Acta Biologica Hungarica 53 (1–2), pp. 221–227 (2002)

MODULATION OF BACKWARD PATTERN MASKING BY FOCAL VISUAL ATTENTION*

Z. VIDNYÁNSZKY**

Neurobiology Research Group, United Research Organization of the Hungarian Academy of Sciences
and Semmelweis University Medical School, Tűzoltó u. 58, H-1094 Budapest, Hungary and
Analogical and Neural Computing Laboratory, Computer and Automation Research Institute
of the Hungarian Academy of Sciences, Budapest, Hungary

(Received: September 30, 2001; accepted: November 17, 2001)

The effect of focal visual attention on backward pattern masking was investigated using an orientation discrimination task. The results show that attention reduces primarily the effect of interruption masking, the later component of pattern masking, which occurs when the delay between the target and mask onset is about 50–150 ms. The strongest spatial cueing effect, i.e. the strongest reduction of the orientation discrimination threshold due to focal attention, was observed at intermediate (~100 ms) target-to-mask stimulus onset asynchrony (SOA). There was a weak effect of cueing at shorter SOAs, and no or a very weak attentional effect was present at longer target-to-mask SOAs, where the pattern masking effect is absent. The dynamics of attentional modulation of backward pattern masking correlates closely with the dynamics of the attentional modulation of neuronal responses in the early visual cortex.

Keywords: Visual attention – backward masking – attentional cueing – orientation discrimination

INTRODUCTION

In general, backward masking refers to a reduction in the visibility of a briefly displayed stimulus, the target, due to a second stimulus, the mask, which follows the target with a very short delay. Visual masking can be divided into two types, on the basis of the spatial relationship between the contours of the target and mask patterns. Backward masking that involves the spatial superimposition of contours is commonly referred to as pattern masking, while masking that involves closely adjacent but nonoverlapping contours is called metacontrast masking (for a review, see [2]).

It has been suggested that in pattern masking the mask interferes with the processing of the target in two stages. The first conflict is in the early stages of visual information processing. In consequence of the imprecise temporal resolution of the visual system when the mask is presented in very close temporal proximity to the target, they are perceived as part of the same pattern. In this case, the masking is similar to the addition of noise to the target signal and this is referred to as integration masking [1, 3, 8]. The second component of the pattern masking is a conflict, due to

---

*Dedicated to Professor József Hámori on the occasion of his 70th birthday.

**E-mail: vidnyanszky@ana.sote.hu

the interruption of the target processing by the mask, which appears in the same spatial location before the target has been fully processed. This is called interruption masking [4]; it occurs when the mask follows the target with a certain delay.

In addition to their temporal characteristics, the two components of pattern masking are also distinguishable on the basis of their sensitivity both to the physical attributes of the mask and to the task-specific attentional state. Integration masking increases with the luminance contrast of the mask, whereas contrast has little effect on interruption masking [1, 8]. Conversely, it has been shown that varying set size, i.e. the number of potential targets, has little effect on integration masking, but markedly increases masking by interruption [9].

The goal of the present study was to test directly the effect of focal attention on backward pattern masking. To characterize the attentional modulation of the two different components of pattern masking, the size of the spatial cueing effect was measured in an orientation discrimination task as a function of the delay between the presentation of the target and the mask, i.e. the target-to-mask stimulus onset asynchrony (SOA).

MATERIALS AND METHODS

One of the authors and three naïve observers with normal or corrected-to-normal vision participated in the experiments. Stimuli were displayed on an SGI Indigo (1024×1286-pixel monitor) and the viewing distance was 110 cm. The mean luminance was 32 cd/m^2 and the frame rate was 70 Hz. The target and the surrounding flanks were Gabor patches (GPs). The GP wavelength (λ) was 0.24 deg and the Gaussian envelope size was 1.5 λ. The target GP contrast was 36%. A plaid, composed of two superimposed vertical and horizontal GPs, was used as mask. The mask contrast was 90%. The target GP was displayed randomly in one of the visual quadrants at 4-degree eccentricity. The target-flank separation was 4 λ.

Procedure

The observers initiated each trial by pressing a key. After the key press there was a randomly selected delay (300–500 ms duration), which was followed by the target in the no-cue conditions and by a spatial cue in the cued conditions. The cue was 100% valid and was displayed for 97 ms. The target was displayed immediately after the cue offset. In all conditions the target was presented for 56 ms. The SOA, which separated the target and mask onset, was the independent variable. The observers were required to report whether the target was tilted left or right in a two-alternative forced-choice (2AFC) procedure. Audio feedback was given for incorrect responses. Contrast thresholds were estimated by a staircase procedure [10], which established the 75% correct discrimination threshold. Each staircase was terminated after thirteen reversals. The mean of the last ten reversals was taken as the discrimination threshold. Each data point represents the mean of six replications, and the bars represent ±1 standard error of the mean.

RESULTS

We measured the orientation discrimination threshold as a function of the SOA, which is the time between the onsets of the target and a high-contrast mask. In a 2AFC procedure, the observers were required to report whether the target was tilted left or right of vertical (see Fig. 1).

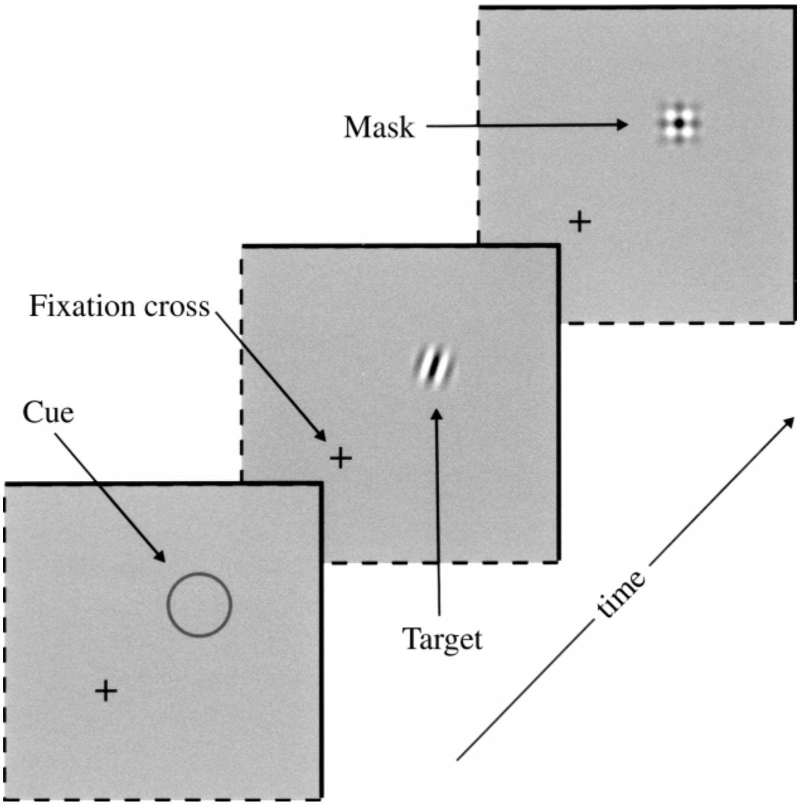
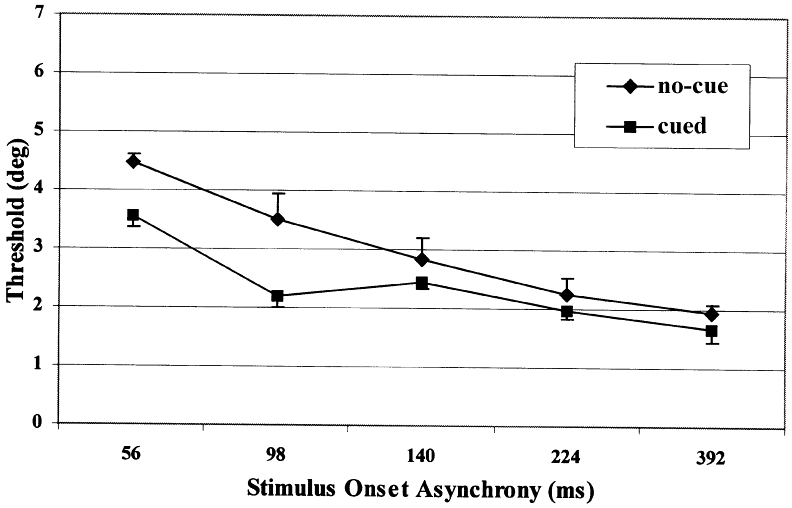
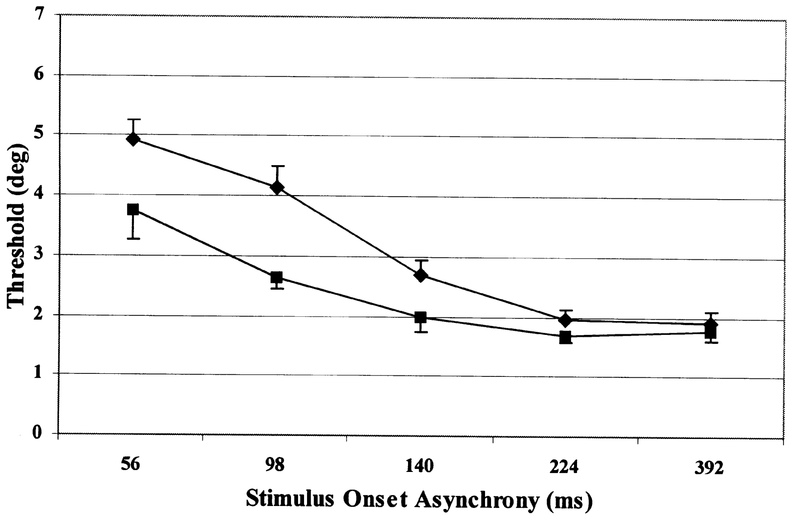


Fig. 1. Schematic stimulus configurations for measuring orientation discrimination thresholds, with either cued target location (shown here), or cue-absent conditions. Observers were required to fixate on the cross in the monitor center during the whole trial period. Observers initiated each trial by a keypress. The sequence of the trial was as follows: spatial cue (in the cued condition), target display, and mask. The observer's task was to report whether the target was tilted left or right of vertical. The target appeared in one of four possible locations, each 4° away from fixation in a quadrant that was selected randomly. Only the upper right part of the display is shown here, as schematized by the dashed left and bottom edges. See the text for further details

The shortest SOA was 56 ms, which is equal to the target duration. There was a strong masking effect for all four observers in the no-cue condition. On average, the orientation discrimination threshold was more than twice as high at the shortest SOA as compared to the longest, which was 392 ms. Figure 2 shows how the thresholds varied with SOA for the four observers.

Cueing had a significant effect on the orientation discrimination threshold. To illustrate the magnitude of the cueing effect as a function of SOA, the data are replotted in Fig. 3 in terms of threshold elevation, i.e. a decrease in threshold in the cued condition relative to that in the no-cue condition.





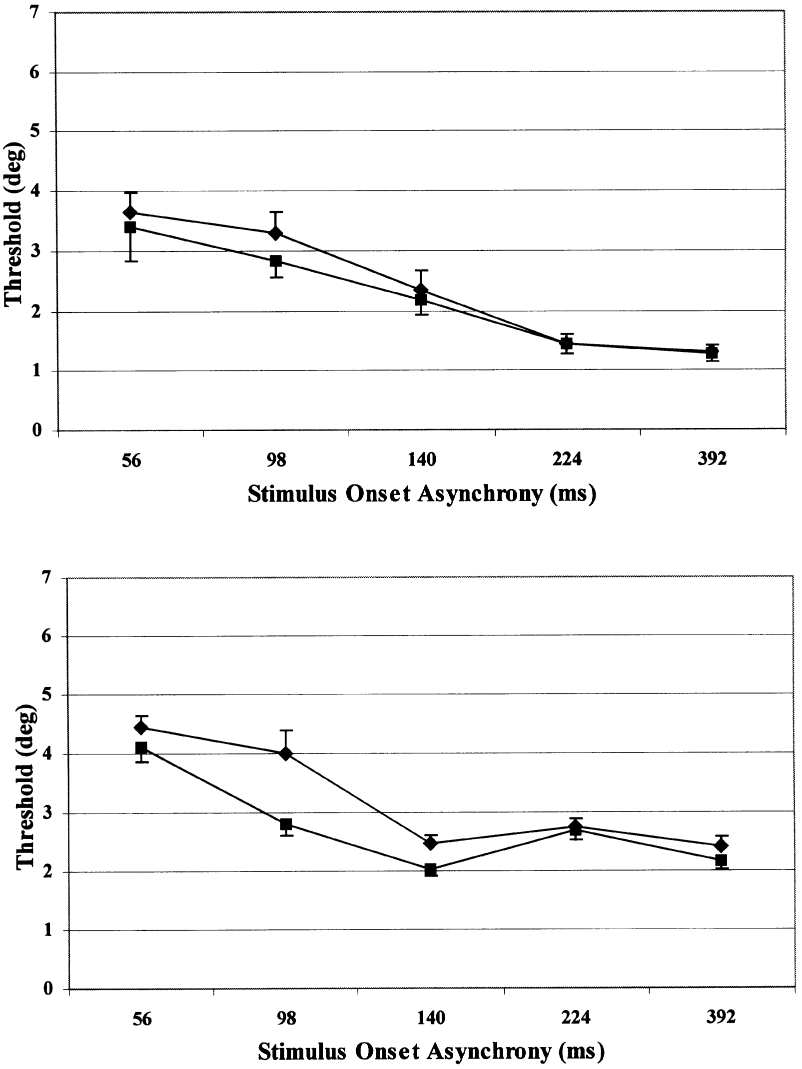


Fig. 2. Effect of the focal attention on the orientation discrimination threshold. Orientation discrimination thresholds (ordinate) are plotted against SOA (abscissa). Results from the four observers are shown. The threshold elevation at short SOA in the no-cue condition (diamond-shapes) represents the backward masking effect. Cueing the target location (squares) resulted in threshold reduction at SOAs smaller than 200 ms

It can be seen that in all observers the strongest cueing effect occurred when the SOA was about 100 ms. At both shorter and longer SOAs, the cueing-induced threshold reduction was much weaker. In fact, there was a very weak or no cueing effect when the SOA was more than 200 ms.

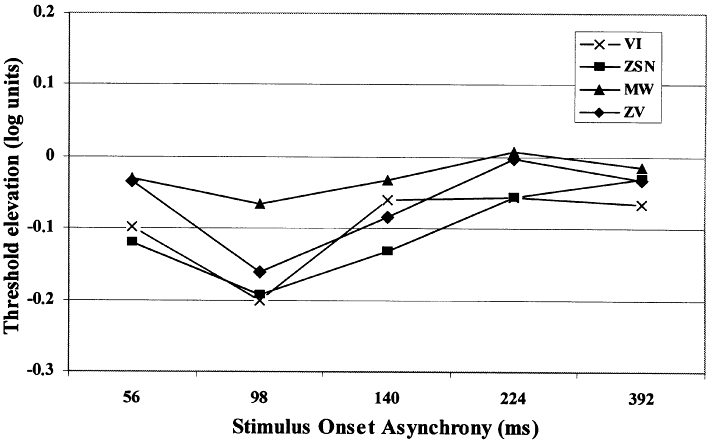


Fig. 3. Cueing-induced threshold reduction as a function of SOA. Results are shown for the four subjects (VI, ZSN, MW, ZV are the initials of the subjects). The ordinate is the log of the ratio of the threshold in the cued condition and the no-cue condition. The cueing effect peaks at an SOA of around 100 ms

DISCUSSION

It was found that backward pattern masking significantly increases the orientation discrimination threshold, and the strongest masking effect is at short SOAs and disappears when the SOA is longer than 200 ms. The spatial cueing effect, i.e. the reduction in the orientation discrimination threshold due to focal attention, is most pronounced at intermediate (~100 ms) SOAs. The cueing effect at the shortest (56 ms) SOA is about two times weaker than that at intermediate SOA. There was no or very little attentional effect at longer SOAs where the pattern masking effect is absent.

According to the two-component models of backward pattern masking (for a review, see [2]), these results suggest that the strongest modulation by focal attention is during the second component, the interruption masking, which is in effect at intermediate SOAs. The effect of spatial cueing on backward pattern masking observed in the present study is very similar to the effect of increasing the positional uncertainty on backward masking, found in an earlier study by use of a letter identification task [9]. In this study the strongest attentional modulation of backward masking was likewise found at SOAs ranging from 60 to 100 ms.

It has recently been shown that attention also has a strong effect on metacontrast masking, where the target and the mask are presented in adjacent, but not overlapping locations [2]. It is important to note that, similarly to interruption masking, metacontrast masking occurs when the presentation of the mask is delayed by 50–100 ms with respect to the target [1]. In fact, the high sensitivity of metacontrast masking to attentional manipulations led to a new model of backward masking being suggested. This model is called object-substitution masking [2], and it suggests that, for both metacontrast masking and interruption masking, the masking effect is due to the disruption of the recurrent interactions between higher and lower visual areas.

A similar explanation of backward masking was proposed recently on the basis of the known response characteristics of visual cortical neurons [5, 7].

These new models suggested the following explanation for the SOA-dependent attentional modulation of backward masking. In the early visual cortex, e.g. in V1, the neuronal responses can be divided into two components (for a review, see [6]). The first is a transient component that reflects mainly feedforward processing, and carries information mainly about receptive field tuning properties. The second component starts about 100 ms after the stimulus onset and exhibits modulations due to figure-ground segregation and attention. When the mask is presented in very close temporal proximity to the target, as in the case of integration masking, the response to the mask will influence or will already have been integrated into the first transient response component evoked by the target. Since attentional modulation of neuronal responses starts later and is present only in the second, sustained response component, the integration masking which has its neural correlates in the first response component will not be affected by attention. However, in the case of interruption and metacontrast masking, the second sustained component of the neuronal response to the target will be affected by the neuronal activity due to the mask. Therefore, attentional effects temporally coincide with the neural effects of interruption masking and thus would be able to modulate it.

In conclusion, the present psychophysical results, which reveal a strong attentional modulation of the later component of backward pattern masking, are in close agreement with the dynamics of the attentional modulation of neuronal responses in the early visual cortex.

ACKNOWLEDGMENT

This work was supported by the Hungarian Scientific Research Fund (OTKA, No. T022297)

REFERENCES

1. Breitmeyer, B. G. (1984) *Visual Masking: An Integrative Approach*. Oxford University Press.
2. Enns, J. T., Di Lollo, V. (2000) What's new in visual masking? *Trends in Cognitive Sciences, 4*, 345–352.
3. Kahneman, D. (1968) Method, findings, and theory in studies of visual masking. *Psychological Bulletin, 70,* 404–425.
4. Kolers, P. A. (1968) Some psychological aspects of pattern recognition. In: Kolers, P. A., Eden, M. (eds), *Recognizing Patterns*. MIT Press, pp. 4–61.
5. Lamme, V. A., Roelfsema, P. R. (2000) The distinct modes of vision offered by feedforward and recurrent processing. *Trends in Neuroscience, 23*, 571–579.
6. Lamme, V. A., Super, H., Spekreijse, H. (1998) Feedforward, horizontal, and feedback processing in the visual cortex. *Current Opinion in Neurobiology, 8,* 529–535.
7. Pollen, D. A. (1999) On the neural correlates of visual perception. *Cerebral Cortex, 9,* 4–19.
8. Scheerer, E. (1973) Integration, interruption and processing rate in visual backward masking. *Psychologische Forschung 36,* 71–93.
9. Spenser, T. J., Shuntich, R. (1970) Evidence for an interruption theory of backward masking. *J. Exp. Psychol. 85,* 198–203.
10. Tolhurst, D. J., Barfield, L. P. (1978) Interactions between spatial frequency channels. *Vision Research, 18,* 951–958.