The effects of stimulus sequence and probability on perceptual processing

RANDALL S. HANSEN and ARNOLD D. WELL
University of Massachusetts, Amherst, Massachusetts

Two experiments that tested the hypothesis that the effect of stimulus presentation probability on perceptual processing is a function of the preceding stimulus sequence are reported. Replicating previous findings, the magnitude of the probability effect was affected by stimulus quality. The interaction was unchanged when sequential effects were eliminated from the data. Stimulus quality and sequence displayed an additive relationship. These results suggest that the probability effect on perceptual processing is not an indirect result of sequential effects. Together with the results of Miller and Anbar (1981), they suggest that practice gradually acts to facilitate the perceptual processing of highly probable stimuli.

It is a well-established phenomenon that the processing of a stimulus can be influenced by the state of the observer. In studies of word recognition, for example, stimulus processing has been influenced by preceding a target word with words of varying degrees of semantic association (e.g., Meyer, Schvaneveldt, & Ruddy, 1975), and by preceding the target with predictive or nonpredictive sentential contexts (e.g., Tulving & Gold, 1963). Similar effects have been produced in studies of choice reaction time (CRT) by asking subjects to predict ensuing stimuli (e.g., Bernstein & Reese, 1967), repeatedly presenting stimuli (e.g., Bertelson, 1963), providing a hint prior to stimulus presentation (e.g., LaBerge, van Gelder, & Yellott, 1970), and varying stimulus presentation probabilities (e.g., Hyman, 1953). A major theoretical concern has been the manner in which these non-stimulus factors exert their effects and, in particular, the extent to which they may affect perceptual processing (i.e., processing to the point of stimulus identification).

Employing the CRT paradigm, a number of investigators have attempted to describe the mechanism by which the manipulation of stimulus probability (or relative frequency) affects perceptual processing. Miller and Pachella (1973) observed that the magnitude of the probability effect varied inversely with the luminance (or contrast in this case) of the display in both a naming and a button-pressing task. This finding has been replicated a number of times (e.g., Mil-

ler, 1979; Miller & Hardzinski, 1981; Miller & Pachella, 1976; Stanovich & Pachella, 1977), and, given Sternberg's (1969) additive factors logic and the assumption that luminance affects only perceptual processes, has been interpreted as indicating that stimulus probability has at least part of its effect at a perceptual level.

One hypothesis regarding the nature of the probability effect at perceptual encoding states that it occurs as a result of expectations that change over trials. Since frequent events are correctly expected more often than infrequent ones (Myers, 1976), and reaction times (RTs) are less to expected stimuli than to unexpected ones (Bernstein & Reese, 1967), this hypothesis is at least plausible. The observation of a probability effect when prediction outcome has been controlled (e.g., Geller, Whitman, Wrenn, & Shipley, 1971; Hinrichs & Craft, 1971) does not refute the hypothesis, since this "residual" probability effect may have a purely postperceptual locus. In other words, expectancy may underlie the probability effect at encoding, while some other mechanism is responsible for the effect at later processing stages. This possibility was tested by Miller and Anbar (1981), who varied probability, expectancy (by means of a pretrial cue), and luminance, permitting conclusions regarding perceptual encoding. They observed the usual interaction of probability with luminance, but noted no tendency for expectancy to interact with luminance. These results imply that probability affects perceptual processing, but expectancy does not. They are thus inconsistent with the notion that the probability effect at encoding is produced indirectly via expectancies. Miller and Anbar, instead, suggested that it is differential practice with more and less probable stimuli that is responsible for the probability effect on perceptual processing.

Although it seems reasonable to suppose that practice may have a critical role in producing the prob-

This research is based on a thesis submitted by the first author in partial fulfillment of the requirements for the Master of Science degree at the University of Massachusetts at Amherst. Preparation of this report was supported in part by National Science Foundation Grant SED-8113323 to the second author. The authors wish to thank Jerome L. Myers, Jeff Miller, Charles Eriksen, and Edward O'Brien for their comments. Reprint requests should be sent to Randall S. Hansen, University of Massachusetts, Amherst, MA 01003.

ability effect at encoding, other potential mediating factors remain for consideration. One such factor is the stimulus sequence prior to a particular trial. Since RTs to repetitions are less than to nonrepetitions (Bertelson, 1963), and more probable stimuli are repeated more often than less probable ones, the probability effect at encoding may be the indirect result of variation in the preceding stimulus sequence across probability levels. Because Remington (1969) found that RT was affected by the identities of stimuli presented prior to the immediately preceding stimulus, a sequence of some length should be the factor of interest, rather than merely the immediately preceding stimulus. Although probability effects have been observed with sequence held constant (e.g., Remington, 1969), previous studies have not investigated whether or not sequential effects contribute to the probability effect at perceptual encoding. The implied distinction between expectancy effects (discussed above) and sequential effects is supported by the observation by Schvaneveldt and Chase (1969) that predictions of ensuing stimuli did not correspond well with sequential effects on RT. Also, Geller and Pitz (1970) and Geller et al. (1971) observed effects of run length with prediction outcome held constant.

In the present study, probability and luminance were manipulated in two experiments and sequential effects were examined. If sequential effects underlie the effect of probability at perceptual encoding, it should be possible to observe an interaction of sequence and luminance with probability held constant. This assumes that probability will have its typical effect at encoding, as should be evidenced by a probability $\times$ luminance interaction. Specifically, the effects of both probability and sequence should be greater at the low level of luminance. An additive relation between sequence and luminance would be evidence against the proposal of a sequential mechanism for the probability effect at encoding, and would thus be consistent with Miller and Anbar's (1981) proposal of a gradual practice mechanism for the effect.

EXPERIMENT 1

Method

Subjects. Twenty-six students at the University of Massachusetts received course credit for their participation in an experimental session lasting about 40 min. The data of two subjects were replaced because they exceeded a predetermined cutoff of 8% errors in at least one luminance condition.

Apparatus and Stimuli. A Hewlett-Packard 2114B computer controlled the presentation of stimuli and recorded responses and response latencies. Stimuli were presented on an HP1300A X-Y display oscilloscope in a dimly lit room. Responses were made by pressing, with the left and right index fingers, one of two keys located on a response panel in front of the subject. The stimuli were approximately .7 cm wide and 1.2 cm high and were viewed from a distance of about 100 cm. The low-luminance

stimulus condition was achieved by placing a 1.5 log unit neutral-density filter in front of the oscilloscope screen. Luminance was monitored using a Honeywell Pentax 1°/21° exposure meter before and after each session.

The stimuli were the uppercase letters G, N, S, and K. One pair of stimuli (either G-N or S-K, formed so as to consist of one globally curved and one globally angular letter, was assigned to each response. Probability was manipulated over a range of values to examine the continuous nature of the effect. In a block of 100 trials, the members of one stimulus pair appeared with frequencies of 10 and 40, and the members of the other pair appeared with frequencies of 20 and 30. There were eight possible assignments of stimuli to probabilities. The assignment of stimuli to probabilities was held constant across blocks for a given subject.

Procedure. An experimental session consisted of six blocks of 100 trials each. The first two blocks were considered to be practice and were not analyzed in detail. Luminance level alternated from block to block. The luminance level of the first block was counter-balanced across subjects to avoid a confounding of luminance with practice. Within each block of trials, the order in which stimuli were presented was randomly determined.

The subjects were allowed approximately 5 min to dark-adapt before the first practice block. There was a 1- to 2-min rest period between blocks. A trial began with the presentation of a warning signal (two crosses above and below the location of the ensuing stimulus) for 250 msec, with the stimulus appearing 250 msec after its offset. The stimulus remained on the screen until a response was made. One second elapsed before the next warning signal, during which time the screen remained blank or the word "error" was presented, depending on the response. The subjects were informed that the different stimuli would not necessarily appear equally often, and were instructed to respond as quickly and accurately as possible.

Results and Discussion

RTs to error trials and RTs of 2 sec or longer were not analyzed. The latter comprised less than 1% of the data. Mean RT and proportion of correct responses (PC) were computed for each level of probability and sequence for each of the last four trial blocks. Analyses regarding the probability effect will be considered first, followed by analyses of sequential effects.

A 2 (order of luminance alternation) $\times$ 2 (luminance) $\times$ 2 (practice) $\times$ 4 (probability) analysis of variance was performed on the RT data. The practice variable was constructed by assigning Blocks 3 and 4 to one level and Blocks 5 and 6 to the other. The results are summarized in Table 1. RTs increased as probability decreased [$F(3,66) = 22.25$, $p < .01$, $MSe = 4,695$], and the subjects responded 26 msec faster in Blocks 5 and 6 than in Blocks 3 and 4 [$F(1,22) = 7.15$, $p < .05$, $MSe = 8,890$]. The 236-msec

Table 1
Mean RTs (in Milliseconds) and PCs as a Function of
Probability Condition in Experiment 1

Lum. Level	Probability							
	.10		.20		.30		.40	
	RT	PC	RT	PC	RT	PC	RT	PC
Low	801	.902	760	.960	716	.969	708	.972
High	538	.935	516	.968	506	.972	480	.980

Note—Lum. Level = luminance level.

Table 2
Mean RTs (in Milliseconds), PCs, and Luminance Effects as a Function
of Preceding Stimulus Sequence in Experiment 1

Luminance Level	Sequence															
	Nonrepetitions								Repetitions							
	BBBA*		ABBA		BABA		AABA		BBAA		ABAA		BAAA		AAAA	
	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC
Low	734	.954	733	.972	716	.976	739	.979	672	.980	682	.980	674	.969	601	.979
High	512	.974	500	.972	486	.972	492	.979	458	.986	463	.980	412	1.000	403	1.000
Luminance Effect	222		233		230		247		214		219		262		198	

*A refers to the stimulus on trial N and B means "not A."

luminance effect was highly significant [$F(1,22)=139.25$, $p < .01$, $MSe=38,515$]. As expected, the magnitude of the probability effect was greater at low than at high luminance [$F(3,66)=4.66$, $p < .01$, $MSe=2,731$], indicating that probability had an effect on perceptual encoding (cf. Miller, 1979). Only the linear components of the probability effect were significant at both low luminance [$F(1,22)=55.62$, $p < .01$, $MSe=4,528$] and at high luminance [$F(1,22)=36.19$, $p < .01$, $MSe=2,220$]. The linear components differed at the two levels of luminance [$F(1,22)=10.38$, $p < .01$, $MSe=2,299$]. No other effects on RT approached significance.

There was no suggestion that any of the above effects was due to a speed-accuracy tradeoff. An analysis of the PC data revealed that more probable stimuli were responded to more accurately [$F(3,66)=24.07$, $p < .01$, $MSe=.0014$], and there was a trend toward greater accuracy at high luminance [$F(1,22)=3.81$, $.05 < p < .10$, $MSe=.0020$]. The probability $\times$ luminance interaction did not approach significance.

Fourth-order sequential effects were examined by taking into account the preceding three stimuli, which were classified as "same" or "different" with respect to the stimulus on the trial of interest. Fourth-order effects were examined in order to consider as many preceding stimuli as possible, while maintaining a reasonable number of observations at each sequence level. Only the data from the .4 probability condition were used, since there were not enough observations at each sequence level to permit analyses at probability levels of $p < .4$. A 2 (order of luminance alternation) $\times$ 2 (luminance) $\times$ 8 (sequence) analysis of variance was performed on the RT data. The results are summarized in Table 2. The 228-msec luminance effect was significant [$F(1,22)=108.37$, $p < .01$, $MSe=46,184$], as was the effect of the preceding sequence [$F(7,154)=21.35$, $p < .01$, $MSe=4,055$]. Consistent with past observations of sequential effects (e.g., Schvaneveldt & Chase, 1969), it is apparent in Table 2 that RT tends to decrease with increasing run length. The sequence $\times$ luminance interaction did not approach significance [$F(7,154)=1.65$, $p > .10$, $MSe=2,872$], suggesting

that stimulus sequence does not affect encoding, and thus cannot be responsible for the probability effect there. No other RT effects were significant, and an analysis of the PC data revealed no significant effects.

The decision to examine fourth-order sequences was somewhat arbitrary, and yielded fewer observations per subject than would analyses of shorter sequences. Consequently, third- and second-order sequences were examined in additional attempts to reject the null hypothesis of an additive relationship between sequence and luminance. The interaction did not approach significance in either analysis [$F(3,66) < 1$, $MSe=2,281$, for third-order sequences; $F(1,22)=1.49$, $p > .20$, $MSe=294$, for second-order sequences].

An estimate of the power to detect a 117-msec¹ sequence $\times$ luminance interaction effect was obtained using the data of the second-order sequence (i.e., repetition) analysis. The power to reject the null hypothesis at the .05 level was greater than .99. Furthermore, even if it is (incorrectly) assumed that all stimuli in the .4 probability condition were repetitions and all those in the .1 condition were nonrepetitions, the power of the second-order analysis against an effect of 35 msec (the observed magnitude of the probability $\times$ luminance interaction) was .98.

In order to further substantiate the conclusion that sequential effects do not underlie the probability effect at encoding, an additional analysis of variance was performed on the probability RT data from non-repetition trials. As can be seen in Table 3, the pattern of results was essentially unchanged by eliminating the repetitions. Most importantly, the probability effect at encoding was still present, as indicated

Table 3

Mean RTs (in Milliseconds) as a Function of Probability Condition in Experiment 1, Excluding Repetition Trials

Luminance Level	Probability			
	.10	.20	.30	.40
	RT	RT	RT	RT
Low	810	777	739	730
High	543	526	522	499

by the presence of a probability $\times$ luminance interaction [$F(3,66)=4.13$, $p < .01$, $MSe=1,365$]. Considering the .1 and .4 conditions, the probability effect was 36 msec greater at low luminance in this analysis, as opposed to 35 msec greater when repetitions were included in the data. Neither the fourth-order sequence effect nor the sequence $\times$ luminance interaction approached significance when analysis was limited to the data from the four nonrepetition sequence conditions [$F(3,66)=1.56$, $p > .20$, $MSe=4,071$; $F(3,66) < 1$, $MSe=2,499$].

The results of Experiment 1 did not support the hypothesis that sequential effects underlie the probability effect at encoding. When probability was held constant, the effect of sequence was unaffected by luminance, implying that stimulus sequence does not affect encoding. Also, the effect of probability on encoding was unaffected when sequential effects were eliminated from the data by confining the analysis to nonrepetitions.

EXPERIMENT 2

The purpose of this experiment was to seek confirming evidence that the effect of stimulus sequence does not vary with luminance, and the probability effect at encoding is independent of sequence.

Method

Thirty-three students at the University of Massachusetts received course credit for their participation in an experimental session lasting about 40 min. The data of one subject were replaced because the 8% error criterion at a single level of luminance was exceeded.

The design and procedure were identical to those of Experiment 1, with the following exceptions. There were two levels of stimulus probability, .05 and .45. One member of each letter pair (G-N and S-K) was assigned to each level. This provided 180 observations per subject at each level of luminance for the fourth-order sequential analysis (conducted on the data from the $p=.45$ condition), as opposed to 80 in Experiment 1. An initial practice block was added; subjects always viewed stimuli in this block at the high luminance level so that the stimuli would be familiar when seen for the first time at low luminance. Lastly, the absolute level of luminance was raised a small amount relative to Experiment 1 in order to make stimuli in the dim condition slightly easier to see.

Results and Discussion

Analyses regarding the probability effect will be considered first, followed by analyses of sequential effects. Only data from the last four trial blocks were analyzed. RTs of 2 sec or longer ($<1\%$ of the data) and RTs to error trials were not analyzed.

A 4 (S-R mapping) $\times$ 2 (order of luminance alternation) $\times$ 2 (practice) $\times$ 2 (luminance) $\times$ 2 (hand used to respond) $\times$ 2 (probability) analysis of variance was performed on the RT data. The results are summarized in Table 4. The subjects responded 17 msec faster with practice [$F(1,24)=4.88$, $p < .05$, $MSe=7,938$] and 16 msec faster with the dominant hand [$F(1,24)=7.92$, $p < .01$, $MSe=4,297$]. The effects of luminance and probability were highly sig-

Table 4
Mean RTs (in Milliseconds) and PCs as a Function
of Probability Condition in Experiment 2

Luminance Level	Probability			
	.05		.45	
	RT	PC	RT	PC
Low	776	.927	591	.978
High	616	.930	455	.983

nificant [respectively, $F(1,24)=81.96$, $p < .01$, $MSe=34,154$; $F(1,24)=93.37$, $p < .01$, $MSe=41,265$]. As in previous studies and Experiment 1, the probability effect was larger at low luminance [$F(1,24)=5.04$, $p < .05$, $MSe=3,664$]. Three interactions that were not of particular interest were significant at the .05 level, and may be instances of Type I error. They are the following: order $\times$ luminance, mapping condition $\times$ order $\times$ probability, and order $\times$ luminance $\times$ hand $\times$ probability. None of these could be meaningfully interpreted, and the first-order interaction did not approach significance in Experiment 1 ($F < 1$). An analysis of the PC data did not suggest that any of the RT effects was due to a speed-accuracy tradeoff. The subjects were more accurate in the high/low luminance alternation condition [$F(1,24)=5.67$, $p < .05$, $MSe=.0113$] and to highly probable stimuli [$F(1,24)=24.44$, $p < .01$, $MSe=.0072$].

Sequential effects were examined using the data from the .45 probability condition. A 4 (S-R mapping) $\times$ 2 (order) $\times$ 2 (practice) $\times$ 2 (luminance) $\times$ 8 (sequence) analysis of variance was performed on the RT data. The results are summarized in Table 5. The effects of luminance [$F(1,24)=98.64$, $p < .01$, $MSe=48,346$] and sequence [$F(7,168)=22.51$, $p < .01$, $MSe=4,362$] were highly significant. As in previous studies and Experiment 1, RT tended to decrease with increasing run length. There was no indication that the effect of sequence was sensitive to luminance level [$F(7,168)=1.01$, $p > .25$, $MSe=1,786$]. This supports the earlier conclusion that stimulus sequence does not affect perceptual encoding.

As in the probability analysis, the order $\times$ luminance interaction was significant ($p < .05$); additionally, the practice $\times$ luminance and order $\times$ practice $\times$ sequence interactions were significant at the .05 level. These interactions are not especially meaningful, and do not appear to affect the major conclusions regarding the effect of sequence on encoding.

An analysis of the PC data was consistent with the conclusions drawn from the RT data. Accuracy was greater for stimuli presented at high luminance [$F(1,24)=6.12$, $p < .05$, $MSe=.0016$], and accuracy tended to increase with run length [$F(7,168)=2.64$, $p < .01$, $MSe=.0022$].

As in Experiment 1, third- and second-order sequential data were examined for the presence of a sequence $\times$ luminance interaction. The interaction failed to approach significance in either analysis

Table 5
Mean RTs (in Milliseconds), PCs, and Luminance Effects as a Function
of Preceding Stimulus Sequence in Experiment 2

	Sequence															
	Nonrepetitions								Repetitions							
	BBBA*		ABBA		BABA		AABA		BBAA		ABAA		BAAA		AAAA	
Luminance Level	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC
Low	602	.980	616	.975	604	.974	596	.984	594	.972	601	.973	544	.982	536	.993
High	472	.975	471	.988	461	.979	466	.981	459	.987	453	.978	415	.995	403	.999
Luminance Effect	130		145		143		130		135		148		129		133	

*A refers to the stimulus on trial N and B means "not A."

[$F(3,72) < 1$, $MSe = 915$, for third-order sequences; $F(1,24) < 1$, $MSe = 688$, for second-order sequences]. A power calculation similar to that of Experiment 1 (using the second-order sequential data) revealed that the power to reject the null hypothesis at the .05 level, assuming a 58-msec repetition $\times$ luminance interaction effect, was greater than .99. Again assuming the extreme case in which all stimuli in the .45 and .05 probability conditions were repetitions and nonrepetitions, respectively, the power against an effect of 24 msec (the observed magnitude of the probability $\times$ luminance interaction) was .82.

Also as in Experiment 1, a probability analysis was conducted using only data from nonrepetition trials. A comparison of Tables 6 and 4 reveals that the pattern of results is virtually unaffected by eliminating repetitions from the data. The probability effect was 23 msec greater at low luminance in this analysis [$F(1,24) = 3.83$, $.05 < p < .10$, $MSe = 4,250$] and 24 msec greater when repetitions were included. When only the four nonrepetition sequence conditions were considered, however, there was a marginal effect of fourth-order sequence [$F(3,72) = 2.53$, $.05 < p < .10$, $MSe = 1,550$], which was not sensitive to luminance [$F(3,72) = 1.71$, $p > .10$, $MSe = 1,165$]. These results support the conclusion that the probability effect at perceptual encoding is independent of stimulus sequences.

Confirming the findings of Experiment 1, the results of Experiment 2 did not support the hypothesis that sequential effects underlie the probability effect at encoding. An additive relationship between sequence and luminance was again observed, as was the

insensitivity of the probability $\times$ luminance interaction to stimulus sequence.

GENERAL DISCUSSION

The results of these experiments are inconsistent with the hypothesis that sequential effects are responsible for the probability effect on perceptual processing. Replicating previous results (e.g., Miller, 1979; Miller & Hardzinski, 1981), the probability effect was twice observed to be greater at low levels of luminance. In both experiments, the effect of stimulus sequence was insensitive to luminance level when probability was held constant. Finally, the magnitude of the probability $\times$ luminance interaction was unchanged when sequential effects were effectively eliminated from the data by excluding repetitions from analysis.

As stated in the introduction, the observation of a probability $\times$ luminance interaction has been regarded as evidence that probability affects perceptual processing. Additive factors logic (Sternberg, 1969) has typically been invoked to arrive at this conclusion. By similar reasoning, the finding of an additive relationship between stimulus sequence and luminance suggests that the former does not affect perceptual processes, or at least does not do so in the same fashion as probability. It follows that sequential effects cannot be responsible for the probability effect at encoding. This conclusion is strengthened by the observed independence of the probability effect at encoding from stimulus sequence.

The validity of conclusions made on the basis of additive factors logic has recently been questioned (e.g., McClelland, 1979). Of particular concern in the present study are the assumptions that luminance affects only perceptual processing, and that it affects the rate, and not the quality of output, of those processes. These assumptions are consistent with findings from the literature on visual masking. For example, Schiller (1965) found that a light flash effectively masked a form if presented monocularly, but not when presented dichoptically. In the first

Table 6
Mean RTs (in Milliseconds) as a Function of Probability
Condition in Experiment 2, Excluding Repetition Trials

	Probability	
	.05	.45
	RT	RT
Luminance Level		
Low	780	603
High	620	466

case, target and mask presumably travel via the same peripheral pathway, permitting the mask to have its effect at an early level of processing. The convergence of the two is more central in the dichoptic condition, however. A light flash may be thought of (like luminance) as reducing the intensity of a stimulus against its background. Furthermore, Schiller (1965) and Turvey (1973) found that a pattern mask was effective in dichoptic presentation, thus ruling out the possibility that stimuli presented in this manner are simply immune to masking.

Pachella and Fisher (1969) found that asymptotic performance in a discrimination task was unaffected by luminance level, but was lowered by increasing stimulus similarity. This supports the claim that the effect of luminance is on the rate of information accrual, rather than the product of the identification process. Also, Hardzinski and Pachella (1980) observed that scanning rates in a memory-scanning task were relatively unaffected by luminance manipulation, suggesting that the effect of luminance does not persist beyond encoding.

Finally, the finding in the present study that probability interacts with luminance, but sequence does not, is also consistent with the assumption that the effects of luminance are removed prior to postperceptual processing. If this were not the case (i.e., if the luminance effect is "passed along"), and it is assumed that probability and sequence have effects at a postperceptual locus, it is difficult to explain why the effect of one factor is sensitive to luminance, but the effect of the other is not.

The results of the present study are consistent with Miller and Anbar's (1981) suggestion that practice gradually acts to facilitate the perceptual processing of highly probable stimuli. These investigators demonstrated that expectancy was incapable of producing the probability effect at a perceptual level, and the present study has resulted in a similar conclusion regarding the factor of stimulus sequence. Other mediating factors may exist, but it is a task for future research to specify them and assess their viability. Also needed is a more complete description of a hypothetical mechanism enabling practice to facilitate perceptual processing.

REFERENCES

- BERNSTEIN, I. H., & REESE, C. (1967). Behavioral hypotheses and choice reaction time. *Psychonomic Science*, 9, 189-190.
- BERTELSON, P. (1963). S-R relationships and reaction time to new versus repeated signals in a serial task. *Journal of Experimental Psychology*, 65, 478-484.
- GELLER, E. S., & FITZ, G. F. (1970). Effects of prediction, probability, and run length on choice reaction speed. *Journal of Experimental Psychology*, 84, 361-369.
- GELLER, E. S., WHITMAN, C. P., WRENN, R. F., & SHIPLEY, W. G. (1971). Expectancy and discrete reaction time in a probability reversal design. *Journal of Experimental Psychology*, 90, 113-119.
- HARDZINSKI, M., & PACHELLA, R. G. (1980). The manipulation of stimulus quality and the definition of stimulus encoding operations in memory scanning experiments. *Perception & Psychophysics*, 27, 232-240.
- HINRICHS, J. V., & CRAFT, J. L. (1971). Verbal expectancy and probability in two-choice reaction time. *Journal of Experimental Psychology*, 88, 367-371.
- HYMAN, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, 45, 188-196.
- LABERGE, D., VAN GELDER, P., & YELLOTT, J. (1970). A cueing technique in choice reaction time. *Perception & Psychophysics*, 7, 57-62.
- MCCLELLAND, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review*, 86, 287-330.
- MEYER, D., SCHVANEVELDT, R., & RUDDY, M. (1975). Loci of contextual effects on visual word recognition. In P. Rabbitt & S. Dornic (Eds.), *Attention and performance V*. New York: Academic Press.
- MILLER, J. (1979). Cognitive influences on perceptual processing. *Journal of Experimental Psychology: Human Perception and Performance*, 5, 546-562.
- MILLER, J., & ANBAR, R. (1981). Expectancy and frequency effects on perceptual and motor systems in choice reaction time. *Memory & Cognition*, 9, 631-641.
- MILLER, J., & HARDZINSKI, M. (1981). Case specificity of the stimulus probability effect. *Memory & Cognition*, 9, 205-216.
- MILLER, J. O., & PACHELLA, R. G. (1973). Locus of the stimulus probability effect. *Journal of Experimental Psychology*, 101, 227-231.
- MILLER, J. O., & PACHELLA, R. G. (1976). Encoding processes in memory scanning tasks. *Memory & Cognition*, 4, 501-506.
- MYERS, J. L. (1976). Probability learning and sequence learning. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes: Vol. 3. Approaches to human learning and motivation*. Hillsdale, N.J.: Erlbaum.
- PACHELLA, R. G., & FISHER, D. F. (1969). Effect of stimulus degradation and similarity on the trade-off between speed and accuracy in absolute judgments. *Journal of Experimental Psychology*, 81, 7-9.
- REMINGTON, R. J. (1969). Analysis of sequential effects in choice reaction times. *Journal of Experimental Psychology*, 82, 250-257.
- SCHILLER, P. H. (1965). Monoptic and dichoptic visual masking by patterns and flashes. *Journal of Experimental Psychology*, 69, 193-199.
- SCHVANEVELDT, R. W., & CHASE, W. G. (1969). Sequential effects in choice reaction time. *Journal of Experimental Psychology*, 80, 1-8.
- STANOVICH, K. E., & PACHELLA, R. G. (1977). Encoding, stimulus-response compatibility, and stages of processing. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 411-421.
- STERNBERG, S. (1969). The discovery of processing stages: Extensions of Donders' method. In W. G. Koster (Ed.), *Attention and performance II*. Amsterdam: North Holland.
- TULVING, E., & GOLD, C. (1963). Stimulus information and contextual information as determinants of tachistoscopic recognition of words. *Journal of Experimental Psychology*, 66, 319-327.
- TURVEY, M. T. (1973). On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with patterned stimuli. *Psychological Review*, 80, 1-52.

NOTE

1. The 117-msec effect was determined by assuming that the observed probability $\times$ luminance interaction was wholly due to a repetition $\times$ luminance interaction. Let L_R = luminance effect for repetitions, I = magnitude of the repetition $\times$ luminance interaction, L_{HP} = luminance effect for high probability (.40) stimuli, and L_{LP} = luminance effect for low probability (.10) stimuli. Then

$$L_{LP} = .10(L_R) + (1 - .10)(L_R + I) \quad (1)$$

and

$$L_{HP} = .40(L_R) + (1 - .40)(L_R + I). \quad (2)$$

From Table 1, $L_{LP} = 263$ msec and $L_{HP} = 228$ msec. Substituting

these values and subtracting Equation 2 from Equation 1 results in $I = 117$. In other words, the size of the repetition $\times$ luminance interaction must be 117 msec in order to produce the observed probability $\times$ luminance interaction effect of 35 msec.

(Manuscript received June 17, 1983;
revision accepted for publication October 7, 1983.)