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Extending the shine-through effect to classical masking paradigms

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Abstract

A vernier, presented for a short time, *shines through* a following grating if the grating contains nine and more elements but remains largely invisible for smaller gratings. Therefore, extended grating masks yield, surprisingly, less masking than smaller ones. Here, we show that this mask size effect is not unique to grating masks. Masking diminishes if the size of classical pattern-, noise-, light-, and metacontrast masks increases *and* if these masks are regular, i.e. highly ordered.

Keywords: Shine-through effect; Spatial vision; Visual masking; Metacontrast; Verniers

1. Introduction

Shine-through (Fig. 1) can occur for vernier presentation times as short as 10 ms, i.e. corresponding to a few spikes of a neuron, with vernier offsets in a spatial range as small as 20″ (arc seconds). Small spatial deviations from the homogeneity of the grating, such as missing elements, strongly decrease performance (Herzog, Fahle, & Koch, 2001). Because of these short vernier durations and the subtle spatial dependencies, the shine-through effect has been a very useful tool in research on feature binding (Herzog, Koch, & Fahle, 2001a), backward masking (Herzog & Koch, 2001), figure-ground-segmentation (Herzog et al., 2001), temporal dynamics of visual information processing (Herzog, Koch, & Fahle, 2001b), visual consciousness (Herzog & Koch, 1999), and schizophrenia (Herzog, Kopmann, & Brand, submitted). In this publication, we show that both the mask size effect and the importance of the mask regularity are not unique to grating masks.

Four types of spatial masks are of paramount interest in backward masking: pattern-, light-, noise-, and metacontrast masks (Bachmann, 1994; Breitmeyer, 1984; Turvey, 1973; see Fig. 2). Each of these mask types is associated with different processing characteristics. *Light* and *noise* masks, i.e. patches of luminance, are thought to impair target detection by decreasing low level signal to noise ratio (e.g. Eriksen, 1966). *Pattern* or structure masks often consist of (randomly) distributed elements with features similar to the target, e.g. a vertical line target is followed by lines of random orientation and position. *Metacontrast* mask are pattern masks that do not spatially overlap with the target. Pattern and metacontrast masks, in addition to decreasing the signal to noise ratio, are assumed also to interfere with the processing, e.g. the contour processing, of the target (e.g. Werner, 1935).

Backward masking can be differentiated into two fundamentally different types according to its *temporal* characteristics: *A-type* and *B-type* masking (Kolers, 1962). In A-type masking, the masking strength decreases, and therefore performance improves, with increasing inter-stimulus interval (ISI) between target and mask. B-type follows a U-shape function: performance is best for short and long ISIs and strongly deteriorates for intermediate ISIs, usually peaking between 30 and 100 ms. In A-type masking, mask and target usually overlap spatially, while B-type masking usually is investigated for masks flanking but not overlapping the target, e.g. an annulus surrounding a disk (but see Enns

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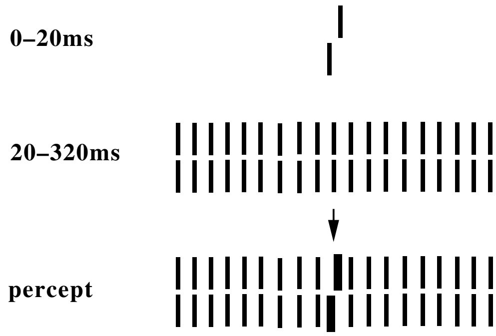

Fig. 1. The shine-through effect. A vernier is presented for a short duration and followed by a grating comprising more than seven elements. The preceding vernier appears to be superimposed on the grating and to look wider, brighter, and for some observers even longer than it is in reality (see Herzog & Koch, 2001).

& Di Lollo, 2000; Francis, 2000). Masking in the shine-through effect reveals A-type masking (Francis & Herzog, in press).

Here, we show that with all four main types of classical backward masking, performance improves with increasing size of regular masks. The results can be explained with a network of the Wilson–Cowan-type which was already employed to explain the shine-through effect with regular grating masks (Herzog, Ernst, Etzold, & Eurich, in press).

2. General materials and methods

2.1. General set up

Stimuli were displayed on an analog monitor (HP 1333A or 1332A), controlled by a Power Macintosh computer via fast 16 bit D/A converters (1 MHz pixel rate). A vertical vernier preceded a variable mask. Vernier segments were 600″ long, oriented vertically, and separated by a vertical gap of 60″. Thus, total vernier length was 1260″. The vernier appeared always in the middle of the screen. Except for experiment 2 and for the "jitter" condition of experiment 1, grating masks were also centered on the middle, i.e. the center element of the mask appeared at the same position as the vernier (disregarding its offset). Masks lasted for 300 ms and followed immediately after the vernier, i.e. without ISI (except for the timing study of experiment 3). Horizontal spacing between the elements of the regular gratings was 200″. The basic shine-through condition, i.e. a vernier followed by a grating with 25 elements, is called the "standard condition" and the grating is defined as the "standard grating". The corresponding condition with a 5 element mask is referred to as a "standard grating with 5 elements".

Subjects observed the stimuli from a distance of 2 m in a room illuminated dimly by a background light (around 0.5 lx). Luminance of stimuli was approximately 80 cd/m^2. Before the stimuli were presented, a fixation spot was turned on in the center of the screen simultaneously with four markers at the corners of the screen for one second followed by a blank screen for 200 ms. Refresh time was 10 ms.

2.2. Observers

Data were obtained from graduate students of the University of Bremen, Germany, and from two of the authors. Each observer was informed about the general aim of the experiment, but most observers were naive regarding the exact purpose of the study. All observers had normal or corrected-to-normal visual acuity as tested by means of the Freiburg visual acuity test (Bach, 1996). To participate in the experiments subjects had to reach a visual acuity of 1.0 (corresponding to 20/20) in this test at least for one eye.

Before the experiment proper took place, we tested whether the naive observers were able to perceive the vernier as a shine-through element in the condition with

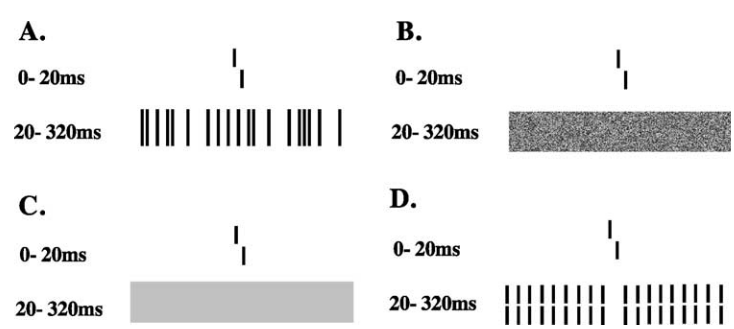

Fig. 2. Examples of mask types used. These are the equivalents of the 25 element standard grating (Fig. 1). (A) Pattern line mask. Vertical lines are randomly positioned along the *x*-axis while *y*-coordinates are identical. Pattern line masks are gratings with irregular spacing. (B) Noise mask. One-pixel dots are randomly distributed over an area corresponding to the size of the standard grating. (C) Light masks are dot masks with a regular spacing, appearing as a uniform field of light. (D) Metacontrast grating mask. The center element of the standard grating is omitted. Energy of the masks in A–C is identical to the standard grating and differs for the metacontrast mask only by the center element. Stimuli were greenish or blueish white on a black background.

the standard 25 element grating (Fig. 1). If not stated otherwise, the shortest duration of the vernier was used for each observer individually which allowed perceiving shine-through comfortably in the standard condition. This time is called the "minimal time". For all but two observers vernier durations of 20 ms were employed while 10 ms or else 30 ms for the remaining two subjects.

2.3. Task

Observers had to discriminate, in a binary forced choice task, the offset-direction of the vernier by pressing one of two push buttons. A tone produced by the computer followed incorrect responses.

2.4. Strategies

We determined performance by means of an adaptive staircase procedure (PEST; Taylor & Creelman, 1967). In many conditions, subjective visibility of the preceding vernier can be strongly diminished (with "visibility" we refer to the *subjective* reports by observers about the perception of the foregoing vernier). Adaptive strategies cannot properly handle such conditions since these strategies present increasingly larger offsets in search of the (non-existent) discrimination threshold, defined as 75% correct responses. Therefore, we prevented the PEST-procedure from offering offset sizes of the foregoing vernier exceeding 300″ (that is 1.5 times the horizontal spacing of 200″ between grating elements). If observers were unable to obtain 75% correct responses for an offset value below 300″ the condition was considered as "sub-threshold" and an offset of 350″ was tabulated if, firstly, increasingly larger offsets were presented by PEST; secondly, an offset value of 300″ was offered by PEST at least once; and, thirdly, the hit rate for this value was below 75% correct responses. In ambiguous cases, the block was repeated. If vernier visibility is strongly diminished for most observers, standard errors can be artificially small revealing a floor effect, i.e. performance cannot be correctly determined because of strong masking. We like to emphasize that restricting the PEST-procedure avoids large performance differences that would occur otherwise. For comparisons with other conditions with a "clear" vernier visibility this procedure is rather conservative since extreme thresholds are avoided which would strongly shift means. We never statistically compared conditions for which floor performance occurred in both conditions, i.e. conditions in which a value of 350″ was recorded for at least one observer.

For every subject, every condition was measured twice. The order of conditions was randomized individually for every observer to reduce possible hysteresis or order effects. After every condition had been measured once, the order of conditions was reversed for the second round of measurements in order to, at least partly, compensate for possible learning effects. A block contained 80 trials.

3. Results

3.1. Mask extension

Shine-through is perceived best with extended and homogeneous gratings. In this experiment, we investigate mask size effects for pattern-, noise-, and light masks.

3.1.1. Methods

In the first part of the experiment, we determined performance both in the standard condition, i.e. for a vernier followed by a grating of 25 elements, and with a grating with 5 elements. Thresholds were also determined for an unmasked vernier. Second, we presented (after the vernier) 25 or 5 element line masks with the horizontal x-positions of the lines pseudo-randomly chosen at each trial. Length of lines was 1260″, i.e. the same size as standard grating elements (including vertical gap). These random lines were presented in an area identical to the area spanned by the 25 respectively 5 element standard gratings (Fig. 2A). Lines never overlapped. Thus, these random line pattern masks might be considered as gratings with irregular spacing. These masks have a low degree of regularity while energy and orientation of elements are identical to the standard condition. With "energy" we refer to the sum over luminances $\times$ duration of the individual elements of the mask. As a control, we presented the standard grating with its position "jittered" along the x-axis. The grating position could be shifted to the left or right by a value randomly chosen in the range of 0–500″, i.e. more than half of the horizontal extension of a grating with 5 elements. In the third part of the experiment, verniers were masked by noise. As with random lines, noise masks extended over areas corresponding to the size spanned by the 25 respectively 5 element gratings and consisted of the same number of pixels as those. Each noise dot had a size of 1 pixel. Performance was also tested for a noise mask corresponding to the size of a 25 element grating with about one third or one fifth of the number of pixels (a fifth is equivalent to the number of pixels of a 5 element grating). For the fourth part of the experiment, we employed homogeneous light masks, i.e. noise masks with regularly spaced dots. Again, two masks with the same energy and extension as the 25 and 5 elements gratings were used. Five observers participated.

In a recent publication (Herzog et al., in press), we showed that a simple model of the Wilson–Cowan type can capture the results of the basic shine-through effect. This spatially one-dimensional model focuses on the vernier visibility only while ignoring the vertical spatial dimension and the vernier offset. The model consists of an excitatory and an inhibitory layer that are mutually inter-connected. Here, we show that the very same model can explain the empirical results also for other mask types. Results for the random line, jitter, and noise mask conditions are based on the mean value of 100 simulation trials each. For further details and the mathematical equations describing the temporal dynamics of the model (see Herzog et al. (in press)).

3.1.2. Results

Performance for the extended grating, noise, and light masks is significantly superior compared to the corresponding smaller masks (paired *t*-test: $p = 0.0008$, 0.0052, 0.0358). Performance for the extended random line mask is better than for the small (#5) random line mask. However, we did not compare conditions statistically because of floor effects caused by the cutoff procedure of the adaptive method (see Section 2).

Performance strongly deteriorates if the elements of line masks are not regularly spaced, i.e. if the *order* of the grating is lost while the number and orientation of lines, and therefore their energy, are kept constant (see Fig. 3; paired *t*-test: $p = 0.0275$, for jitter vs. #25 r-lines). Randomizing the *x*-position of the standard grating has almost no effect on performance (means and se: 46.3, 2.92 (standard); 51.5, 7.4 (jitter)).

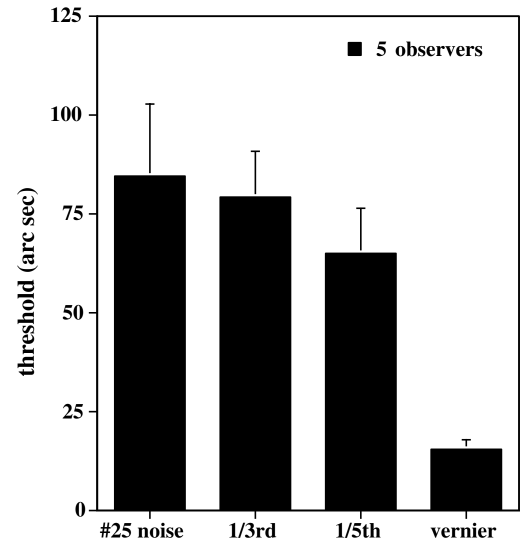

Fig. 4. The number of noise dots was varied for the #25 noise mask condition: one third (1/3rd) or one fifth (1/5th) of the pixels of this #25 noise mask were used. Thresholds decrease slightly with decreasing number of dots but are clearly worse than in the unmasked condition ("vernier"). Please note scaling of the ordinate compared to Fig. 3.

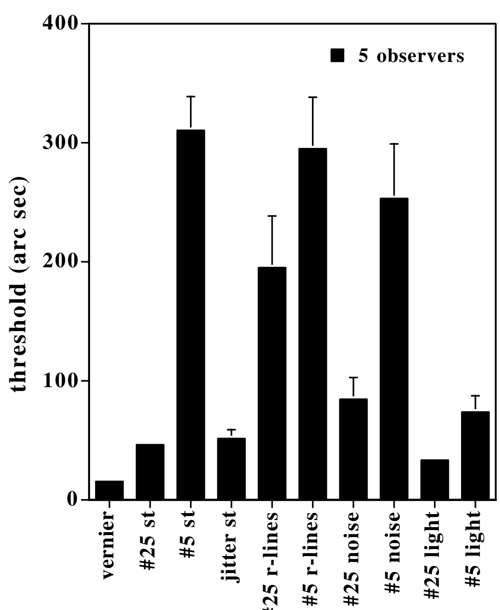

Fig. 3. A vernier preceded a grating-, random line-, noise-, or light mask. Masks extended over areas corresponding to the 25 and 5 element standard gratings ("#25 st" and "#5 st") and are denoted accordingly, e.g. "#25 noise" and "#5 noise" (r-lines = random lines). In the "jitter st" condition the horizontal position of the 25 element standard grating is randomized. Performance in the #25 conditions is better than in the corresponding #5 conditions. Randomizing the *x*-position of the regular 25 element grating has virtually no effect compared with the non-jittered standard grating condition. The unmasked vernier ("vernier") yields best performance.

Noise masks, corresponding to the 25 element grating, increase thresholds compared to the standard condition but yield better results than random line masks (see Fig. 3; paired *t*-test: $p = 0.0245$, for #25 r-lines vs. #25 noise). Reducing the energy of the #25 noise mask to about two thirds or even one fifth improves vernier discrimination only slightly (Fig. 4). Thresholds are still worse than for an unmasked vernier (1/5th noise vs. vernier, paired *t*-test: $p = 0.009$). Extended light masks yield performance even slightly superior to the standard 25 element condition (Fig. 3). Performance for the small light mask is much better than for the 5 element standard grating and the #5 noise mask (paired *t*-test: $p = 0.0007$, 0.0053 respectively). Performance can be quite heterogeneous between observers in the 5 element light mask condition.

Fig. 5 shows the computer simulation results for the stimuli used in the experimental conditions described above. The simulations show a good qualitative and a fair quantitative agreement with the empirical results except for the #25-noise and #5-noise condition. Here, the simulations show nearly identical thresholds while psychophysical performance differs. The reason for this is that the stimuli of the #25- and #5-noise conditions can only be represented accurately in a two-dimensional arrangement which is beyond the scope of a one-dimensional model.

3.2. From order to noise

Clearly, both the size of the mask and its regularity are important. However, also the *similarity* between

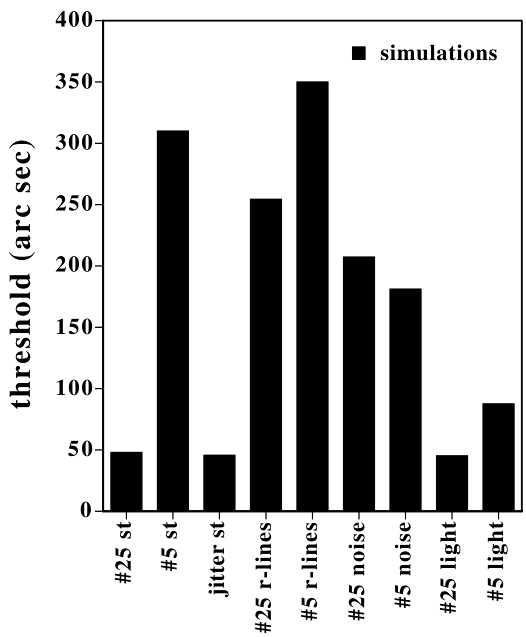

Fig. 5. Computer simulation results: performance for the stimuli used in experiment 1. The abscissa shows the various masks that are one-dimensional in the model. As in Fig. 3, performance for extended masks is superior than for smaller masks except for the noise masks. Here, performance for the extended noise mask is slightly worse compared to the smaller one. Regular masks yield lower thresholds than irregular ones.

mask and target elements may play an important role since #25 noise masks yield better results than #25 random line masks. Moreover, small light masks interfere less than homogeneous 5 element gratings. Here, we investigate the influence of target–mask similarity and possible contour interactions by varying the orientation and length of line elements while keeping the mask energy constant.

3.2.1. Methods

A varying number of vertical or horizontal lines was presented after the vernier target in an area corresponding to the size of the standard 25 element grating mask. These pattern masks always appeared immediately after the vernier. The overall energy and line length of the masks were always identical, i.e. doubling the number of lines was associated with halving the length of each line. In the condition with 25 vertical lines, all elements had the same y-coordinates, i.e. only the horizontal position was *irregular*, leading to the same condition as in Fig. 3, #25 r-lines. For more than 25 vertical lines and for horizontal lines x- and y-coordinates were randomized. In the condition with only 5 horizontal lines, all elements had the same x-coordinates while their y-positions were randomized (it is impossible to cover the area, spanned by the standard grating, with 5 vertical elements while keeping energy constant). Lines never overlapped. We determined performance also for the standard condition. Three observers participated. All conditions were tested both with vernier presentation times that corresponded to the individual observers' minimal time and with a vernier duration lasting 10 ms longer.

3.2.2. Results and discussion

If the vernier is displayed at observers' minimal time, performance strongly decreases for pattern masks comprised of random vertical lines compared to the standard condition (Fig. 6, left panel). Performance reveals a floor effect. In the "100 lines condition", the length of each of these lines is 315″, i.e. they are fairly small. Still, performance is clearly worse than with the noise mask that can be taken as a line mask with line length of about 30″. The noise mask has the same energy as the line pattern masks. For horizontal lines, performance strongly decreases if line length decreases and, hence, the number of lines increases. For 25, 50, and 100 lines performance is clearly worse than for the standard condition or the noise mask. More regular masks, such as the 5 element horizontal line mask, lead to better performance than masks with more elements that are randomly positioned in their x- and y-coordinates. Arguably, regularity decreases with the increasing number of horizontal lines. Vernier durations lasting an additional 10 ms increase performance for both orientations, most pronounced for the horizontal lines (Fig. 6, right panel). Therefore, this kind of backward masking reveals subtle spatial and temporal characteristics.

3.3. Metacontrast

In the following experiments, we used metacontrast grating masks to study the role of the central grating element.

3.3.1. Methods

Regularly spaced gratings were presented with a variable number of elements but the central element was always omitted, i.e. the vernier itself was not covered by a following element (Fig. 2D). Hence, the grating contained a gap of a width of 400″ at the center in all conditions. For metacontrast gratings with 4, 8, and 24 elements, we determined performance also for a regularly spaced grating comprised of the identical elements as the metacontrast grating but additionally containing the central grating element. Thus, these gratings contained 5, 9, and 25 elements, respectively. Verniers were displayed for 20 ms for the four subjects participating.

In the second part of the experiment, we varied the SOA between vernier and metacontrast gratings of 24 and 2 elements, i.e. 12 and 1 elements on each side respectively. SOA denotes the difference between the onset of mask and target. Two new observers participated.

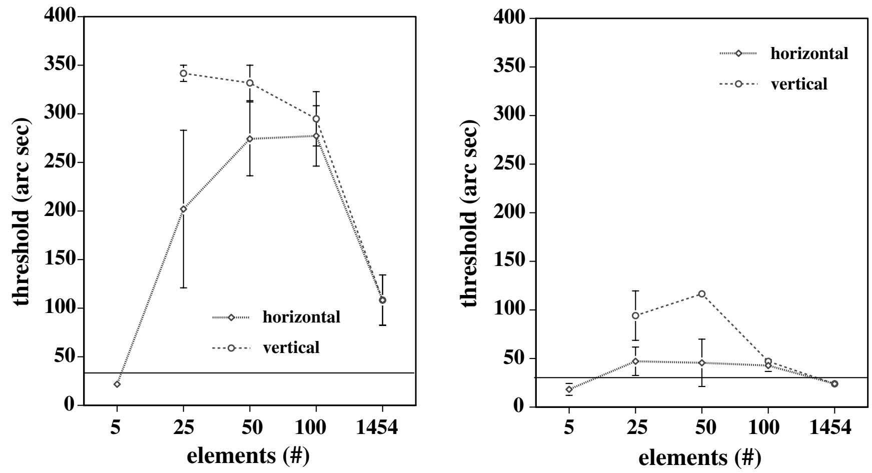

Fig. 6. Varying numbers of horizontal or vertical mask elements were presented. Total line length of mask elements was constant, hence higher element numbers mean shorter line size. Physical mask energy was constant in all conditions. Verniers were presented for the individual minimal times required by the observers (left part of figure) or else 10 ms longer (right part). Performance was also determined for the noise mask condition (see Fig. 2B). Noise masks consisted of 1454 dots (see "1454" on the abscissa). In the standard condition (horizontal line) the 25 grating elements are regularly spaced while in the condition with 25 vertical lines the *x*-position of each of these lines is randomized (see Fig. 2A). The more horizontal lines are presented, the worse is performance (left part). For vertical lines a floor effect occurs: offset discrimination is impossible. Noise masks yield better results but performance is worse compared with the standard condition. Increasing vernier duration considerably improves performance (right part of figure). Three observers participated. Please note scaling of the abscissa.

3.3.2. Results

Performance is best for a metacontrast grating with 24 elements, decreases for fewer elements but improves slightly for only one element displayed to the left of the vernier (Fig. 7; paired *t*-test: $p = 0.008$ for a 2 vs. 24 element metacontrast grating). Still, performance for the metacontrast mask with 24 elements is worse than performance for the standard grating (paired *t*-test: $p = 0.018$).

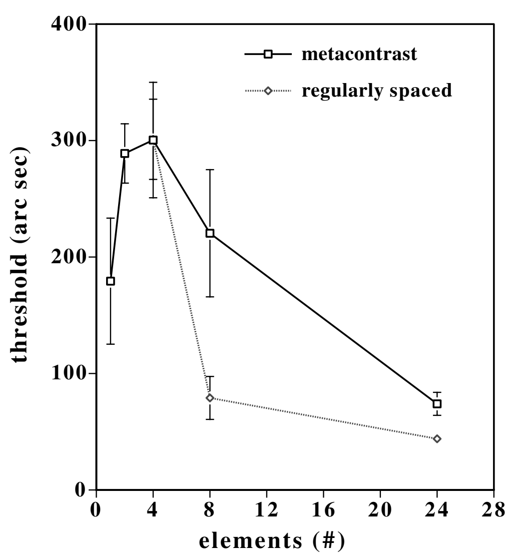

Fig. 7. A vernier preceded a metacontrast grating (Fig. 2D). We varied the number of elements of this mask. Thresholds decrease monotonically with increasing number of elements, except that for a single masking line performance is better than with a mask of two elements. Performance for regular gratings covering the vernier with 5, 9, and 25 elements is also shown. These thresholds are plotted together with the corresponding metacontrast gratings, e.g. a standard 25 element grating appears under the label of 24 elements. Four subjects participated.

Varying the SOA improves performance monotonically for 24 and 2 elements, i.e. our "metacontrast grating masks" do not yield B-type masking (Fig. 8).

4. General discussion

4.1. Mask extension

One of the most intriguing features of the shine-through effect is its dependency on the size of the masking grating. As our results show, also other mask types reveal this size effect. Target discrimination for extended pattern-, noise-, light-, and metacontrast masks is superior compared to smaller masks. Similar size effects were found earlier in *simultaneous* masking paradigms (e.g. Banks & White, 1984; Li, Thier, & Wehrhahn, 2000; Westheimer, 1967). Macknik, Martinez-Conde, and Haglund (2000) showed that the width of opaque masks, analogously to the light masks used here, determines performance in a backward masking task.

4.2. Regularity

Offset discrimination for masks with 25 random lines deteriorates strongly compared to 25 regularly spaced lines, i.e. the standard condition, though both masks

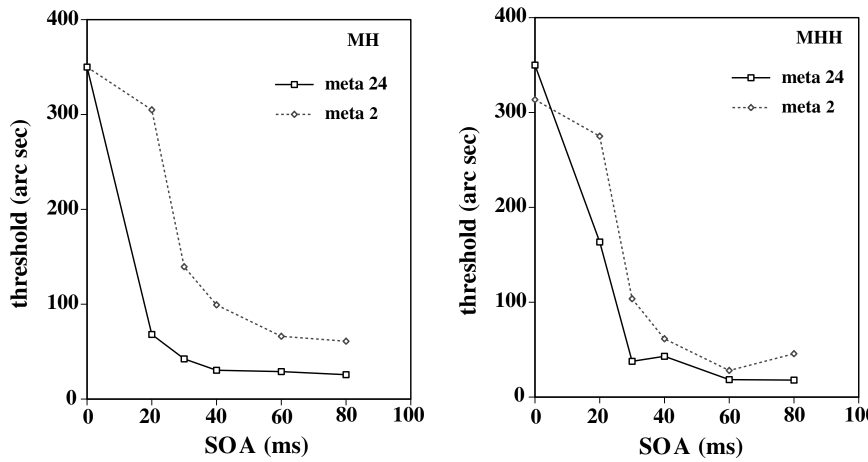

Fig. 8. Vernier discrimination thresholds as a function of the SOA between the preceding vernier and a 24 (meta 24) or 2 (meta 2) element metacontrast grating. Increasing SOA improves performance, i.e. thresholds decrease monotonically in both conditions. Two experienced observers participated. An SOA of 0 ms indicates that the vernier and the mask appeared at the same time.

have the same physical energy. Therefore, the *regularity* of the grating is essential for the shine-through effect to occur. Deterioration of performance with the random line masks cannot be explained by the un-predictability of the grating position relative to the vernier position since randomizing the horizontal position of the entire standard grating does not deteriorate performance significantly ("jitter condition" of experiment 1).

In Herzog et al. (2001), we have shown that shine-through depends strongly on the *homogeneity* of the grating. For example, performance dramatically deteriorates if gaps are inserted between the second and third grating element to the left and right of the central element. The energy of this "gap grating" is identical to that of the standard grating while performance differs strongly. The gap grating still reveals a strong degree of regularity deviating just in two positions from the standard grating. Regularity is an important parameter also for other mask types, e.g. homogeneous light masks yield better results than noise masks. Schuboe, Schlaghecken, and Meinecke (2001) showed that perceptual learning improves much stronger with regular than with irregular masks.

We argued that neural activity corresponding to discontinuities in gratings, e.g. at gaps or edges, causes interference with activity corresponding to the preceding vernier. Evidence for such an interference could be shown by computer simulations with a Wilson–Cowan type model in the basic shine-through conditions (Herzog et al., in press). Using the same model, we here find an analogous interference with the vernier target for other mask types, too. This Wilson–Cowan type model highlights edges and inhomogeneities by an increased neural activity in accordance with psychophysical and physiological studies (MacKay, 1973; Macknik et al., 2000; McCarter & Roehrs, 1976; Sagi & Hochstein, 1985). Through intra-cortical lateral interactions, strong neural activity in the spatial vicinity of the vernier reduces activity of the vernier representation thus increasing thresholds for vernier detection.

4.3. Similarity

Similarity between the elements of the mask and the target seems to be another important factor. Performance for the extended noise mask is better than for the extended random line mask. Small light masks yield better results, hence, mask less than the homogeneous 5 element gratings. Vertical lines interfere more strongly than horizontal ones (see also Li et al., 2000; Wehrhahn, Li, & Westheimer, 1996).

4.4. Metacontrast

Size effects occur also for metacontrast masks since masking strength *decreases* in our study if the number of elements of the metacontrast mask *increases* (Fig. 7). This result is in good agreement with a study by Breitmeyer (1978) who showed that *two* lines on each side of a vernier deteriorate performance less than *one* flanking line on each side (lines were displayed following the vernier for the same duration as the vernier). In Breitmeyer's paradigm B-type masking occurred, i.e. threshold performance, as a function of SOA, followed a U-shape. Enns (2002) demonstrated that performance can improve when the width of metacontrast flankers increases.

In our third experiment, verniers were presented shortly while the masks lasted for 300 ms. We found A-rather than B-type masking with these metacontrast gratings. B-type masking vanishes if the strength of a mask exceeds that of a target (e.g. Breitmeyer & Ganz, 1976; Francis, 2000). The metacontrast masks employed in the present study are much stronger than the vernier target and, hence, may yield A-type masking (mask duration per se cannot explain this outcome since metacontrast masking occurred for flanking lines in other spatial configurations with the same mask durations of 300 ms; Francis & Herzog, in press).

Since in all metacontrast conditions the central grating element is missing, mask size effects are not due to the central grating element. If the metacontrast mask contains only two lines, one on each side of the vernier, feature inheritance is observed, i.e. the flanking lines appear to be offset in the direction of the almost invisible vernier (see also Enns, 2002).

4.5. Independence of the shine-through element

Randomizing the horizontal position of the entire standard grating, while keeping the vernier position constant, seems not to affect performance (Fig. 3, "jitter st"). In this condition, the spatial relation between the grating elements and the vernier varies strongly from trial to trial. This result is in good agreement with a result by Herzog et al. (2001a), who showed that performance is not affected when the vernier is permanently presented 100″ away from the mid-point in the standard condition, i.e. verniers never overlap with grating elements (at least for moderate offsets). In the jitter condition the vernier is directly covered by a grating element in some presentations while not in others. It follows that the shine-through element does not result from strictly local (luminance) fusion of the preceding vernier and the following central grating element.

4.6. Masking

In the shine-through effect, the global spatial layout, rather than the energy or local spatial aspects, determines performance (Fig. 3; Herzog & Fahle, 2002; Herzog & Koch, 2001). These results make strong restrictions on general models of masking. Most of these models deal primarily with the ratio between target and mask energy or focus on local spatial interactions. For example, metacontrast theories explain B-type masking often with local contour interactions between the target and the mask (e.g. Breitmeyer, 1984; Werner, 1935). However, performance improves if the number of elements in the metacontrast gratings increases while the distance between vernier and the innermost elements of the metacontrast gratings remains identical (Fig. 7; see also Breitmeyer, 1978).

Quantitative models of masking focus primarily on the ratio between target and mask energy often excluding any spatial processing at all (for a mathematical analysis of these models see Francis, 2000). However, shine-through depends on the spatial layout of the mask more than on its energy (Fig. 3).

The predominant view of masking proposes that (metacontrast) masking occurs by an interaction between the transient and the sustained visual system corresponding to the magno- and parvocelluar pathways. A-type masking is attributed to intra-channel interactions of the sustained visual system (Breitmeyer, 1984; Breitmeyer & Ganz, 1976; Breitmeyer & Oegmen, 2000). Shine-through reveals A-type masking characteristics, hence, masking may occur by a decreased signal to noise ratio (Francis & Herzog, in press). However, it is not clear why extended, homogeneous masks exert so far weaker masking effects compared to irregular ones (Fig. 3).

Substitution masking proposes that masking occurs since parts of the target are substituted with parts of the mask during target processing (Di Lollo, Enns, & Rensink, 2000; Enns & Di Lollo, 2000). Mask elements and vernier targets were quite similar in our experiments and hence may be compatible with substitution. However, it is not clear why an irregular extended 25 element grating deteriorates performance so far more than a regular standard grating does (Fig. 3). The elements are identical in both masks, only the layout of the differs.

It seems that the shine-through effect challenges most if not all explanations and models of masking at least partly. The effects of extension and regularity on masking in the shine-through effect are not a peculiar feature of grating masks. These effects occur also for the classical masks employed for more than a century.

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