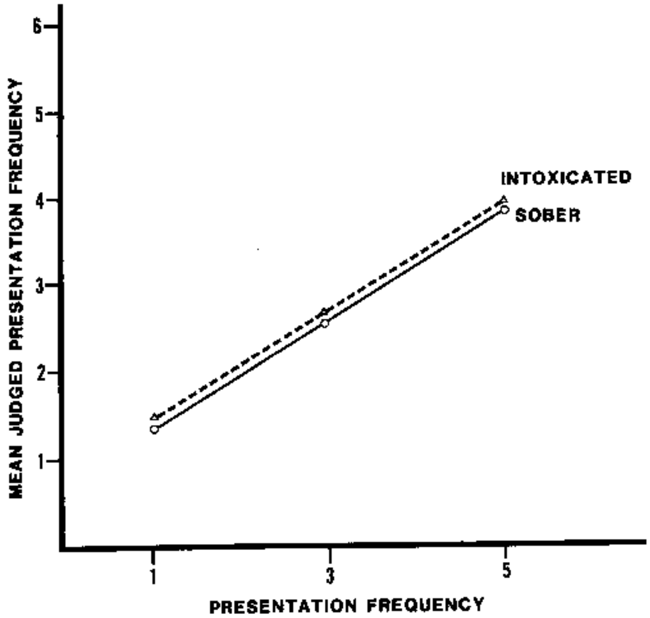

Figure 4. Mean judged presentation frequency as a function of actual presentation frequency: Experiment 4.

Results

Because of equipment difficulties we can only report the mean blood alcohol concentration measured 25 min after the frequency-judgment task was completed; at that time, the means were .08 g/100 ml (SD = .01) for the intoxicated group and zero for the sober group.

Figure 4 shows mean judged presentation frequency as a function of actual presentation frequency, with group as a parameter. A two-way ANOVA yielded only one significant effect, presentation frequency, $F(2, 92) = 224.17$, $MS_e = 0.33$, $p < .001$. For the main effect of group and the interaction of Group × Presentation Frequency, Fs < 1.00. Thus, both the appearance of Figure 4 and the statistical analysis support the conclusion that alcohol intoxication did not affect estimates of presentation frequency.[2] This finding supports the notion that the occurrence of an event has less impact on intoxicated than sober subjects; the translation of mnemonic information to magnitude estimates appeared to be uninfluenced by intoxication. Additionally, it should be noted that change of state from presentation to testing did not affect the estimates of presentation frequency.

General Discussion

Our results add to a growing body of data pointing to the need to reexamine conclusions regarding automaticity of en-

[2] The delay between acquisition and testing was greater in Experiment 4 than Experiment 3. In order for the delay alone to have eliminated the differences found in Experiment 3, it would have to be assumed that sober subjects showed more rapid forgetting of frequency information than do intoxicated subjects, which would bring the functions together. Because there is no evidence in the literature to suggest more rapid forgetting for sober subjects, this is an unlikely possibility.

coding of frequency information. In three studies, intoxicated subjects were less influenced than sober subjects by increases in either presentation or generation frequency.[3] Results of the fourth study indicated that this effect occurred at the registration or input stage as opposed to the time at which the frequency judgments were made. These findings indicate that the process of frequency encoding may violate one of the six criteria of automatic encoding, ". . . all of which must be jointly satisfied, for us to conclude that an aspect or attribute of experience is automatically encoded" (Hasher & Zacks, 1984, p. 1373). Specifically, the sixth criterion listed by Hasher and Zacks is that variables such as stress and depression, which reduce processing capacity, will have little or no impact on automatic processes. Presumably, drugs such as alcohol also fall into this category (Craik, 1977). The finding that alcohol intoxication reduced the effect of recurrence suggests that the processing of frequency information is not automatic. Naveh-Benjamin and Jonides (1986) also found diminished sensitivity to frequency when additional demands were placed on processing capacity.

Any conclusions about the nonautomatic nature of frequency encoding should be tempered by our finding that even under conditions in which subjects did not expect a memory test ("truly incidental" conditions; Kausler, Lichty, & Hakami, 1984), both intoxicated and sober subjects reliably discriminated between different frequencies of presentation or generation. There may be a point of extreme intoxication where subjects are still conscious and do perceive events but do not discriminate at all between items of different frequencies. However, we do not believe that the results have to be quite so dramatic to challenge the idea of automatic frequency encoding. The issue is whether the ability to make frequency judgments should be considered an all-or-none phenomenon. Most investigators are willing to conclude that recall or recognition has been disrupted on the basis of performances that are above zero or chance, but less than some control condition. Similarly, better-than-chance frequency discrimination is not the same as maximum frequency discrimination. Thus, insofar as independent variables affect the subjective frequency difference between events of different actual frequency, frequency judgments appear to be the consequence of processes that can produce intermediate levels of performance. Of course, whether these intermediate levels of performance result from variations in qualitative characteristics of events or from variations in judgment processes (including retrieval of encoded information) remains to be specified for particular situations.

Other findings also raise questions about the hypothesis that frequency encoding is automatic. For example, one of the criteria for automaticity of encoding is invariance with age. Although a considerable body of data shows such invariance for frequency encoding (Hasher & Zacks, 1984, pp. 1377–1378), there are some conflicting reports. Differences were found in sensitivity to frequency information between grade-school children and college students (Johnson, Raye, Hasher, & Chromiak, 1979), between college students and older adults (Hasher & Zacks, 1979, Experiment 2), and between elderly adults and young adults (Kausler et al., 1984). Although it might be retrieval rather than encoding that is affected, it is not at all clear that sensitivity to event frequency is uninfluenced by age.

Another criterion of automaticity, invariance with different encoding activities, is not always met with frequency judgments. Fisk and Schneider (1984) showed that task variables can influence frequency judgments. Specifically, estimates of the frequency of occurrence of words were better after a semantic-categorization task than a graphic-categorization task; also, word-frequency estimates were extremely poor after an intentional or an incidental word-reading task when a digit-search task was performed simultaneously. In another study, Chua-Yap, Johnson, and Thompson (1984) found that subjects were insensitive to differences in the frequency with which letters occurred in particular typeface when the primary task involved reporting the location of the letters. Earlier work by Rose and Rowe (1976) and Rowe (1974) showed that frequency estimates were more accurate after semantic than orthographic tasks. Greene (1984) found that frequency estimation was influenced by intention to learn and type of orienting task. In summary, although a substantial body of evidence supports Hasher and Zacks' conclusion that "the encoding of frequency information is uninfluenced by most task and individual difference variables" (1984, p. 1385), the accumulation of new evidence from different directions may require that this conclusion be modified. The question of the automaticity of encoding of frequency information is far from resolved.

What mechanism might account for decreased sensitivity to recurrence information under alcohol intoxication? It is possible that sober subjects engage in more uncontrolled rehearsal or internal review of presented and generated words than do intoxicated subjects. If this were the case, then the presentation frequency-estimation functions of sober subjects might have steeper slopes than those of intoxicated subjects. In other words, intoxicated subjects may not have reduced sensitivity to event frequency but rather may experience fewer (internally generated) events compared with sober subjects. However, a steeper slope for judged presentation frequency is not a necessary consequence of more uncontrolled rehearsal. If subjects engaged in more covert rehearsal of infrequent than frequent items (a plausible learning strategy), the result would be a reduction in slope.

Our earlier work on alcohol-induced deficiencies in recognition memory suggested that intoxication leads to a reduction in elaborative processing of incoming information (Birnbaum, Johnson, Hartley, & Taylor, 1980; see also Hashtroudi, Parker, DeLisi, & Wyatt, 1983). Elaboration is important for recognition memory (e.g., Mandler, 1980); it may also be important for frequency judgments. When subjects are sober, perhaps each occurrence of an event produces a well-elaborated trace (Craik & Tulving, 1975). Such traces of the same event may be readily retrieved and/or differentiated from one another, and their frequency may be easily estimated (Hintzman, 1976). When subjects are intoxicated, individual traces of the same event may have a paucity of embellishment and hence may be less easily differentiated from one another. If that were the case, then their apparent frequency would be reduced. Thus, the mechanism of reduced elaborative processing could account for reduced

[3] It should be noted that the levels of intoxication under which the tasks were completed in the present studies were far from severe, that is, well below the legal definition (in California) of "intoxicated."

sensitivity to recurrence information as well as for impaired recognition memory.

Cognitive activity that occurs when one is intoxicated very likely differs in a number of ways from cognitive activity that occurs when one is sober. Whether differences in rehearsal, elaboration, or other processes explain the present results remains to be seen. In any case, these experiments indicate that one consequence of alcohol intoxication is reduced sensitivity to frequency of occurrence.

Our original hypothesis regarding alcohol and reality monitoring received only limited support in Experiment 1 (when subjects judged presentation frequency) and no support in Experiment 2 (when subjects judged generation frequency). However, similar evidence for greater susceptibility to confusion when judging perceived events compared to generated events has been reported previously (Raye et al., 1980). Thus, although the present results are not strong, the hypothesis that moderate doses of alcohol disrupt reality monitoring deserves further investigation, as does the possibility that judgments of internal-event frequency may be more stable across a range of conditions than are judgments of external-event frequency.

References

Battig, W. F., & Montague, W. E. (1969). Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology Monograph, 80*(3, Pt. 2).

Birnbaum, I. M., Johnson, M. K., Hartley, J. T., & Taylor, T. H. (1980). Alcohol and elaborative schemas for sentences. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 293–300.

Birnbaum, I. M., & Parker, E. S. (Eds.). (1977). *Alcohol and human memory.* Hillsdale, NJ: Erlbaum.

Chua-Yap, E., Johnson, M. K., & Thompson, S. (1984, April). *Processes involved in the acquisition of frequency information.* Paper presented at the meeting of the Eastern Psychological Association, Baltimore, MD.

Craik, F. I. M. (1977). Similarities between the effects of aging and alcoholic intoxication on memory performance, construed within a levels of processing framework. In I. M. Birnbaum & E. S. Parker, (Eds.), *Alcohol and human memory* (pp. 9–21). Hillsdale, NJ: Erlbaum.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and retention of words in episodic memory. *Journal of Experimental Psychology: General, 104,* 268–294.

Fisk, A. D., & Schneider, W. (1984). Memory as a function of attention, level of processing, and automatization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 181–197.

Flexser, A. J., & Bower, G. H. (1975). Further evidence regarding instructional effects on frequency judgments. *Bulletin of the Psychonomic Society, 6,* 321–324.

Greene, R. L. (1984). Incidental learning of event frequency. *Memory & Cognition, 12,* 90–95.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356–388.

Hasher, L., & Zacks, R. T. (1984). Automatic processing of fundamental information. *American Psychologist, 39,* 1372–1388.

Hashtroudi, S., Parker, E. S., DeLisi, L. E., & Wyatt, R. J. (1983). On elaboration and alcohol. *Journal of Verbal Learning and Verbal Behavior, 22,* 164–173.

Hintzman, D. L. (1976). Repetition and memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 10, pp. 47–91). New York: Academic Press.

Johnson, M. K. (1977). What is being counted none the less? In I. M. Birnbaum & E. S. Parker, (Eds.), *Alcohol and human memory* (pp. 43–57). Hillsdale, NJ: Erlbaum.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review, 88,* 67–85.

Johnson, M. K., Raye, C. L., Hasher, L., & Chromiak, K. (1979). Are there developmental differences in reality monitoring? *Journal of Experimental Child Psychology, 27,* 120–128.

Johnson, M. K., Raye, C. L., Wang, A. Y., & Taylor, T. H. (1979). Fact and fantasy: The roles of accuracy and variability in confusing imaginations with perceptual experiences. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 229–240.

Johnson, M. K., Taylor, T. H., & Raye, C. L. (1977). Fact and fantasy: The effects of internally generated events on the apparent frequency of externally generated events. *Memory & Cognition, 5,* 116–122.

Kausler, D. H., Lichty, W., & Hakami, M. K. (1984). Frequency judgments for distractor items in a short-term memory task: Instructional variation and adult age differences. *Journal of Verbal Learning and Verbal Behavior, 23,* 660–668.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87,* 252–271.

Mason, M. F., and Dubowski, K. M. (1976). Breath-alcohol analysis: Uses, methods, and some forensic problems. *Journal of Forensic Sciences, 21,* 9–41.

Naveh-Benjamin, M., & Jonides, J. (1986). On the automaticity of frequency coding: Effects of competing task load, encoding strategy, and intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 378–386.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology, 76*(1, Pt. 2).

Raye, C. L., Johnson, M. K., & Taylor, T. H. (1980). Is there something special about memory for internally generated information? *Memory & Cognition, 8,* 141–148.

Rose, R. J., & Rowe, E. J. (1976). Effects of orienting task and spacing of repetitions on frequency judgments. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 142–152.

Rowe, E. J. (1974). Depth of processing in a frequency-judgment task. *Journal of Verbal Learning and Verbal Behavior, 13,* 638–643.

Thorndike, E. L., & Lorge, I. (1944). *The teacher's word book of 30,000 words.* New York: Teachers College, Columbia University.

Received June 3, 1985
Revision received June 9, 1986 ■