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ABSTRACT

In a visual recognition masking experiment, a target stimulus to be identified is either preceded or followed by a second stimulus called a masking stimulus. The experiments described here provide estimates of both developmental and aging differences in visual backward masking under conditions which maximize interference in the central visual system. The results indicate that when no-mask recognition performance is at 100 percent, significant Age X Stimulus Onset Asynchronies interactions can be detected. However, the absence of this type of interaction when no-mask recognition performance is adjusted to the 70 percent level suggests that these interactions are caused by factors other than rate of processing differences. (Author/BW)

# Developmental and Aging Differences in Visual Information Processing[1]

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Information processing models of memory suggest that stimulus information is processed in discrete stages (see Massaro, 1975). An early processing stage is the sensory register. For visual information this register has also been referred to as iconic memory. Stimulus information in the sensory register is posited to be literal copies of the external physical stimuli and this information can be held in this stage for about 250 msec before fading or being read out into the next stage like short term memory.

There has been considerable interest in the possibility that developmental differences exist in the rate at which information is processed from the sensory register (see Hoving, Spencer, Ross, and Schulte, 1978; Ross and Ward, 1978). One method which has been used to study this problem is visual recognition masking. In a visual recognition masking experiment, a target stimulus to-be-identified is presented for a brief exposure by a tachistoscope. This target stimulus is either preceded or followed by a second stimulus called a masking stimulus. If the target and mask occur within close temporal proximity of each other, target recognition is typically poorer than when no mask is presented or when the time interval between target and mask is very long. This impairment of target recognition is known as visual recognition masking.

Two different sources of masking effects have been identified (see Turvey, 1973). For example, when the target and mask are presented simultaneously, or separated by short stimulus onset asynchronies (i.e., SOAs), masking occurs primarily because the target and mask energies are summed in the <u>peripheral</u> visual system and thereby present the central visual system with a target-mask montage. When the mask precedes the target in forward masking, this type of luminance summation, also known as peripheral masking, is generally considered to be the only source of visual masking effect.

Alternatively, when the target precedes the mask in backward masking, impairment of target recognition at SOAs above 30 msec are usually attributed to a different source. That is, it is argued that the after-coming mask serves to interfere with and perhaps terminates the ongoing processing of the target. This type of interference occurs in the <u>central</u> rather than the peripheral visual system. Thus, if it is assumed that an after-coming mask terminates the processing of the target, then the <u>rate</u> at which target recognition increases with SOA can provide direct information about the rate of visual information processing.

Our recent review of the developmental literature suggests that adults and older children (about age eleven) show more rapid recognition improvement over SOAs than young children (about age five) in backward masking. Whether this finding from previous studies can be interpreted to indicate developmental differences in the rate of visual information processing, however, is unclear.

One problem is that the backward masking procedures used in many of the relevant studies were not designed to maximize interference in the central visual system. Furthermore, the energy of the masking stimulus exceeded that of the target stimulus in some of the studies. Under this condition, differences in backward masking can reflect interference in the peripheral and/or central visual systems (see Turvey, 1973). In the backward masking experiments we have conducted, precautions were taken to directly implicate interference in the central visual system and to minimize peripheral visual system interference in backward masking at SOAs greater that 30 msec. This was accomplished by using a 1:1 target to mask energy ratio and a mask which shared identical visual features with the target. Furthermore, estimates of forward masking were obtained in order to facilitate identification of the locus of backward masking effects. Specifically, it was anticipated that backward masking effects observed at SOAs longer than those at which subjects escaped from forward masking would reflect interference primarily in the central visual system.

Another problem with estimates of the rate of visual information processing obtained in previous developmental studies is that they may have been contaminated. For example, the use of multi-item targets, verbal stimuli, and/or a verbal response in previous studies may have allowed other developmentally sensitive processes to be involved in successful task performance. These processes include selective attention, strategic encoding, verbal encoding and verbal response decoding. Substantial evidence indicates that older children and adults are more skilled in the production and application of these forenamed processes than young children. Procedures in our experiments were designed to minimize the implication of these processes by using a single nonverbal target item in conjunction with a nonverbal response method.

Our first experiment was conducted with participants from grades kindergarten, third, sixth, and college. Each observer was presented with an arrowhead target for 10 msec in a tachistoscope. The arrowhead target could point in one of four different directions, up-down-left-right, resulting in four different targets. Subjects were required to give evidence of target recognition by pointed in the same direction as the arrowhead target. These targets were either preceded (i.e., forward masking) or followed (i.e., backward masking) by a masking stimulus which looked like a star with four points. This mask was constructed from the four arrowheads and positioned so that it overlapped exactly each of targets. The mask was also presented for a 10 msec duration. The luminance of both the target and mask fields was 6.5 ft-lamberts.

In forward masking, the mask preceded the target at SOAs of 40 or 70 msec, while in backward masking the target preceded the mask by SOAs of 10, 40, 70, 100, 130, 160, 190, 220, 250, 280, or 310 msec. At each SOA subjects received each of the four targets twice, resulting in 8 trials at each SOA. Order of forward masking versus backward masking trials was counterbalanced over subjects.2

The upper panel of figure 1 presents the percentage of correct responses as a function of SOA for each grade level.

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Insert Figure 1 about here

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Negative and positive SOAs refer to forward- and backward masking conditions, respectively. The high levels of target recognition achieved in forward masking by the -40 SOA indicates that backward masking at SOAs greater than 40 msec will be caused primarily by mechanisms other than peripheral luminance summation. Inspection of recognition performance in backward masking at SOAs greater than 40 msec reveals a systematic improvement in recognition performance over SOAs. Furthermore, a Grade Level X SOA interaction is clearly evident such that older subjects recover from backward masking much more rapidly than younger subjects.

The Grade Level X SOA interaction in backward masking observed in our first experiment is consistent with previous experimental work (see Ross and Ward, 1978). Furthermore, this interaction was obtained under task conditions designed to maximize central masking and with a single nonverbal target and nonverbal response. Results like these have been used to argue for age differences in visual information processing. However, caution should be exercised in accepting such an interpretation because of the ceiling effect which is clearly evident in subjects' recognition performance depicted in the upper panel of figure 1. That is, all subjects were able to identify targets perfectly in the absence of a mask, so that the masking functions all reach asymptote at 100%. With recognition performance at a 100% asymptote, there is no guarantee that the Grade Level X SOA interaction could not have been produced by other factors such as the quality of stimulus reception at the different grade levels. With this in mind we conducted a second experiment in which subjects no-mask recognition performance levels were adjusted to a 70% to 80% level. This was accomplished by varying the size of the target and its corresponding mask. That is, based on a series of preexperimental trials, a target size was identified for each subject which was associated with about a 75% level of recognition performance. Other procedures could have been used to adjust no-mask recognition performance levels. For example, changes in target intensity or duration have been used in previous experiments. However, variation in target and mask energies can affect the degree of luminance summation in backward masking and it would have been undersirable to produce masking for qualitatively different reasons in the different grade levels. By varying target size in our experiment, no-mask recognition performance was manipulated while holding constant the nature of the experimental task and the target and mask energies. Thus, if the age effects observed in the first experiment were caused by processing rate differences, a similar Grade Level X SOA interaction should emerge in our second experiment.

The results of the second experiment are presented in the lower panel of figure 1. Inspection of the backward masking results (i.e., the positive SOAs) at SOAs greater than 40 msec indicate that recognition performance improves over SOA. A systematic grade difference in target recognition improvement as a function of SOA (i.e., a Grade Level X SOA interaction), like that observed in the first experiment, was not found. This finding suggests that factors other than rate of processing are responsible for the Grade X SOA interaction observed in our first experiment.

We have recently extended our analysis of visual masking to include a comparison between college age subjects and the elderly (age range 60 to 73). Generally speaking the procedures used in our developmental work were also applied in the aging study. An important exception, however, is that complete forward and backward masking functions were obtained for all subjects. Furthermore, forward and backward masking trials were randomly intermixed as opposed to the blocked presentation used in the developmental studies. The following SOAs were sampled in both forward and backward masking: 40, 70, 100, 130, 160, 210, 260, and 310 msec. The upper panel of figure 2 shows the results from the first aging study.

Insert Figure 2 about here

In this study, no-mask target recognition was at 100% correct. Our statistical analysis of backward masking treated each subject's forward masking point as a covariate in the analysis of variance. This allows us to statistically remove from the backward masking results effects that may be due to luminance summation (i.e., peripheral masking). The results in backward masking (i.e., the positive SOAs) reveal a highly significant Population X SOA interaction indicating that college age subjects escaped from the interference of backward masking earlier than the elderly subjects. This outcome is consistent with previous reports of aging differences (e.g., Walsh, 1976) and is similar to our findings from the first developmental study when recognition performance was at a 100% asymptote.

A second aging study was conducted using identical experimental procedures to the first except that subject's no-mask performance levels were adjusted to a 70% level prior to the start of the masking trials. No mask recognition performance was adjusted for each subject by manipulating the size of the arrowhead target in a manner identical to the procedures used in our developmental study. The no-mask performance levels for the college subjects and the elderly subjects were 66% and 68%, respectively.

The results for this second aging experiment are presented in the lower panel of figure 2. The backward masking performance in this experiment is distinguished from that observed in the first aging experiment in that there is no evidence for a systematic Population X SOA interaction. Similar to the statistical treatment for the first aging experiment, subject's forward masking performance was treated as a covariate in the analysis of backward masking performance.

The experiments described provide estimates of both developmental and aging differences in visual backward masking under conditions which maximize interference in the central visual system. Furthermore, task conditions were arranged to minimize the possibility that estimates of age differences in backward masking would be contaminated by age-related changes in other processes such as strategic encoding or decoding. The results from the studies indicate that when no-mask recognition performance is at 100%, significant Age X SOA interactions can be detected. However, the absence of this type of interaction when no-mask recognition performance is adjusted to the 70% level (i.e., when the ceiling effect is removed) suggest that these Age X SOA interactions are caused by factors other than rate of processing differences.

It may be that attentional factors are responsible for the observed differences. For example, young and elderly subjects may not fixate as consistently on the target locations as college age subjects. On the masking trials when the subject's gaze is not directly fixated on the target location, it is likely that the subject's acuity for the target may be diminished relative to trials when the subject successfully fixates on the target. For example, subjects may have to process what would be analogous to a degraded stimulus when they do not fixate successfully, thereby impairing target recognition. Thus, if children and elderly subjects do not fixate on the target location as consistently as college age subjects, corresponding differences in the quality of stimulus reception probably results. Evidence from our studies is consistent with this view. Recall that in order to adjust subject's no-mask performance levels to a 70% level, subjects were pre-tested with different size targets. In our developmental sample a negative correlation was observed between age and target size required to adjust performance to a 70% level, whereas in the elderly sample a positive correlation was observed. Thus, it appears that the larger arrowhead targets used by young subjects and elderly subjects relative to college age subjects serve to equate the quality of stimulus reception in the second experiment with each group (i.e., developmental and aging), thereby resulting in the absence of a significant Age X SOA interaction. An evaluation of this attentional hypothesis and how other attentional factors may influence backward masking performance in different age groups are important problems for future research.

# Footnotes

1. This research was conducted in collaboration with Dr. Joseph Hellige of the University of Southern California and Dr. Virginia Lawrence of Human Systems Dynamics. The preparation of this paper was facilitated by an Affirmative Action Faculty Development Grant, California State University, Fullerton.

2. Complete details of the experimental procedures are provided in Lawrence, Kee, and Hellige (1980).

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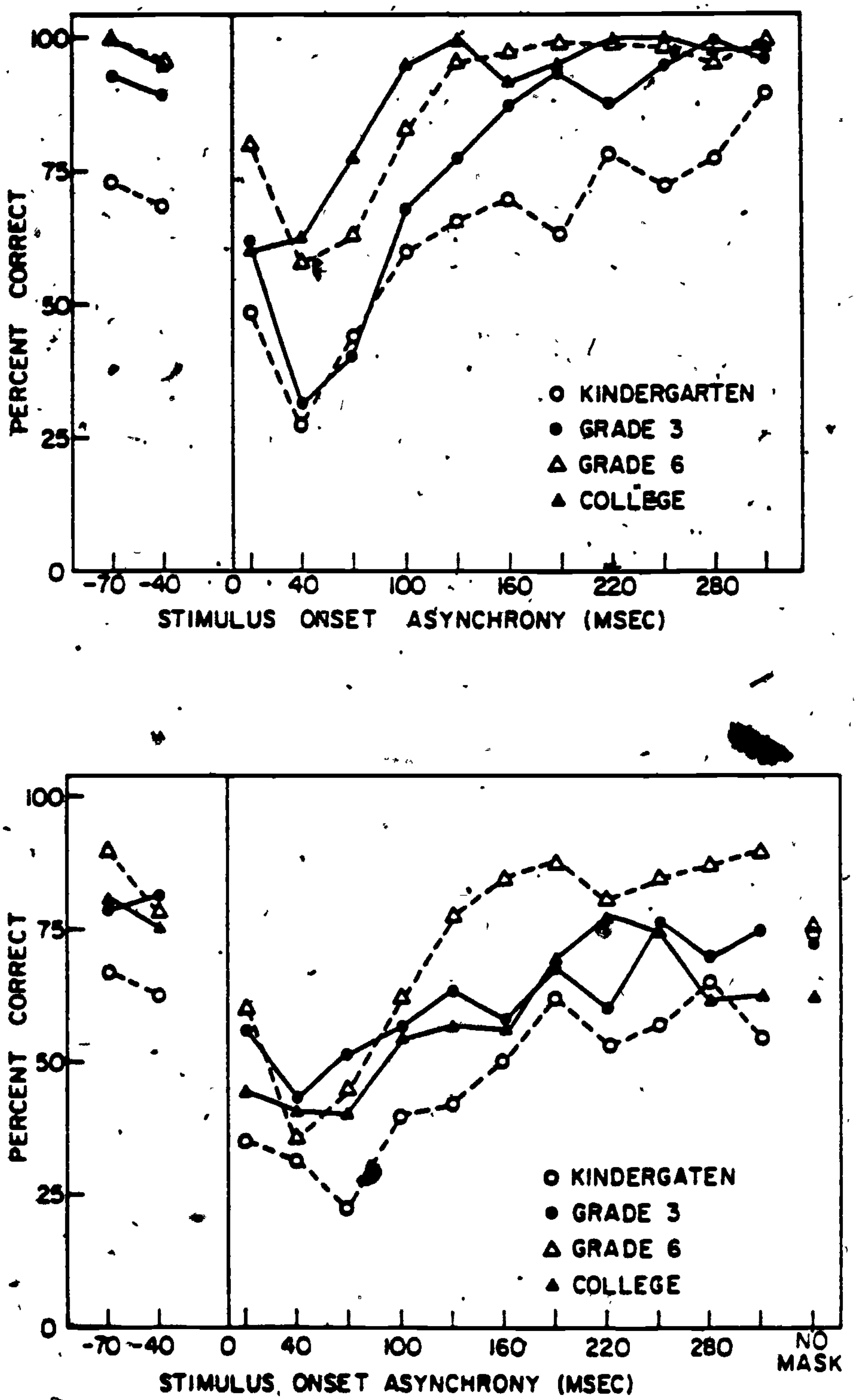


Figure 1. Percentages of targets correctly recognized as a function of grade level and stimulus onset asynchrony. Negative and positive SOAs refer to forward and backward masking conditions, respectively.

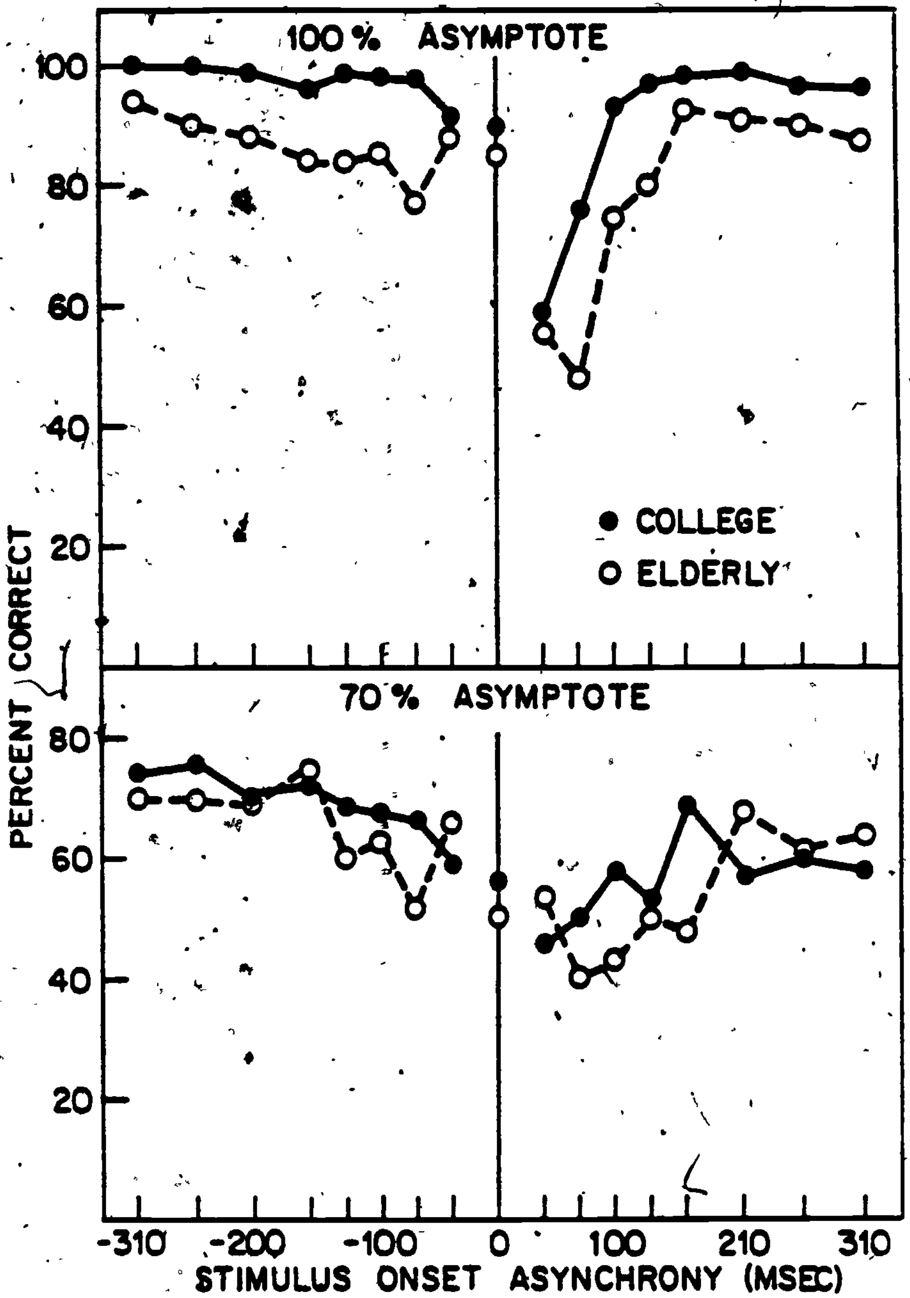


Figure 2. Percentages of targets correctly recognized as function of population and stimulus onset asynchrony. Negative and positive SOAs refer to forward and backward masking conditions, respectively.