Proceedings of the Annual Meeting of the Cognitive Science Society

Backward Masking Reflects the Processing Demand of the Masking Stimulus

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 18(0)

Authors

Ohnesorge, Clark

Theios, John

Publication Date

1996

Backward Masking Reflects the Processing Demand of the Masking Stimulus

Clark Ohnesorge
Department of Psychology
Middlebury College
Middlebury, VT 05753
ohnesorg@midd-unix.middlebury.edu

John Theios
Department of Psychology
University of Wisconsin-Madison
Madison, WI 53706
theios@macc.wisc.edu

Abstract

Backward masking is often used to limit visual processing in studies of word recognition, semantic priming, and text processing. However, the manner in which the masking stimulus interferes with perception of the target is not well understood. Several explanations of the backward masking effect are considered, a termination hypothesis, an attention capture hypothesis, and a capacity sharing hypothesis. A point of distinction, the effect of manipulating the processing demands of the masking stimulus, is tested in two experiments. Frequency in print of the masking stimulus is manipulated in a first experiment and both frequency and repetition of the masking stimulus are tested in the second. The results disconfirm two of the hypotheses, termination and attention capture, and support the capacity sharing hypothesis.

Introduction

In backward pattern masking a stimulus is presented to the observer and after a brief interval is followed by another stimulus presented in the same location of the visual field. These are called the target and mask respectively. The presentation of the mask interferes with the processing of the target; the extent of this interference is typically indexed by response accuracy. When the interval between the onsets of the target and mask is small, target recognition is poor. As the time between the onsets of target and mask increases, target recognition improves.

Backward masking is a very useful tool in cognitive and perceptual psychology in spite of the fact that it is not clear exactly how or why the masking stimulus interferes with the visual recognition of the target. Many researchers have adopted, at least implicitly, the notion that the presentation of the mask terminates visual processing of the target. This assumption is instantiated in current models of backward masking, for example Lupker & Massaro (1979) and Muise, LeBlanc, Lavoie, & Arsenault, (1991). These models assume that visual information relevant to target identification begins to accrue shortly after target presentation and continues to build until visual processing of the target is terminated by presentation of the mask. Muise et al. (1991) presented their basic model in terms of the following exponential growth function: $d' = \alpha(1 - e^{-\theta t})$. Where d' is the measure of performance, "α" represents the total information available in the display, and "e" is the base of the natural log. The critical parameters are "θ" (the growth rate of effective information) and "t" (time between target and mask). The accrual of information effective for target identification ceases at time "t"; in other words, visual processing of the target is terminated by the presentation of the mask. The sole determinant of information accrual is "t", or the amount of time the target has enjoyed uninterrupted access to whatever resources are necessary for recognition. This model does a very good job of predicting performance with single-letter targets and a much larger, brighter, pattern mask. However, backward masking is employed effectively in situations in which the mask and target are much more equivalent in terms of spatial extent and luminance (Perfetti & Bell, 1991; Perfetti, Bell, & Delaney, 1988; Naish, 1983; Taylor & Chabot, 1978; Theios & Amrhein, 1989a). Further, research from two distinct areas suggests that the activation resulting from target processing is not necessarily obliterated or terminated by the presentation of the mask.

The first is a class of results grouped under the heading of perception without awareness. The empirical result is that under conditions of masking so severe that observers cannot reliably identify a prime word, facilitation of semantically related targets results (Dietrich & Theios, 1994; Evett & Humphreys, 1981; Greenwald, Klinger & Liu, 1989; Marcel, 1983; Morgan, 1994). Marcel (1983), Coltheart (1980), and Theios & Marmolejo (1991) have all offered similiar theoretical interpretations of the backward masking effect. They argue that the presentation of the masking stimulus "snatches" or captures attention away from the target stimulus, preventing conscious awareness of the target but not destroying all results of perceptual processes.

Another line of evidence against the termination hypothesis is provided by Dember and colleagues: Dember & Purcell (1967), Dember, Schwartz, & Kocak (1978), Briscoe, Dember & Warm (1983). In several experiments these researchers have demonstrated that it is possible to "mask the mask and unmask the target" . This is accomplished by adding a second mask, following the first mask, to the sequence of stimuli.

Like the studies on perception outside of awareness, these results support a conclusion that the mask interferes with attentional processes leading to the conscious perception of the target, but does not obliterate activation resulting from target processing.

How could the process of recognizing the mask interfere with recognition of the target? Coltheart (1980), Marcel (1983), Morgan (1993), Ohnesorge & Theios (1991a) and Theios & Marmolejo (1991) have all suggested that attention is captured away from the target by the presentation of the masking stimulus. A reasonable prediction, based on this notion, is that masking stimuli that are easily or quickly recognized should capture attention quickly, resulting in more or better masking than masks that are difficult to process and capture attention more slowly. However, a different conceptualization of the masking effect leads to a contrasting prediction.

Given that the transfer of information from iconic representation to short term memory is dependent in some sense on capacity (Gegenfurtner & Sperling, 1993; LaBerge & Brown, 1989; Reeves, 1986) it seems plausible that masking might be in part a result of insufficient capacity to concurrently process both target and mask to a level sufficient for conscious awareness. The result of this line of thinking is the capacity sharing hypothesis. Masks that require more processing resource, rather than less, will result in the greatest degree of masking.

With these three hypotheses there is an exhaustive partition of the possibility space. The termination hypothesis predicts no effect of manipulating the processing demands of the mask, the attention capture hypothesis predicts more masking with low demand masks, and the capacity sharing hypothesis predicts more masking with high demand masks.

The Processing Demand of the Mask

The following experiments will hold constant the low-level physical characteristics of masking words and manipulate higher order characteristics of the masking stimuli that can reasonably be associated with processing demands. We assume that the demand for resources can be indexed through response time and accuracy, with longer response times and lower accuracy rates indicating a greater demand for processing resources. Word Frequency and Stimulus Repetition are both good candidates for manipulating the processing demands of lexical stimuli. The word frequency effect (WFE) is ubiquitous, words that are high in printed frequency are responded to more quickly, and with fewer errors than low frequency or less familiar words (Scarborough, Cortese, & Scarborough, 1977). Likewise, stimuli that are repeated within an experimental context yield faster and more accurate recognition scores than non-repeated stimuli (Forster & Davis, 1984; Scarborough, Cortese, & Scarborough, 1977; Theios & Walter 1973; Woltz 1990) Manipulating either the printed word frequency or repetition of stimuli used as masks should affect the amount of processing required for their recognition, and allow a critical test of the termination, attention capture, and capacity sharing hypotheses. Word frequency and repetition are useful variables to manipulate because explanations of the somewhat vague term "processing resources" can be made with respect to models of word recognition that incorporate processing cycles in simulations of the word recognition process (e.g. the Activation-Verification model of Paap, Newsome, McDonald, & Schvaneveldt, 1982; or the Interactive Activation model of McClelland & Rummelhart, (1981, 1985). A slightly different conceptualization of word frequency and repetition effects is embodied in the activation level account of the Logogen model (Morton, 1969). Our first experiment examines the effect of manipulating the printed frequency of the mask. On the basis of a pilot study we concentrated on levels of SOA up to 53 milliseconds.

Experiment One

Subjects

Twenty-three students with normal or corrected vision at the University of Wisconsin-Madison participated.

Apparatus

The experiment was designed and conducted using the software program PsyScope (Cohen, MacWhinney, Flatt & Provost, 1993). A Power Macintosh 7100 controlled the display sequence and collected the data. **Design** There were two within-subjects variables, Stimulus Onset Asynchrony or SOA, and Mask Frequency. There were four levels of SOA (13.3, 26.6, 40, 53.3 ms.) and two levels of Mask Frequency, (High and Low).

Procedure

Subjects sat 500 millimeters from the computer monitor. Each trial consisted of 300 ms of fixation, a 50 ms blank interval, a 13 ms presentation of the target, one of the four randomly selected levels of SOA, and, following a 300 ms blank interval, the choice alternative pair until response. The computer provided feedback on each trial of the 45 practice and 216 experimental trials.

Stimuli

The stimuli were selected using the third index of the Kucera and Francis (1967) word frequency corpus. The experimental stimuli comprised three sets: a set of 216 low frequency choice alternative pairs, a set of 216 high frequency masks and a set of 216 low frequency masks. All of the words used in the experiment, both masks and targets, were four letters long. The vast majority were single syllable. The target set was constructed by selecting pairs of words that differed by one or two letters. The substituted letter ranged across the four possible positions within words (e.g. "LAVA & JAVA" vary in the first position, "HECK & HICK" in the second). The target for each trial was randomly selected, the other member of the pair became the foil in the identification phase. The printed frequency of all words in the choice alternative pair set was between 1 and 10, with a mean frequency of 3.3. The low frequency masking words ranged from 1 to 10, with a mean frequency of 3.6. The high frequency masking words ranged from 50 to 500 occurrences, with a mean frequency of 187. Summed Positional Bigram Frequency (SPBF) for the stimulus sets was calculated using the norms published by Massaro, Taylor, Venezky, Jastrzembski,& Lucas,(1980).The masking sets differed greatly in frequency but only slightly in SPBF.

Results

The effect of Mask Frequency was significant, F(1,22) = 17.3, $p < .05$. The mean percentage of targets correctly recognized in the High Frequency mask condition was 62%, versus 57% in the Low Frequency mask condition. The effect of SOA was also significant, F(3,66) = 8.9, $p < .05$. The interaction of Mask Frequency and SOA did not approach significance F(3,66) = .18, $p > .05$. Cohen's epsilon (ε) revealed a strong relationship between Mask Frequency and target recognition performance, $\varepsilon = .64$.

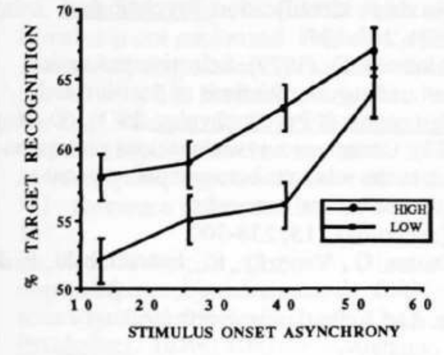

Figure 1: Target recognition under masking by High and Low Frequency masking words.

Discussion

This result provides support for the capacity sharing hypothesis and infirms the termination and attention capture hypotheses. Target recognition is influenced by the demand of the mask. Low frequency (high demand) masks, are more effective than high frequency masks, i.e. result in lower levels of target recognition. The frequency effect produces about 5% difference in recognition accuracy between conditions in this 2AFC design. However, the proportion of variance accounted for, $\varepsilon^2 = .41$, is large enough to show that this difference is not trivial.

Experiment Two

Word frequency is a manipulation of processing difficulty that can be understood within current simulations of word recognition processes. In order to further test the distinctive predictions of the three hypotheses we conducted an experiment that manipulated the demand of the mask using a repetition manipulation. The stimulus repetition effect is quite robust; faster and more accurate processing upon subsequent exposures to a stimulus (Forster & Davis, 1984; Theios & Walter, 1973, Woltz 1990). By inference masking stimuli that are repeated will require less processing than masks that are presented only once. The predictions for Experiment Two are analogous to those derived for Experiment One. The termination hypothesis predicts no effect of repeating the mask, the attention capture hypothesis predicts more masking when the mask is repeated, and the capacity sharing hypothesis predicts less masking when the mask is repeated.

Subjects Twenty-six students with normal or corrected vision from the University of Wisconsin-Madison participated in the experiment.

Design There were two within-subjects variables, Mask Frequency (High & Low) and Mask Repetition (Single Exposure & Repeated Exposure), with a single SOA of 26 milliseconds.

Stimuli

The stimuli were those used in Experiment 1.

Procedure

There were two significant differences in the procedure used in experiement two. First, only one level of SOA was used to reduce the overall complexity of the task. Second, an additional stimulus was presented for one second immediately prior to the target:mask sequence. This stimulus was either the mask that would appear later in the trial (repeated exposure condition) or a different mask of the appropriate frequency (single exposure condition).

Results

The effect of frequency was again significant, F(1,25) = 13.1, $p < .05$, and the strength of asociation was relatively high, $\varepsilon = .56$. The main effect of the Mask Repetition factor was also significant, F(1,25) = 44.1. $p < .05$. Observers correctly identified more targets in the Repeated Exposure condition (mean = 70%) than in the Single Exposure condition (mean = 62%). The Repetition factor was also strongly related to performance, $\varepsilon = .79$. The interaction of Frequency and Repetition was not significant F(1,25) = .021.

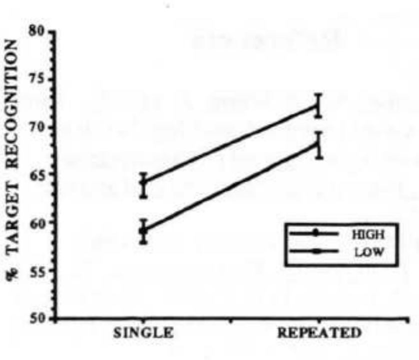

Figure 2: Target recognition under masking by High and Low frequency masking words presented once (single condition) or twice (repeated condition).

Conclusion

The interpretation of these studies is straightforward. Factors that affect the processing demand of a masking stimulus affect the degree of masking that occurs. This finding is sufficient to disconfirm the termination hypothesis. Were the termination hypothesis true the manipulation of masking word frequency and mask repetition should not have affected the extent of masking that occurred. Given our tight stimulus control, only changes in target processing time (the parameter "t" in the model described by Muise et al., 1991) should have affected the accrual of information and thus recognition performance. The attention capture hypothesis is also disconfirmed. The attention capture hypothesis admits a role for higher-level processesing resources in backward masking but makes a prediction in the opposite direction from that which occurred. In contrast, the capacity sharing hypothesis is supported. Masks that are more easily processed interfere less with the processing of the target, allowing better target recognition performance. In hindsight, the capacity sharing hypothesis can be seen to fit neatly into the large body of work on dual-task performance. When the difficulty of one task is increased, performance on a concurrent task falls, to the extent that the two tasks compete for common resources. The results of these studies support the conclusion that the target and mask compete for resources from a common pool that are needed by both for recognition. Given its later arrival, the mask enjoys privileged access to this pool and can demand sufficient resources to support its own recognition, with an attendant reduction in resources available for target recognition.

Acknowledgements

The authors would like to thank Robin Chapman, William Epstein, Robert French, Morton Gernsbacher, Mike Hogan, Bob Kachelski, and Steve Morgan for their contributions to this research. Special thanks go to Virginia Marchman for her many helpful comments on stimulus materials and to Josh Reichman for his help in implementing the studies.

References

Briscoe, G., Dember, W., & Warm, J. (1983). Target recovery in visual backward masking: No clear explanation in sight. Journal of Experimental Psychology, Human Perception and Performance, **9**(6), 898-911.

Coltheart, M. (1980). Iconic memory and visible persistence. Perception & Psychophysics, **27**, 183-228.

Dember, W. N., & Purcell, D.G. (1967). Recovery of masked visual targets by inhibition of the masking stimulus. Science, **157**, 1335-1336.

Dember, W., Schwartz, M., & Kocak, M. (1978). Substantial recovery of a masked visual target and its theoretical interpretation. Bulletin of the Psychonomic Society, **11**(5), 285-287.

Dietrich, D. & Theios, J. (1992). Priming outside of awareness and subsequent stimulus identification. Perceptual and Motor Skills, **75**, 483-493.

Forster, K., & Davis, C. (1984). Repetition priming and frequency attentuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition, **10**(4), 680-698.

Forster, K., Booker, J., Schacter, D., & Davis, C. (1990). Masked repetition priming: Lexical activation or novel memory trace? Bulletin of the Psychonomic Society, **28**(4), 341-345.

Gegenfurtner, K., & Sperling, G. (1993). Information transfer in iconic memory experiments. Journal of Experimental Psychology, Human Perception and Performance, **19**(4), 845-866.

Greenwald, A. G., Klinger, M.R., & Liu T.J. (1989). Unconscious processing of dichoptically masked words. Memory & Cognition, **17** 35-47.

LaBerge, D., & Brown, V., (1989). Theory of attentional operations in shape identification. Psychological Review, **96**(1), 101-124.

Lupker, S., & Massaro, D. (1979). Selective perception without confounding contributions of decision and memory. Perception & Psychophysics, **25**(1), 60-69.

Marcel, A. (1983). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. CognitivePsychology, **15**, 238-300.

Massaro, D., Taylor, G., Venezky, R., Jastrzembski, J., & Lucas, P. (1980). *Letter and word perception.* Amsterdam, The Netherlands: North Holland publishing company.

McClelland, J., L., & Rumelhart, D., E. (1981). An interactive activation model of context effects in letter perception: 1. An account of basic findings. Psychological Review, **88**, 375-407.

McClelland, J., L., & Rumelhart, D., E. (1985). Distributed memory and the representation of general and specific information .Journal of Experimental Psychology: General, **114**, 159-188.

Morgan, S., T. (1993). Shifts of visual-spatial attention initiated by unconscious symbolic cues. Unpublished doctoral dissertation, University of Wisconsin-Madison

Muise, G., LeBlanc, R., Lavoie, M., & Arsenault, A. (1991). Two-stage model of backward masking: Sensory transmission and accrual of effective information as a function of target intensity and similiarity. Perception & Psychophysics, **50**(3), 197 204.

Ohnesorge, C.G. & Theios J. (1991a). The Effect of Extremely Small Intensity Differences in Tachistoscopic Presentations of Picture-Word Pairs. Paper presented at Midwestern Psychological Association, (May), Chicago, Ill.

Ohnesorge, C.G. & Theios J. (1991b). Signal Detection Analysis of Two Extremely Brief Stimuli, Paper presented at Meeting of the Society for Mathematical Psychology, (August), Bloomington, In.

Paap, K., Newsome, S., McDonald, J., & Schvaneveldt, R. (1982). An activation-verification model for letter and word recognition: The word-superiority effect. Psychological Review, 89 (5), 573-594.

Perfetti, C.A., Bell, L.C., & Delaney, S. M. (1988). Automatic (prelexical) phonetic activation in silent word reading: evidence from backward masking. Journal of Memory and Language, 27, 59-70.

Perfetti, C.A., & Bell, L.C. (1991). Phonemic activation during the first 40 ms of word identification: evidence from backward masking and priming. Journal of Memory and Language, 30, 473-485.

Reeves, A. (1986). Attention and the order of items in short term visual memory. Special issue : Visual Attention Psychological Research, **48(4)**, 239-250.

Scarborough, D., Cortese, C., & Scarborough, H. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology, Human Perception and Performance, **3**(1), 1-17.

Theios, J., & Marmolejo, G. (1991). A backwardly masked stimulus is not subliminal. Paper presented at the 32nd Annual Meeting of the Psychonomic Society, (November), San Francisco, CA.

Theios, J., & Morgan, S., T. (1990). On the evolution of a visual percept. In *Proceedings of the Twelfth Annual Meeting of the Cognitive Science Society.* Hillsdale N.J.: Lawrence Erlbaum Associates, Publishers, 590 597.

Theios, J., & Walter, D., G. (1973). Stimulus and response frequency and sequential effects in memory scanning reaction times. Journal of Experimental Psychology, **102**(6) 1092-1099.

Turvey, M. (1973). On peripheral and central processes in vision: inferences from an information-processing analysis of masking with patterned stimuli. Psychological Review, **80**(1) 1-52.

Woltz, D. (1990). Repetition of semantic comparisons: Temporary and persistent priming effects. Journal of Experimental Psychology: Learning, Memory, and Cognition, **16** (3), 392-403.