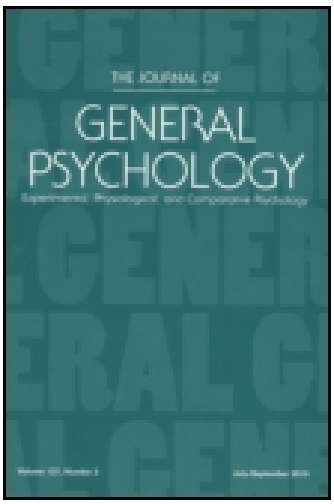

The Journal of General Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vgen20

Memory for Frequency of Bizarre and Common Stimuli: Limitations of the Automaticity Hypothesis

James B. Worthen [a], Jeffrey D. Baker [a], Scott A. Hutchens [b] & Paul D. Nicodemus [b]

[a] Department of Psychology, Southeastern Louisiana University

[b] Department of Psychology, Delta State University

Published online: 30 Mar 2010.

To cite this article: James B. Worthen, Jeffrey D. Baker, Scott A. Hutchens & Paul D. Nicodemus (2002) Memory for Frequency of Bizarre and Common Stimuli: Limitations of the Automaticity Hypothesis, The Journal of General Psychology, 129:3, 212-225, DOI: 10.1080/00221300209602096

To link to this article: http://dx.doi.org/10.1080/00221300209602096

The Journal of General Psychology, 2002, *129*(3), 212–225

Memory for Frequency of Bizarre and Common Stimuli: Limitations of the Automaticity Hypothesis

JAMES B. WORTHEN
JEFFREY D. BAKER
Department of Psychology
Southeastern Louisiana University

SCOTT A. HUTCHENS
PAUL D. NICODEMUS
Department of Psychology
Delta State University

ABSTRACT. In 2 experiments, the influence of intention to process frequency on accuracy of memory for frequency of bizarre and common sentences was investigated. The results from multiple regression analyses indicated that intentional processing increased the accuracy of frequency judgments when memory for frequency was tested after a 2-min (Experiment 1) and after a 48-hr (Experiment 2) retention interval. Furthermore, the results of Experiment 2 indicated that unintentional processors tended to overestimate frequencies of bizarre relative to common items after a delay. The implications of the results are discussed with regard to L. Hasher and R. T. Zacks's (1984) automaticity hypothesis, human performance, and the accuracy of judgments of frequency of occurrence of unusual events.

Key words: automatic process, bizarreness effect, frequency encoding, memory for unusual events

FREQUENCY OF OCCURRENCE INFORMATION plays an integral role in several higher order cognitive processes, including knowledge representation (Barsalou, 1985; Rips & Collins, 1993; Worthen, Hutchens, Roark, & Gutierrez, 1998; Worthen & Nakamura, 1995) and decision making (Bacon, 1979; Hasher, Goldstein, & Toppino, 1977; Mumma, 1993; Zajonc, 1968). Fundamental to understanding the role of frequency information within the larger cognitive system is the determination of whether frequency judgments are the result of an automatic or controlled process. Although a fair amount of research has

addressed the issue of automaticity of frequency judgments using common materials, no previous research has examined the influence of stimulus bizarreness on memory for frequency.

The importance of examining stimulus bizarreness in the context of the automaticity paradigm is twofold. First, because processing bizarre information requires more cognitive resources than does processing common information (Hauk, Walsh, & Kroll, 1976; McDaniel & Einstein, 1986; Nappe & Wollen, 1973; Worthen, Garcia-Rivas, Green, & Vidos, 2000), a manipulation of stimulus bizarreness allows one to determine whether memory for frequency meets a key criterion of an automatic process: that the process neither benefits nor suffers from fluctuations in the allocation of cognitive resources. Second, the accuracy of memory for frequency of bizarre relative to common events may have important implications regarding the accuracy of eyewitness testimony and memory-based judgments in situations in which a witnessed event was unusual, surprising, or both.

Early research investigating the automaticity of frequency judgments indicated that memory for frequency remained invariant across levels of a wide variety of variables, including age; education; training; psychological state; and, most important, effort (see Hasher & Zacks, 1984, for a review). Despite these findings, several subsequent studies demonstrated fluctuations in the accuracy of frequency judgments as a function of levels of processing, encoding strategy, or both (Greene, 1984, 1986; Maki & Ostby, 1987; Naveh-Benjamin & Jonides, 1985, 1986). Specifically, these studies indicated that the accuracy of frequency judgments is enhanced by semantic processing and intentional learning procedures—thus suggesting that frequency encoding is not entirely automatic. The notion that frequency judgments are influenced by levels of processing raises interesting questions regarding the accuracy of frequency judgments of bizarre events. First, previous research has consistently demonstrated that more time is required to comprehend and image bizarre than common information (Hauk et al., 1976; Kroll & Tu, 1988; McDaniel & Einstein, 1986; Nappe & Wollen, 1973; Worthen et al., 2000). On the basis of these results, one would expect frequency judgments to differ for bizarre and common items only if memory for frequency is the result of an effortful (not automatic) process. However, if memory for frequency is the result of an automatic process, then the bizarreness of stimuli should have no influence on frequency judgments.

Although the effortful view of frequency encoding clearly predicts differences in memory for frequency of bizarre and common information, it is not clear whether bizarre or common information should be judged most accurately. More-

Portions of this article were presented at the 46th Annual Meeting of the Southeastern Psychological Association, New Orleans, LA.

Address correspondence to James B. Worthen, Department of Psychology, Southeastern Louisiana University, SLU Box 10831, Hammond, LA 70402; jworthen@selu.edu (e-mail).

over, no studies specifically designed to investigate memory for frequency of bizarre and common stimuli within an automaticity paradigm can be found in the literature. However, two studies that address issues related to those addressed here suggest that the accuracy of frequency judgments for bizarre and common stimuli differs. First, Williams and Durso (1986) examined frequency judgments for categories referenced by either typical or atypical category exemplars. Although their atypical exemplars (e.g., duck for the category *bird*) did not differ from the typical exemplars (e.g., robin) in a way that would necessarily be considered bizarre or surprising, frequency judgments for categories referenced by atypical exemplars were found to be less accurate than frequency judgments for categories referenced by typical exemplars. Similarly, Wiggs (1993) found that participants made more errors in a frequency judgment task with novel stimuli (Japanese ideograms) than in one with common verbal stimuli (English words). Inasmuch as category atypicality and novelty are analogous to bizarreness, these findings are consistent with the prediction that the bizarreness of an item disrupts memory for its own frequency of occurrence. Thus, on the basis of these findings one would predict that common frequency judgments would be more accurate than bizarre frequency judgments.

We must note, however, that stimulus type was manipulated between participants in both the Williams and Durso (1986) and Wiggs (1993) studies. Thus, there was no possibility of the unusual items actively disrupting memory for frequency of the common items within a particular list. The importance of the between-groups manipulation is underscored when one considers research indicating that the effects of bizarreness are dependent on list composition. For example, McDaniel and colleagues (McDaniel & Einstein, 1986; McDaniel, Einstein, DeLosh, May, & Brady, 1995) have demonstrated that several effects of bizarreness occur when stimulus type is manipulated within groups (using mixed lists), but these effects do not occur in between-groups designs (unmixed lists). Furthermore, several studies (DeLosh & McDaniel, 1996; McDaniel, DeLosh, & Merritt, 2000; McDaniel et al., 1995) have demonstrated that order memory for common items is disrupted in lists containing both common and bizarre (or unusual) items. If bizarreness disrupts memory for frequency in a similar fashion, then one might expect less accurate frequency judgments for common items than for bizarre items. In keeping with this notion, Kroll, Jaeger, and Dornfest (1992) used a within-subjects manipulation of item type in an investigation of metamemory for common and bizarre verbal stimuli and found memory for frequency of bizarre stimuli to be relatively more accurate than memory for frequency of common stimuli. Specifically, Kroll et al. found that participants underestimated the frequency of common items to a greater degree than they underestimated the frequency of bizarre items. Although Kroll et al. did not manipulate intention to process frequency (no participants were aware of the impending frequency memory task), the results of their study are consistent with the notion that bizarreness disrupts

memory for frequency of common information. However, it should be noted that Kroll et al. compared the mean frequency judgment for bizarre items with the mean frequency judgment for common items. Thus, judged frequency and actual frequency were not directly compared.

Despite methodological differences, previous research converges on the notion of accuracy differences in memory for frequency of bizarre and common information. Although this research appears to support an effortful account of memory for frequency, further research directly assessing the influence of stimulus bizarreness within an automaticity paradigm is needed. To remedy this need, two experiments incorporating an automaticity paradigm (cf. Hasher & Chromiak, 1977) were conducted. In Experiment 1, memory was tested for frequency of common and bizarre stimuli after a 2-min retention interval; in Experiment 2, memory was tested for frequency after a 48-hr retention interval. In order to treat actual frequency as a continuous variable, the data from both experiments were analyzed using multiple regression procedures. In terms of significance tests, multiple regression and analysis of variance procedures produce identical results when a continuous variable is manipulated in an experimental design. However, multiple regression is the preferred procedure because it provides a more complete analysis of the proportion of variance in the dependent variable accounted for by the independent variables (see Pedazur, 1997, for a discussion).

EXPERIMENT 1

In Experiment 1, we used multiple regression procedures to determine the utility of intention to process frequency, stimulus bizarreness, and actual frequency in predicting the accuracy of memory for frequency of occurrence after a 2-min retention interval. If frequency judgments are the result of an automatic process, as suggested by Hasher and Zacks (1984), then neither intention to process nor stimulus bizarreness should account for a significant proportion of the accuracy of frequency judgment variance. However, if memory frequency is an effortful process, then intention to learn, stimulus bizarreness, or both should account for a significant proportion of accuracy variance.

Method

Participants

Forty-eight undergraduate student volunteers drawn from psychology courses at Delta State University served as participants in Experiment 1 for course credit. Twenty-four participants were randomly assigned to the intentional frequency processing condition, and 24 participants were randomly assigned to the unintentional condition. All participants were tested individually.

Materials

Three lists of sentences, each containing equal numbers of bizarre and common items, were used in this study. The sentences used in our study were drawn from materials used in previous bizarreness research (e.g., Worthen et al., 2000). Furthermore, the sentences had been previously normed to ensure equivalency of average sentence length between item types within each list. An example of a bizarre sentence was "The ball captured the instructor with the net." The common form of the same sentence was "The instructor served the ball over the net." Each sentence appeared in either its bizarre form or its common form (not both) in each list. Each list contained 6 unique bizarre and 6 unique common sentences that varied in frequency of occurrence between one and six times. As such, each list contained a total of 42 items. All stimuli were presented in the middle of a computer monitor, and the order of presentation was randomized for each participant.

The frequency memory test was administered as a pencil-and-paper task. Each of the 12 unique sentences appearing on the stimulus list appeared in a randomized order on the frequency memory test as well as 2 additional sentences (1 bizarre and 1 common) that had not been presented previously (frequency of occurrence = 0). The frequency test sheet contained instructions for the task, and a blank space was provided beside each test sentence for participants to record their frequency estimate.

Design

Each participant was randomly assigned to either an intentional or an unintentional processing condition. Within each of these conditions, the participants were tested for common and bizarre sentences that were presented 0, 1, 2, 3, 4, 5, or 6 times. Thus, each participant contributed 14 data points to the analysis, for a total of 672 analyzable data points.

Procedure

The participants were tested individually in a room free from distractions. Those in the intentional processing condition were told that they would be required to read a series of sentences with the purpose of memorizing the frequency of occurrence of each sentence. Those in the intentional condition were explicitly told that their ability to remember the number of times each sentence was presented would be tested. Those in the unintentional condition were told that they would be required to read a series of sentences with the purpose of memorizing each sentence. Thus, the participants in the unintentional condition were not informed of the impending frequency judgment task. The participants in both conditions received both oral and written instructions.

After the participants were properly instructed, they were presented with the 42 stimulus sentences. Each sentence appeared in the middle of a computer monitor for a total of 8 s. After all sentences had been presented, the participants in both processing conditions solved simple math problems for 2 min. After the 2-min distractor task, each participant was presented with a sheet of paper containing the 12 unique stimulus sentences presented previously as well as 1 common and 1 bizarre sentence that had not been presented previously. Each participant was then instructed to place a number in the blank space beside each sentence corresponding to the frequency with which each sentence had been presented in the previous phase of the experiment. The participants were made aware that any given sentence appearing on the test sheet may or may not have been presented in the earlier phase of the experiment. After a frequency judgment had been made for all 14 test sentences, the participants were debriefed and then dismissed.

Results and Discussion

We scored accuracy of memory for frequency by taking the absolute value of the difference between the actual and judged frequency (Williams & Durso, 1986). However, because this method of scoring results in a measure that is insensitive to the direction of error, potentially interesting patterns of differences between item types may have been obscured. For example, the Williams and Durso accuracy measure would not be sensitive to a situation in which one item type is chronically overestimated and the other item type is chronically underestimated. Thus, to investigate the possibility of directional differences in frequency judgments, we also analyzed the raw frequency judgments. We used standard multiple regression analyses to ascertain both the accuracy scores and raw frequency judgments. For the purposes of these analyses, processing condition was dummy coded such that 0 equaled intentional processing and 1 equaled unintentional processing. Similarly, item type was dummy coded such that 0 equaled bizarre and 1 equaled common. Actual frequency and both criterion variables were treated as continuous variables. To correct for violations of homoscedasticity resulting from ceiling effects for judgments when the actual frequency was zero, we included only judgments for actual frequencies of 1–6 in each analysis. As such, each participant contributed 12 data points, resulting in a total of 576 data points in each analysis. The mean frequency judgment for bizarre and common items at each level of actual frequency in both processing conditions can be found in Table 1.

Accuracy Scores

Actual frequency, processing condition, and item type were entered into a standard multiple regression analysis as predictors of accuracy scores. (Prelimi-

TABLE 1
Mean Raw Frequency Judgments for Common and Bizarre Items at Each Level of Frequency Under Intentional and Unintentional Frequency Processing Conditions in Experiment 1

Processing condition	Actual frequency					
	1	2	3	4	5	6
Intentional processing						
Bizarre	0.96	2.58	3.21	4.83	5.25	5.67
Common	1.25	2.62	4.00	4.58	5.21	5.54
Unintentional processing						
Bizarre	1.79	3.04	4.00	4.75	5.25	6.00
Common	1.54	3.17	3.67	4.92	5.58	5.96
M	1.38	2.85	3.72	4.77	5.32	5.79

nary analyses indicated that the inclusion of interaction terms did not contribute significantly to the predictability of the model.) The analysis indicated that a significant proportion of accuracy variability was accounted for by a combination of the predictor variables, $F(3, 572) = 9.59, p < .0001, R^2 = .05$. Further analysis indicated that only actual frequency, $t(575) = 4.59, p < .0001$, and processing condition, $t(575) = 2.72, p < .01$, contributed uniquely to the prediction of accuracy scores. The results indicate that frequency judgments became less accurate as actual frequency increased and that intentional processors were more accurate than unintentional processors. The latter finding suggests that memory for frequency is influenced by effort and is thus not entirely the result of an automatic process.

Raw Frequency Judgments

The same pattern of results found with accuracy scores was found in the analysis of raw frequency judgments. Specifically, the combination of actual frequency, processing condition, and item type variables accounted for a significant proportion of raw frequency judgment variance, $F(3, 572) = 157.04, p < .0001, R^2 = .45$, and only actual frequency, $t(575) = 21.57, p < .0001$, and processing condition, $t(575) = 2.39, p < .05$, contributed uniquely to the prediction of those judgments. The former finding indicates that estimated frequency increased as actual frequency increased, whereas the latter finding indicates that unintentional processors overestimated frequency to a greater degree than intentional processors.

The results of this experiment argue against the notion put forth by previous researchers (e.g., Hasher & Zacks, 1984; Zacks, Hasher, & Hock, 1986) that memory for frequency is the result of a fully automatic process. Contrary to the automaticity hypothesis, the accuracy of frequency judgments was influenced by

intention to process frequency such that memory for frequency was more accurate when the participants intended to process frequency information than when they were not intending to process frequency. Moreover, the results of the present experiment suggest that the inaccuracy associated with unintentional processing of frequency is the result of overestimation of frequency relative to intentional processing.

Experiment 1 failed to support the notion that stimulus bizarreness significantly influences the accuracy of frequency judgments, their direction, or both. Despite these null findings, it is possible that some of the effects of bizarreness on memory for frequency were moderated by the use of a short retention interval. Several studies (Worthen & Wood, 2001a, 2001b) have demonstrated disruptive effects of bizarreness after a delay. Specifically, Worthen and Wood (2001a, 2001b) have demonstrated that memories for bizarre stimuli are more susceptible to distortion and memory bias than memories for common stimuli after a 48-hr retention interval. Thus, we designed Experiment 2 to explore the possibility that bizarreness has an influence on memory frequency after a 48-hr retention interval.

EXPERIMENT 2

Method

Participants

Forty-eight undergraduate student volunteers drawn from psychology courses at Delta State University served as participants in Experiment 2 for course credit. Twenty-four participants were randomly assigned to the intentional frequency processing condition, and 24 participants were randomly assigned to the unintentional condition. None of the participants tested in Experiment 2 were also tested in Experiment 1. All participants were tested individually.

Materials, Design, and Procedure

All aspects of Experiment 2 were identical to those of Experiment 1 except that in Experiment 2 memory frequency was tested 48 hr after the presentation of stimuli. Also, the distractor task (mathematics problems) used in Experiment 1 was not used in Experiment 2.

Results and Discussion

As in the previous experiment, we used standard multiple regression procedures to analyze accuracy scores and raw frequency judgments for actual frequencies 1–6. As in Experiment 1, judgments for actual frequencies of 0 were

omitted because the inclusion of those data caused a violation of the assumption of homoscedasticity. The mean frequency judgment for bizarre and common items at each level of actual frequency in both processing conditions can be found in Table 2.

Accuracy Scores

Standard multiple regression analysis of actual frequency, processing condition, and item type as predictors of accuracy scores indicated that a significant proportion of accuracy variability was accounted for by a combination of the predictor variables, $F(3, 572) = 9.02$, $p < .0001$, $R^2 = .05$. Further analysis indicated that actual frequency, $t(575) = 2.44$, $p < .02$, processing condition, $t(575) = 4.12$, $p < .0001$, and item type, $t(575) = -2.04$, $p < .05$, each contributed uniquely to the prediction of accuracy scores. Like the results obtained after immediate testing, accuracy of frequency judgments made after a 48-hr delay was greater for intentional processors than unintentional processors, and the accuracy of frequency judgments decreased as actual frequency increased. Unlike the results obtained after immediate testing, the present results indicated that frequency judgments for common items were more accurate than frequency judgments for bizarre items after a 48-hr retention interval.

Raw Frequency Judgments

Preliminary analyses indicated that the inclusion of the Processing Condition × Item Type interaction significantly increased the predictability of raw frequency judgments above and beyond that which was predicted by the combination of actual frequency, processing condition, and item type. The final model (including the three predictor variables and the interaction term) accounted for

TABLE 2
Mean Raw Frequency Judgments for Common and Bizarre Items at Each Level of Frequency Under Intentional and Unintentional Frequency Processing Conditions in Experiment 2

	Actual frequency					
Processing condition	1	2	3	4	5	6
Intentional processing						
Bizarre	1.42	2.62	3.04	3.83	5.00	4.42
Common	0.96	2.17	3.25	4.21	4.62	5.33
Unintentional processing						
Bizarre	2.71	2.96	3.29	5.17	5.62	5.50
Common	1.04	3.46	2.83	4.42	4.54	4.88
M	1.53	2.80	3.10	4.41	4.94	5.03

a significant proportion of raw frequency judgment variance, $F(4, 571) = 73.50$, $p < .0001$, $R^2 = .34$. Confirming the results of Experiment 1, actual frequency contributed uniquely to the prediction of raw frequency judgments, $t(575) = 16.55$, $p < .0001$, after a 48-hr retention interval. Furthermore, both processing condition, $t(575) = 3.26$, $p < .005$, and the Processing Condition × Item Type interaction, $t(575) = -2.40$, $p < .02$, contributed uniquely to the prediction of raw frequency estimates. Also confirming the results of Experiment 1, the unique contribution of processing condition indicated that unintentional processors overestimated frequency relative to intentional processors after a delay. Further analysis of the Processing Condition × Item Type interaction indicated that unintentional processors overestimated bizarre relative to common frequencies, $t(575) = -2.83$, $p < .01$, but bizarre and common judgments did not significantly differ for intentional processors.

Overall, the results of Experiment 2 indicate that intention to process frequency increases accuracy of frequency judgments in lists containing bizarre and common materials even after a 48-hr delay. This finding confirms the finding of Experiment 1 and is inconsistent with the notion that memory frequency is the result of a fully automatic process. Moreover, the present findings support previous research (Greene, 1984, 1986; Williams & Durso, 1986) that has demonstrated an influence of intentional processing on memory for frequency.

The present results also suggest that the bizarreness of stimuli influences memory for frequency after a substantial retention interval. Specifically, frequency judgments for bizarre stimuli were significantly less accurate than frequency judgments for common stimuli, even after the influence of actual frequency and processing condition was statistically controlled. Thus, the difference in accuracy between common and bizarre frequency judgments was found regardless of whether participants were intending to process frequency information.

Perhaps the most interesting finding regarding the inaccuracy of bizarre frequency judgments is the pattern of results from the analysis of raw frequency judgments in the present experiment. Analysis of the Processing Condition × Item interaction indicated that bizarre judgments were overestimated relative to common judgments (and actual frequencies) when the participants were not intending to process frequency. This pattern of overestimation of the frequency of bizarre information may be explained by spontaneous elaboration induced by unusual experiences. Because of its unusual nature, one may rehearse bizarre information more frequently than common information in an effort to comprehend fully its meaning and relations to other experiences (cf. Merry & Graham, 1978; Worthen et al., 2000). Thus, the overestimation of the frequency of bizarre items for unintentional processors may be the result of a summation of actual frequency and clandestine rehearsals. This explanation is supported by previous research (e.g., Johnson, Taylor, & Raye, 1977) that has demonstrated that covert rehearsals can lead to the overestimation of frequencies for overt events. Moreover, to the extent that this explanation is correct, the present results offer a caveat

regarding the accuracy of frequency judgments for bizarre events. That is, one may inflate frequency judgments for a given bizarre event by mentally "reliving" the bizarre experience.

Another possibility is that the overestimation of the frequency of bizarre items is a result of greater availability of bizarre than common items at retrieval (cf. Tversky & Kahneman, 1973). This explanation suggests that specific instances of stimuli are retrieved during frequency estimation and that frequency estimates are influenced by the number of common and bizarre instances retrieved. Thus, bizarre items are overestimated to the extent that they are more easily retrieved from memory. This explanation has gained support from studies by Riefer and Rouder (1992) and Worthen and Loveland (2001b), who each examined rates of free and cued recall for bizarre and common information and subsequently concluded that bizarre information has a retrieval advantage over common information.

Although it is quite possible that the overestimation of bizarre frequencies is explained by both additional spontaneous elaboration and the use of an availability heuristic, the latter explanation may have some advantages over the former. First, unlike the additional-elaboration explanation, the availability-heuristic explanation of the overestimation of bizarre frequencies can easily explain why the overestimation of bizarre frequencies does not occur for those intending to process frequency. That is, because unintentional processors are unaware that memory for frequency will be tested, we can assume that they do not invoke a strategy to encode such information and are thus more likely than intentional processors to rely on heuristics (such as availability) at testing. Importantly, the notion that reliance on heuristics is less likely when another strategy is available (as would be the case for intentional learners) is in keeping with previous research (e.g., Pratkanis, 1989). Second, the availability-heuristic explanation can also account for the fact that overestimation of bizarre frequencies occurred only with delayed testing. Previous research (O'Brien & Wolford, 1982; Webber & Marshall, 1978) suggests that the facilitative effects of bizarreness on memory may be enhanced by delayed testing. Consistent with the availability-heuristic explanation, overestimation of bizarre frequencies was found in the present study when memory for frequency was tested after 48 hr, but not when memory for frequency was tested after 2 min. However, despite this evidence in support of the availability-heuristic explanation over the additional-elaboration explanation, further research is needed before either explanation of the overestimation of bizarre frequencies can be conclusively accepted or abandoned.

GENERAL DISCUSSION

Overall, the results of the present research suggest that memory for frequency is not the result of a fully automatic process. Results from both of the experiments reported here indicate that those intending to process frequency made fewer errors

than those not intending to process frequency. These results suggest that memory for frequency information is more durable when frequency is encoded with intention than when it is encoded unintentionally. Moreover, these findings suggest that the criteria for automaticity set forth by Hasher and Zacks (1984) were not met in the present investigation. Specifically, Hasher and Zacks stated that information encoded automatically is "no different than when intention is activated" (p. 1373). Clearly, the accuracy results reported here suggest that memory for frequency involves some degree of effortful processing.

The results of the present study also provide important information regarding the accuracy of memory for bizarre events. In keeping with findings from other recent research (Worthen & Loveland, 2001a; Worthen & Wood, 2001a, 2001b) the present study reveals a disruptive influence of bizarreness on memory. Specifically, the results presented here suggest that frequency judgments for bizarre stimuli may be less accurate than judgments for common stimuli after a substantial retention interval. Furthermore, the present results indicate that those not intending to process frequency may overestimate frequencies of bizarre events when delayed memory is tested. The overestimation of bizarre frequencies was most likely caused by the summation of frequencies resulting from actual occurrences and spontaneous rehashing of the bizarre experience, the greater availability of bizarre information at retrieval, or both. The overestimation of bizarre relative to common frequencies found in the present study emphasizes an important limitation regarding the accuracy of memory for frequency of unusual events. Specifically, the frequency of unusual events may become increasingly overestimated as time elapses between the actual occurrences and the subsequent judgment. Given that previous research (e.g., O'Brien & Wolford, 1982; Webber & Marshall, 1978) has also demonstrated an interaction between bizarreness and retention interval, further research investigating the relationship between these variables is needed.

Finally, the results of both experiments indicate that, although frequency estimates were positively correlated with actual frequencies, the accuracy of frequency judgments decreased as actual frequency increased. This finding provides useful information regarding human performance in frequency tracking tasks. Specifically, these results suggests that, although both intentional and unintentional frequency judgments are sensitive to actual frequency, the accuracy of such judgments may be limited to relatively low actual frequencies.

REFERENCES

Bacon, F. T. (1979). Credibility of repeated statements: Memory for trivia. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 241–252.

Barsalou, L. W. (1985). Ideals, central tendency, and frequency of instantiation as determinants of graded structure in categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 629–654.

DeLosh, E. L., & McDaniel, M. A. (1996). The role of order information in free recall:

Application to the word-frequency effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 1136–1146.

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

Greene, R. L. (1986). Effects of intentionality and strategy on memory for frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 489–495.

Hasher, L., & Chromiak, W. (1977). The processing of frequency information: An automatic mechanism? *Journal of Verbal Learning and Verbal Behavior, 16,* 173–184.

Hasher, L., Goldstein, D., & Toppino, T. (1977). Frequency and the conference of referential validity. *Journal of Verbal Learning and Verbal Behavior, 16,* 107–112.

Hasher, L., & Zacks, R. T. (1984). Automatic processing of fundamental information. *American Psychologist, 12,* 1372–1388.

Hauk, P. D., Walsh, C. C., & Kroll, N. E. A. (1976). Visual imagery mnemonics: Common vs. bizarre mental images. *Bulletin of the Psychonomic Society, 7,* 160–162.

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.

Kroll, N. E. A., Jaeger, G., & Dornfest, R. (1992). Metamemory for the bizarre. *Journal of Mental Imagery, 16,* 173–190.

Kroll, N. E. A., & Tu, S. F. (1988). The bizarre mnemonic. *Psychological Research/Psychologishe Forschung, 50,* 28–37.

Maki, R. H., & Ostby, R. S. (1987). Effects of level of processing and rehearsal strategy on frequency judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 151–163.

McDaniel, M. A., DeLosh, E. L., & Merritt, P. S. (2000). Order information and retrieval distinctiveness: Recall of common versus bizarre material. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1045–1056.

McDaniel, M. A., & Einstein, G. O. (1986). Bizarreness as an effective memory aid: The importance of distinctiveness. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 54–65.

McDaniel, M. A., Einstein, G. O., DeLosh, E. L., May, C. P., & Brady, P. (1995). The bizarreness effect: It's not surprising, it's complex. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 422–435.

Merry, R., & Graham, N. C. (1978). Image bizarreness in children's recall of sentences. *British Journal of Psychology, 69,* 315–321.

Mumma, G. H. (1993). Categorization and rule induction in clinical diagnosis and assessment. In G. V. Nakamura, R. Taraban, & D. L. Medin (Eds.), *The psychology of learning and motivation* (Vol. 29, pp. 283–326). San Diego, CA: Academic Press.

Nappe, G .W., & Wollen, K. A. (1973). Effects on instructions to form common and bizarre mental images on retention. *Journal of Experimental Psychology, 100,* 6–8.

Naveh-Benjamin, M., & Jonides, J. (1985). The effects of rehearsal on frequency coding. *Bulletin of the Psychonomic Society, 23,* 387–390.

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.

O'Brien, E. J., & Wolford, C. R. (1982). Effect of delay in testing on retention of plausible versus bizarre mental images. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 148–152.

Pedazur, E. J. (1997). *Multiple regression in behavioral research: Explanation and prediction.* Orlando, FL: Harcourt Brace.

Pratkanis, A. R. (1989). The cognitive representation of attitudes. In A. R. Pratkanis, S. J.

Breckler, & A. G. Greenwald (Eds.), *Attitude structure and function* (pp. 71–98). Hillsdale, NJ: Erlbaum.

Riefer, D. M., & Rouder, J. N. (1992). A multinomial modeling analysis of the mnemonic benefits of bizarre imagery. *Memory & Cognition, 20,* 601–611.

Rips, L. J., & Collins, A. (1993). Categories and resemblance. *Journal of Experimental Psychology: General, 122,* 468–486.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5,* 207–232.

Webber, S. M., & Marshall, P. H. (1978). Bizarreness effects in imagery as a function of processing level and delay. *Journal of Mental Imagery, 2,* 291–300.

Wiggs, C. L. (1993). Aging and memory for frequency of occurrence of novel, visual stimuli: Direct and indirect measures. *Psychology and Aging, 8,* 400–410.

Williams, K. W., & Durso, F. T. (1986). Judging category frequency: Automaticity or availability. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 387–396.

Worthen, J. B., Garcia-Rivas, G., Green, C. R., & Vidos, R. A. (2000). Tests of a cognitive resource allocation account of the bizarreness effect. *Journal of General Psychology, 127,* 117–144.

Worthen, J. B., Hutchens, S. A., Roark, B., & Gutierrez, G. (1998). The internal structure of social categories: Components and predictors. *American Journal of Psychology, 111,* 581–605.

Worthen, J. B., & Loveland, J. M. (2001a). Imagery nonvividness and the mnemonic advantage of bizarreness. *Imagination, Cognition, and Personality, 20,* 373–381.

Worthen, J. B., & Loveland, J. M. (2001b, April). *Recall for bizarre acts: Encoding disruption and retrieval facilitation.* Paper presented at the 47th Annual Meeting of the Southwestern Psychological Association, Houston, TX.

Worthen, J. B., & Nakamura, G. V. (1995). Roles of familiarity and family resemblance in determining representativeness in social categories. *American Journal of Psychology, 108,* 195–211.

Worthen, J. B., & Wood, V. V. (2001a). A disruptive effect of bizarreness on memory for relational and contextual details of self-performed and other-performed acts. *American Journal of Psychology, 114,* 535-546.

Worthen, J. B., & Wood, V. V. (2001b). Memory discrimination for self-performed and imagined acts: Bizarreness effects in false recognition. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 54A,* 49–67.

Zacks, R. T., Hasher, L., & Hock, H. S. (1986). Inevitability and automaticity: A response to Fisk. *American Psychologist, 41,* 216–218.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology Monograph Supplement, 9,* 1–28.

Manuscript received February 21, 2001
Revision accepted for publication May 22, 2001