An ERP indicator of processing relevant gestalts in masked priming

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Abstract

Briefly presented arrows, made indistinguishable by masks that contain arrows, inversely prime responses to following visible arrows. This inverse effect might reflect general regularities of masked priming or be either due to the task-relevant elements of the mask or to special features of arrows. Here we report a slow negative EEG potential recorded from the scalp above the visual cortex, which is evoked by masks that contain arrows. Even being evoked when arrows masks were presented in isolation, this “Nd-mask” appeared to be an obligatory response. Yet Nd-mask was enhanced when primes and targets were arrows and was reduced in the other cases, and even reversed its polarity with appropriate control stimuli. These findings provide support both for the special status of arrows and for the notion of mask relevance. Nd-mask might be one instance of negative EEG potentials evoked by stimuli with familiar gestalts.

Descriptors: Masked priming, Event-related potentials, Relevance, Gestalt, Arrows

Eimer and Schlaghecken (1998) reported a phenomenon new in research on visual masking called either the “negative compatibility effect” (Eimer & Schlaghecken, 2002; Klapp & Hinkley, 2002) or “inverse priming” (Verleger, Jaśkowski, Aydemir, van der Lubbe, & Groen, 2004): Arrows pointing right or left were used as imperative stimuli, requiring corresponding right and left key-press responses. These arrow targets were preceded by masked arrows. When the masked arrows pointed to the same direction as the target arrows, responses to targets were delayed. This finding has been interpreted in three different ways. As originally advocated by Eimer and Schlaghecken (1998; as well as in many following studies by these authors, e.g., Eimer & Schlaghecken, 2002; Schlaghecken & Eimer, 2002), inverse priming might reveal a general regularity in masked priming, reflecting some obligatory inhibitory processing of prime-evoked response tendencies (cf. similar, though diverging interpretations by Klapp & Hinkley, 2002; Lingnau & Vorberg, 2005; Praamstra & Seiss, 2005). In contrast, Lleras and Enns (2004) and Verleger et al. (2004) argued that inverse priming is specific to this combination of stimuli because it had not been observed before in research on masked priming: Usually, responses get speeded rather than delayed when preceded by masked similar stimuli (e.g., Cheesman & Merikle, 1984; Enns & DiLollo, 2000; Jaśkowski, Skalska, & Verleger, 2003; Klotz & Neumann, 1999). Instead, both Verleger et al. (2004) and Lleras and Enns (2004) attributed inverse priming to the fact that the mask contained arrow-like task-relevant elements, thereby acting as a second prime. Yet, the two studies differed in their detailed account, with Verleger et al. (2004) emphasizing the arrow-like character of the mask, Lleras and Enns (2004) the task relevance of the mask. In detail, Verleger et al. (2004) argued that arrows are rather special stimuli because they immediately induce tendencies for shifting attention (Verleger, Vollmer, Wauschkuhn, van der Lubbe, & Wäschler, 2000) and modify the preparatory state (Praamstra, Boutsen, & Humphreys, 2005) such that a sequence of arrows primes and arrows masks induces a “flip-flop” of tendencies first to one side then to the other. Somewhat in contrast, Lleras and Enns (2004) put their emphasis on the fact that, in order to be effective, the mask always contains task-relevant elements, irrespective of the gestalt of the relevant stimuli.

Eimer and Schlaghecken (1998) supported their interpretation by recording EEG from scalp sites overlying the motor cortex. (See also Eimer, 1999; Praamstra & Seiss, 2005; Seiss & Praamstra, 2004.) The lateralized readiness potential (LRP) evoked by the prime was biphasic, interpreted as activation of the primed response followed by inhibition. Replicating these results, Verleger et al. (2004) proposed that the inhibitory phase rather consisted of activation of the alternative response. This argument will be continued elsewhere (Verleger, Ewers, & Jaśkowski, 2005). Of importance to the present argument, we noticed in the EEG experiments reported in Verleger et al. (2004) that electrodes affixed at posterior scalp sites, overlying the visual cortex, indicated striking differences between masks containing arrow-like elements and other masks, with the arrows masks evoking more negativity. This finding of an “Nd-mask” (negative...
Nd-mask is both a privileged response to arrows and is modulated by task relevance. Because inverse priming of response times to targets occurred to different degrees by the different prime-mask combinations used in these experiments, we will also be able to discuss whether Nd-mask, as a stimulus-dependent indicator of mask relevance, has any relationship to the extent of inverse priming and can be used to account for this phenomenon.

EXPERIMENT 1

The data obtained in Verleger et al. (2004) as displayed in Figure 1 are ambiguous with respect to the time course of Nd-mask. In both experiments, Nd-mask was interrupted or overlapped by following components. In the upper panel of Figure 1, these later components were probably evoked by the arrow targets that immediately followed the masks, and possibly were also modified by perceptual interactions between masks and targets. Therefore, Experiment 1 was conducted to get an unambiguous picture of Nd-mask, free from overlap by the following target. To reach this goal, targets were omitted in 50% of the trials. Further, an attempt was made to eliminate at least some part of the physical difference between the mask that contained arrow elements and the mask that did not, because that difference might contribute to the difference in EEG potentials. For this purpose, the non-arrow mask was constructed as a compound of horizontal and vertical lines rather than of small checks as in Verleger et al. (2004).

Methods

Participants

Participants were 14 students of the University of Lübeck, paid 7 € per hour. None was informed about the hypotheses. They had normal or corrected-to-normal vision, were tested in a single session lasting about 50 min (plus 1/2 h needed for preparing the EEG recording). They were 9 men and 5 women, mean age 24 ± 2 years.

Stimuli and Procedure

Primes, masks, and targets were presented on each trial in the center of a 17-in. screen driven by a graphics card at 70 Hz. This frequency was reduced to 60 Hz with 3 of the 14 participants due to a technical error and with another 4 participants by intention, to have subgroups of equal size. Thus, primes were presented for 14 ms or 17 ms for 7 participants each, the immediately following mask for 100 ms, and the immediately following target for another 100 ms. The target was omitted in no-go trials. Primes and targets (see Figure 2) were pairs of black open triangles, symbolizing arrow heads, pointing left (<) or right (>) in random order. No neutral primes were used. Stimuli had a “leaner” design than in the experiments reported in Verleger et al. (2004): The lines forming the arrows were less than 1 mm (0.05”) wide. Arrowheads were 2 cm (1”) high at their extended side and 1 cm wide (0.5”) and the two arrowheads were spaced closely together (0.7 cm = 0.35” distance between parallel lines) such that the inner arrow point was exactly at fixation and pairs of arrow heads were 1.7 cm wide (0.85”). The fixation point was a small, ever-present red plus sign, of about 1.5 mm (0.07”) size. Two different types of masks were used. The arrows mask was composed of four arrowheads, which were the two primes (or targets) overlaid on each other. The lines mask consisted of eight

difference related to the mask), not reported in Verleger et al. (2004) is illustrated in Figure 1. Displayed are recordings from PO8, where this difference was largest. In Experiment 1 of that paper (upper panel) Nd-mask started at about the peak of N1, reached its maximum at around 240 ms, was then interrupted by a negative deflection emerging in those trials where the alternative mask was presented, and reappeared between 375 ms and 500 ms. In Experiment 2 of that paper, consecutive pairs of masks were presented between the arrow primes and arrow targets: 50-ms arrows mask followed by 50 ms of the alternative checks mask, or vice versa. As shown in the lower panel of Figure 1, these sequences were faithfully reflected by differences in Nd-mask, with more negativity in the early portion of the waveshape when the arrows mask came first, and more negativity in the later portion when the arrows mask came second.

The present study was performed to investigate determinants of this Nd-mask and its possible relations to the behavioral effect of inverse priming. Note that, being evoked by the mask, Nd-mask precedes target processing and is therefore largely independent of the relationship between targets and primes. Thus, the relation between primes and targets (identical or opposite to each other) will not be a relevant factor in analysis, different from most other electrophysiological studies of masked priming, including the studies quoted above. Rather, the important factor will be the effect of different masks.

Three experiments were performed. In a first experiment, targets were omitted in 50% of the trials, to measure the potentials evoked by the masks without interfering overlap from the following target-evoked potentials. In the following two experiments, a systematic attempt was made at distinguishing whether Nd-mask was due to the physical layout of the arrows or due to the fact that arrows were task relevant. Results will show that Nd-mask is both a privileged response to arrows and is modulated by task relevance. Because inverse priming of response times to targets occurred to different degrees by the different prime-mask combinations used in these experiments, we will also be able to discuss whether Nd-mask, as a stimulus-dependent indicator of mask relevance, has any relationship to the extent of inverse priming and can be used to account for this phenomenon.

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horizontal and nine vertical lines of differing length and position, with an imaginary outline of 23 × 23 mm (1.1 × 1.1\text{''}). There were six different versions of this mask, randomly selected by the controlling program such that participants could not filter out any regularities of these masks (Schubo¨, Schlaghecken, & Meinecke, 2001). Screen background was white.

In “go” trials, a target was presented after prime and mask, requiring a key press on the side the arrows pointed to. Participants had a keyboard on their lap. Response keys were the lower left “ctrl” key in response to leftward arrows and the “numpad enter” key in response to rightward arrows. In “no-go” trials, no target was presented. Go trials and no-go trials alternated randomly. The mask consisted of arrows in half of these trials and of lines in the other half, likewise randomly alternating. There were 200 trials for each of these four conditions (go or no-go with arrow mask or with line mask). The prime arrow pointed left or right in random order, and the target arrow in go trials was either identical to the prime or pointed to the opposite direction. Intervals between trials amounted to 3 s or to 0.8 s after correct responses, whichever came first.

This target-response task was followed by a prime-response task, to assess prime discriminability. Primes and masks were presented without targets, and participants had to indicate the direction of the prime arrows by pressing the response key on the side the arrows pointed to. There were 160 trials, with mask type (arrows and lines) as well as prime direction (left and right) alternating in random order. There was no time limit for responding. The next trial started 0.8 s after the response.

### EEG Recording and Processing

EEG and EOG were recorded from 19 scalp sites (F3, Fz, F4, FC3, FC4, C3, C1, C2, C4, P7, P3, Pz, P4, P8, PO7, PO8, O1, O2) with Ag/AgCl electrodes (FMS, Munich), were amplified from DC to 250 Hz by a BrainAmp MR plus, and stored at 2500 Hz per channel. Off-line, data were low-pass filtered at 30 Hz, reduced to a sampling frequency of 250 Hz, segmented from 100 ms before prime onset to 1000 ms afterward, and edited for artifacts (rejecting trials with zero lines, followed by correcting ocular artifacts using the linear regression method implemented in the BrainAnalyzer software, followed by rejecting trials with voltage differences more than 200 \(\mu\text{V}\) or voltage steps more than 20 \(\mu\text{V}\). To obtain ERPs, data were averaged across artifact-free trials where responses were correct, separately for each condition and participant. Grand means over participants were calculated for illustrating the results.

### Data Analysis

The main parameter of interest was the difference in negativity between the arrow mask and the line mask, expected to be seen in pure form in the no-go trials. To quantify this parameter, mean amplitudes of 12 adjacent 50-ms epochs were formed, beginning at prime onset and ending at 600 ms after prime onset. Mean amplitudes of the 100-ms interval before prime onset were subtracted as the baseline. Amplitudes from PO7 and PO8 (where the effect was largest) of the no-go condition were submitted to ANOVA with the factors Mask (arrows vs. lines) and Hemisphere (left, right), separately for each 50-ms epoch. Screen Frequency (60 Hz vs. 70 Hz) was added as a between-subjects factor.

For analyses of overt behavior, mean latencies of correct responses, relative to target onset, were measured in go trials (omitting the first four trials as warm-up), averaged separately for the two types of masks and for trials with identical and opposite primes and submitted to ANOVA with the two 2-level factors Mask and Primes and the between-subject factor Screen Frequency. Percentages of wrong and missing responses in go trials were likewise analyzed. Similarly, percentages of erroneous responses in no-go trials were determined for the two types of masks.

Participants’ ability to discriminate the primes was measured by the percentages of correct responses in the prime-response task, separately for either mask, and submitted to ANOVA with the factors Mask (arrows vs. lines) and Screen Frequency.

### Results

#### EEG Potentials

Grand means are displayed in Figure 3 for anterior to posterior midline locations (Fz, Cz, Pz), which are standard for a survey on ERP results, and posterior-lateral recording sites (P7, O1 on the left side of the figure, PO8 on the right side), which are relevant with visual stimulation.

The onset of the sequence of prime-mask-target evoked a visual evoked potential, consisting at posterior sites of the positive (downward) deflection P1, peaking at 100 ms, and the negative deflection N1, peaking at 150 ms. At about the peak of P1, a difference between the two masks became visible at posterior sites, with the arrows mask evoking more negativity than the lines mask. This Nd-mask reached its maximum at around 240 ms, with largest values at posterior-lateral sites PO7 and PO8, as illustrated in the scalp map in Figure 3. In go trials, at about 300 ms, a negative deflection emerged such that this N2 component, both with arrows masks and with lines masks, reached the negative level constantly kept by the arrows mask trials. This deflection was followed by the P3 component. The displayed time course of vertical EOG shows that Nsd-mask had no correlation in eye movements. The blinks often made by participants between 500 ms and 600 ms, probably reflecting closure of the task (Stern, Walrath, & Goldstein, 1984) occurred too late to affect Nd-mask that had already started at 100 ms.

For statistical analysis of the differences between masks, windows of 50 ms length were quantified 105–500 ms after prime onset.
Interrupted from 300 ms to 400 ms, then tended to reappear at mask were significant are marked by gray shade of the horizontal bar. (In 50 ms were analyzed, from 100 ms to 550 ms. Epochs when effects of mask were uninterrupted by target-evoked components, starting at 100 ms, ending at 550 ms. *F*(1,12) values for these nine 50-ms windows ranged between 13.3 and 99.2, *p* < .004 throughout, and Nd-mask amplitudes ranged between 2 µV at its onset (100–150 ms) and 8 µV (250–300 ms). At its onset, Nd-mask was somewhat larger at the right hemisphere (Mask × Hemisphere at 100–150 ms: *F*(1,12) = 9.2, *p* = .01).

In go trials, Nd-mask likewise started at 100 ms, but was interrupted from 300 ms to 400 ms, then tended to reappear at 400–450 ms, and became significant again at 450–550 ms. *F*(1,12) values for the first four windows, 100–300 ms, ranged between 17.9 and 137.9; *p* < .001 throughout, with mean differences ranging between 3 µV and 8 µV. In the final three windows, 400–550 ms, *F*(1,12) ranged between 4.5, *p* = .06, and 42.3, *p* < .001, with mean differences between 2 µV and 5 µV. Like with no-go trials, there was some right-hemisphere advantage when Nd-mask started (Mask × Hemisphere at 100–150 ms: *F*(1,12) = 5.5, *p* = .04) and additionally some left-hemisphere advantage when Nd-mask ended (Mask × Hemisphere at 500–550 ms: *F*(1,12) = 7.6, *p* = .02). Further, Nd-mask was somewhat larger when the target was identical to the prime, at 250–300 ms and at 450–550 ms (Prime × Mask: *F*(1,12) ranging between 8.5, *p* = .01, and 17.3, *p* = .001). During interruption of Nd-mask, the reversed effect of mask became significant from 300 ms to 400 ms, *F*(1,12) ≥ 5.1, *p* ≤ .04, because of the larger negative peak with the lines mask.

Effects of screen refresh rate were noted in 1 out of the 12 50-ms intervals analyzed in either condition, no-go and go: In no-go trials, there was less negativity with the arrows mask than with the lines mask both in go trials (Mask: *F*(1,12) = 26.5, *p* < .001). Resolved to effects of primes, this Mask × Prime interaction indicated that the masked arrows had inverse priming effects on response times with the arrows mask, as in previous studies, *F*(1,12) = 56.6, *p* < .001, but no effect with the lines mask, *F*(1,12) = 2.3, *p* = .15.

Inverse priming was larger with a screen refresh rate of 60 Hz than of 70 Hz (Group × Prime: *F*(1,12) = 5.1, *p* = .007) irrespective of mask (Group × Prime × Mask: *F*(1,12) = 0.2, n.s.; 42 ms vs. 24 ms with the arrows mask, 12 ms vs. −1 ms with the lines mask).

Errors (cf. bars in Figure 4). More errors were made with the arrows mask than with the lines mask both in go trials (Mask: *F*(1,12) = 7.9, *p* = .002) and, as false alarms, in no-go trials, *F*(1,12) = 3.8, *p* = .07. In addition, more errors were committed in go trials with identical than with opposite primes.

**Overt Behavior**

**Target-response task.** As displayed in Figure 4, responses were slower when primes masked by arrows were identical to targets (Mask: *F*(1,12) = 11.9, *p* = .005; Mask × Prime: *F*(1,12) = 26.5, *p* < .001). Resolved to effects of primes, this Mask × Prime interaction indicated that the masked arrows had inverse priming effects on response times with the arrows mask, as in previous studies, *F*(1,12) = 56.6, *p* < .001, but no effect with the lines mask, *F*(1,12) = 2.3, *p* = .15.

In go trials, Nd-mask was larger in the 60-Hz than in the 70-Hz group in the 250–300-ms epoch (10 µV vs. 6 µV; Group × Mask: *F*(1,12) = 8.0, *p* = .02).

**Errors (cf. bars in Figure 4).** More errors were made with the arrows mask than with the lines mask both in go trials (Mask: *F*(1,12) = 7.9, *p* = .002) and, as false alarms, in no-go trials, *F*(1,12) = 3.8, *p* = .07. In addition, more errors were committed in go trials with identical than with opposite primes.

**Figure 3.** Grand average of EEG potentials evoked in Experiment 1. The left half provides a survey of the potentials recorded from several scalp sites. Solid lines are from trials with the arrows mask, dashed lines from trials with lines masks. Bold lines are from no-go trials, thin lines are from go trials (averaged across trials with identical and opposite primes). Time zero denotes prime onset; thus onset of the mask was at 14 (or 17) ms, onset of the imperative arrows was at 114 (or 117) ms. vEOG: vertical electrooculogram. The map displays the topographic distribution of the difference between arrows mask and lines mask at 250 ms. The head is displayed as viewed from the top, scale is from 0 µV (white) to −10 µV (black). Actual recording sites are marked by white circles. The smooth distribution of amplitudes was computed by linear interpolation. The map also serves as legend for the positions of the recording sites. The lower-right panel depicts the effect of interest from the posterior-lateral recording site PO8 (where this effect was largest). Solid, dashed, bold, and thin lines have the same meaning as on the left-hand side. Epochs of 50 ms were analyzed, from 100 ms to 550 ms. Epochs when effects of mask were significant are marked by gray shade of the horizontal bar. (In fact, effects were significant in most epochs, except for the brief epoch in go trials from 400 to 450 ms; lighter shade of gray denotes inverse effects).

**Figure 4.** Response times and errors in Experiment 1. Depicted are means across participants. Solid lines and filled symbols are from trials with the arrows mask, dashed lines and empty symbols from trials with lines masks. Lines denote response times, referred to the right y-axis; bars denote errors, referred to the left y-axis.
Arrows and mask relevance

F(1, 12) = 6.9, p = .02. There were no differences between the 60-Hz and the 70-Hz group.

Prime-response task. Responses were incorrect in 50% of trials (± 0.05) with the arrows mask and in 44% (± 0.12) with the lines mask. Thus, primes tended to be better distinguished with the lines mask (Mask: F[1, 12] = 4.4, p = .06). This appeared to be the case with a refresh rate of 60 Hz above all (only 38% incorrect responses, vs. 50% with 70 Hz), but effects of refresh rate did not become significant.

Discussion

The finding made accidentally in previous experiments was replicated: When the mask consisted of arrows, a sustained negativity, “Nd-mask,” was evoked at posterior recording sites. By omitting the target stimuli that usually follow the mask in this paradigm, Nd-mask was seen in its undisturbed time course, spanning from 100 ms to 550 ms after mask onset.

Behavioral data confirmed that the present paradigm yielded the results usually found with these stimuli: Responses were delayed and error rate was increasing when target stimuli were identical to the preceding primes. Similar to Lleras and Enns (2004) and Verleger et al. (2004), this inverse priming was reduced to insignificance when the mask was made up of horizontal and vertical lines but, as argued by Schlaghecken and Eimer (2002), this does not necessarily speak to the special role of arrows but may reflect less efficient masking by the lines mask.

As a serendipitous finding, inverse priming on response times was more marked with a screen refresh rate of 60 Hz than with 70 Hz, that is, when primes were presented for 17 ms rather than for 14 ms.

EXPERIMENT 2

The mask-related difference, Nd-mask, might be due to purely exogenous factors, reflecting physical differences between the arrows mask and other masks. Alternatively, Nd-mask might be due to endogenous factors, reflecting the fact that the arrow elements that made up the mask were parts of the targets. Experiment 2 was designed to manipulate both factors. Trials with the arrows mask and the lines mask alternated randomly in each of the following conditions. The “mask-response” condition served as baseline for assessing differences between masks without any difference in task relevance. Only the masks were presented, serving as imperative stimuli, requiring right or left key pressing (e.g., right-hand response to arrow masks, left-hand to lines masks). Any difference between masks in this condition was expected to be due to physical differences. In the other conditions, implicit relevance of the masks was varied by using stimuli as primes and targets that shared features either with the arrows mask or with the lines mask. In the arrow condition, arrows were primes and targets, as in Experiment 1. In the line condition, primes and targets were designed of one vertical and two horizontal lines, making the lines mask contain task-relevant elements (cf. Figure 3). Any difference in Nd-mask between the arrow and the line conditions was expected to be due to the difference in task relevance. In detail, if having been entirely due to task relevance of the arrow elements in the previous experiments, then Nd-mask should now be reversed in the line condition, being evoked by the lines mask rather than by the arrows mask.

Methods

Participants

Nine male and 3 female students of the University of Lübeck, mean age 24 ± 3 years, were tested in a single session lasting about 1 h (plus 1/2 h needed for preparing the EEG recording). Of the 12 participants originally tested, none had to be excluded.

Stimuli and Procedure

All stimuli were presented in the center of a 17-in. screen driven by a graphics card working with 75 Hz. This higher refresh rate was chosen to present prime stimuli as briefly as possible, thereby further reducing the probability of consciously perceiving the prime. Primes were presented for 13 ms, masks for 107 ms, and targets for another 107 ms. The two masks, arrows mask and lines mask (in six exemplars, randomly selected) were the same as in Experiment 1. Likewise, the arrows used as primes and targets in the “arrow” condition were identical to Experiment 1. The new, “line” stimuli (cf. Figure 3) were like an “unequal” sign, consisting of two horizontal and one vertical line. These lines were 2.2 cm (1.1”) long and 2 mm (0.1”) wide, with the parallel horizontal lines separated by 0.75 cm (0.4”) and the vertical line shifted either to the left or to the right by 0.75 cm (0.4”). There was a third condition, using “orthogonal” arrows as primes and targets (made up of horizontal and vertical lines rather than of diagonal lines) but because masking was incomplete in this condition, results will not be reported.

The three parts of the experimental session occurred in the same order in all participants: Target response, mask response, prime response. Mask response was used as control condition as detailed above. Target response and prime response were used like in any research on masked priming, measuring effects of the masked primes on behavior in target response and assessing discriminability of the masked primes in prime response. Primes, masks, and targets were presented in target response, only the masks in mask response, and primes and masks in prime response. Masks were the arrows mask or the lines mask in random order, primes pointed left or right in random order, and targets were identical or opposite to primes in random order. Primes and targets were arrows in one block of target response and were lines in the other. Likewise, arrows were primes in one block of prime response and were lines in the other. Order of these blocks alternated between participants and was the same within any participant for target response and prime response. Each target-response block consisted of 320 trials, each prime-response block of 160 trials, and the mask-response block, in the middle between target response and prime response, of 80 trials. Participants had to respond in a compatible way to targets in the target-response blocks (i.e., left key to leftward arrows or lines, right key to rightward arrows or lines) and to primes in prime response, and in an arbitrarily fixed way in mask response (6 participants pressing the left key to the arrows mask and the right key to the lines mask, vice versa with the other 6 participants).

EEG Recording and Processing

These methods were principally identical to Experiment 1, with one minor and one major difference. The minor difference was that sampling rate was reduced to 250 Hz at recording already. The major difference was that EEG potentials were recorded and analyzed not only in the target-response blocks but also in the prime-response blocks, providing a further opportunity to investigate effects on Nd-mask.
Data Analysis
Nd-mask was again quantified by measuring mean amplitudes of adjacent epochs, beginning at onset of the first stimulus, at PO7 and PO8, until 600 ms. Epochs had 25 ms width from 0 ms to 150 ms, to have better temporal resolution, and then 50 ms width from 150 ms to 600 ms. ANOVAs were performed in each of the five conditions separately (two target response, one mask response, two prime response) with the factors Mask (arrows vs. lines) and Hemisphere (left, right). Prime (identical, opposite to target) was an additional factor in the target-response conditions but, because they were not of interest in the present context, results of this factor will not be reported. Further ANOVAs compared the mask effects between mask response, as the baseline condition, to each of the four other conditions. The factors of interest in these four ANOVAs were the interactions of Mask and Condition. (To enter this comparison, data of the target-response conditions were averaged across identical and opposite primes.)

Analysis of overt behavior was performed in a way corresponding to Experiment 1.

Results
EEG Potentials
Grand means from PO8 are displayed in Figure 5 for all five conditions. The difference waveforms between arrows mask and lines mask are presented in the upper panels of Figure 6, in each panel compared to the same difference in mask response (bold black lines) as the baseline condition. ANOVA results are displayed by the dark horizontal bars beneath the waveforms, and are additionally compiled in Table 1.

In the baseline condition (mask response; upper panel of Figure 5), Nd-mask started at 100 ms, at the positive peak of the P100 component, and continued throughout until 450 ms.

When arrows were relevant (middle panels of Figure 5), Nd-mask likewise started at 100 ms. Later on, from 150 ms onward, Nd-mask became larger than in the baseline condition (upper panels of Figure 6). This larger effect continued until 500 ms, uninterrupted in the prime-response task, and interrupted at 300 ms by activity evoked by the target stimulus in the target-response task.

When lines were relevant (lower panels of Figure 5), Nd-mask started 25 ms later than in the baseline condition, and remained throughout smaller in target response than in the baseline condition (dashed line in upper panels of Figure 6).

Overt Behavior

Response times. In mask response, response times did not differ between arrows mask and lines mask (427 ms vs. 431 ms; \( t(11) = -0.5 \), n.s.).

In target response (Figure 7, top left panel), prime effects depended on the type of stimuli and the type of mask (Prime \times Stimulus \times Mask: \( F[1,11] = 12.8, p = .004 \); besides, the two-way interactions of Mask \times Prime and of Mask \times Stimulus were also significant, \( F[1,11] = 25.7, p < .001 \), and \( F[1,11] = 7.6, p = .02 \), and there were main effects of Prime, \( F[1,11] = 19.9, p = .001 \), and of Mask, \( F[1,11] = 7.4, p = .02 \): With arrows,
Arrows and mask relevance

were generally faster than to arrows (Stimulus: response times. analyzed.
varied in the prime-response conditions and were therefore not

When arrows were masked by arrows (Stimulus: $F[1,11] = 6.3$, $p = .03$, and Mask × Stimulus, $F[1,11] = 21.1$, $p = .001$, and to main effects of Prime, $F[1,11] = 6.5$, $p = .03$, and of Mask, $F[1,11] = 9.5$, $p = .01$); Priming was inverse when arrows were masked by arrows ($t(11) = -2.8$, $p = .02$), absent when arrows were masked by lines ($t(11) = +0.5$, n.s.), and inverse when lines were masked by arrows ($t(11) = -2.9$, $p = .01$). The only deviation from the pattern obtained with response times was that inverse priming did

Due to the lack of time restriction, response times greatly

Errors. Error rates followed a pattern very similar to response times.

In mask response, error rates did not differ between arrows mask and lines mask (5.6% vs. 5.3%), $t(11) = 0.2$, n.s.

In target response (Figure 7, bars in top left panel), there was an interaction of Prime × Stimulus × Mask ($F[1,11] = 5.0$, $p = .047$; in addition to two-factor interactions for Mask × Prime, $F[1,11] = 6.3$, $p = .03$, and Mask × Stimulus, $F[1,11] = 21.1$, $p = .001$, and to main effects of Prime, $F[1,11] = 6.5$, $p = .03$, and of Mask, $F[1,11] = 9.5$, $p = .01$); Priming was inverse when arrows were masked by arrows ($t(11) = -2.8$, $p = .02$), absent when arrows were masked by lines ($t(11) = +0.5$, n.s.), and inverse when lines were masked by arrows ($t(11) = -2.9$, $p = .01$). The only deviation from the pattern obtained with response times was that inverse priming did

Table 1. Statistics from Analyses of PO7 and PO8 Recordings in Experiment 2

<table>
<thead>
<tr>
<th>Mask response</th>
<th>Prime response to arrows</th>
<th>Prime response to lines</th>
<th>Target response to arrows</th>
<th>Target response to lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–25</td>
<td>1.0</td>
<td>0.3</td>
<td>0.7</td>
<td>2.2</td>
</tr>
<tr>
<td>26–50</td>
<td>2.0</td>
<td>3.61 (.08)</td>
<td>3.7 (.08)</td>
<td>0.1</td>
</tr>
<tr>
<td>51–75</td>
<td>2.3</td>
<td>4.7 (.052)</td>
<td>5.8 (.04)</td>
<td>0.8</td>
</tr>
<tr>
<td>76–100</td>
<td>0.9</td>
<td>1.8</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>101–125</td>
<td>15.7 (.003)</td>
<td>20.6 (.001)</td>
<td>1.1 (.007)</td>
<td>35.5 (.000)</td>
</tr>
<tr>
<td>126–150</td>
<td>18.2 (.001)</td>
<td>31.6 (.000)</td>
<td>13.8 (.003)</td>
<td>39.0 (.000)</td>
</tr>
<tr>
<td>151–200</td>
<td>28.6 (.000)</td>
<td>48.9 (.001)</td>
<td>7.9 (.01)</td>
<td>76.1 (.000)</td>
</tr>
<tr>
<td>201–250</td>
<td>36.2 (.000)</td>
<td>36.3 (.000)</td>
<td>3.4 (.09)</td>
<td>20.5 (.001)</td>
</tr>
<tr>
<td>251–300</td>
<td>31.4 (.000)</td>
<td>133.0 (.000)</td>
<td>17.5 (.002)</td>
<td>33.1 (.000)</td>
</tr>
<tr>
<td>301–350</td>
<td>10.8 (.007)</td>
<td>44.3 (.000)</td>
<td>5.3 (.04)</td>
<td>7.1 (.02)</td>
</tr>
<tr>
<td>351–400</td>
<td>14.7 (.003)</td>
<td>21.3 (.001)</td>
<td>2.1</td>
<td>10.3 (.008)</td>
</tr>
<tr>
<td>401–450</td>
<td>18.1 (.001)</td>
<td>35.2 (.000)</td>
<td>10.1 (.009)</td>
<td>12.1 (.005)</td>
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<tr>
<td>451–500</td>
<td>4.7 (.05)</td>
<td>20.8 (.001)</td>
<td>5.7 (.04)</td>
<td>8.6 (.01)</td>
</tr>
<tr>
<td>501–550</td>
<td>4.9 (.07)</td>
<td>31.0 (.000)</td>
<td>4.8 (.05)</td>
<td>8.1 (.02)</td>
</tr>
<tr>
<td>551–600</td>
<td>0.6</td>
<td>19.2 (.001)</td>
<td>3.4 (.09)</td>
<td>5.4 (.04)</td>
</tr>
</tbody>
</table>

Analyses were done within each specified window (rows) separately for each of the five tasks (corresponding to Figure 5) and for each of the four target-response and prime-response tasks against the mask-response task (corresponding to upper panels of Figure 6). Compiled are F values obtained for main effects of Mask (arrows vs. lines) from the separate analyses and obtained for Mask × Condition from the combined analyses (where the two levels of conditions are the task under analysis and the mask-response task). When $p < .10$, the probability is listed below the F value. When $p < .05$, the F values are printed in bold. Degrees of freedom are 1/11 for all effects.
not become significant when lines were masked by lines, \( r(11) = -1.1 \), n.s.

In prime response (upper right panel in Figure 7), percentages of correct responses differed between stimuli, \( F(1,11) = 5.9, p = .03 \): Lines were identified better than arrows. These results additionally depended on specific prime-mask combinations (Stimulus \( \times \) Mask: \( F(1,11) = 14.3, p = .003 \)): There was no difference between masks when lines had to be discriminated (39.0% vs. 35.8% errors with lines mask vs. arrows mask, \( t[11] = +1.1, p = .31 \)), but arrows were identified worse with the arrows mask than with the lines mask (53% vs. 42% errors, \( t[11] = -2.6, p = .02 \)), that is, masking was better when the mask contained features similar to the prime stimuli, not surprisingly. When tested against chance performance (50% guessing probability), lines were identified better than chance (\( q[11] \geq 3.0, p < .01 \)), arrows masked by lines tended to be \( (q[11] = 1.9, p = .08) \), and arrows masked by arrows were identified worse than chance (\( q[11] = -2.6, p = .03 \)), that is, in this case participants had a slight but consistent tendency to press the key opposite to the prime.

**Discussion**

Again there was greater posterior negativity with the arrows mask than with the lines mask. This effect even occurred in the mask-response condition where the "masks" were the only stimuli to be presented. Thus, being evoked by arrow stimuli per se, Nd-mask appears to consist of an endogenous component related to stimulus relevance.

Behavioral results for arrows replicated, by and large, previous results. One interesting result was that arrows masked by arrows were systematically identified worse than chance. Behavioral results for lines were interesting insofar as inverse priming was obtained in the presence of incomplete masking.

**EXPERIMENT 3**

There are many possible reasons for an exogenous contribution to Nd-mask. First, the arrows mask had lower spatial frequency than the lines masks. Second, the arrows mask had fewer crossings of lines than the lines masks (5 vs. about 25). Third, the arrows mask possesses a distinct gestalt, forming a possibly meaningful percept. Fourth, the arrows mask is symmetrical along its vertical and horizontal axes and roughly even along its two diagonal axes whereas the lines masks are not. Fifth, the arrows mask is the same across trials whereas there were six different instantiations of the lines mask.

Deciding between these alternatives needs further experimentation. Spatial frequency per se does not seem to be a very likely candidate: Although stimuli with low spatial frequency did evoke larger N180 amplitudes in preceding studies (Kenemans, Kok, & Smulders, 1993; Reinvang, Magnussen, & Greenlee, 2002), the present effect on Nd-mask was much more extended in time than that increase of negativity, which was followed at 200 ms by larger positivity in Reinvang et al. (2002) and preceded by reduced negativity at 80–100 ms in both studies (see for the latter feature also Kenemans, Baas, Mangun, Lijffijt, & Verbaten, 2000; Martinez, Di Russo, Anllo-Vento, & Hillyard, 2001). Furthermore, this effect did not interact with stimulus relevance (which was varied in Kenemans et al., 1993) unlike Nd-mask.

Therefore, in the following experiment, an attempt was made to reduce differences according to those other listed factors, which were constancy, gestalt, and symmetry. The same non-arrow mask was used throughout, its properties of symmetry were similar to the arrows mask, and it possessed a distinct
gestalt. Furthermore, by being composed of overlapping left and right lines stimuli, this new lines mask had the same logical relationship to the line stimuli as the arrows mask had to arrows. If there would still be an Nd-mask between the arrows mask and this lines mask, this would underline the special role played by arrows. Further, in order to reduce any differences in task relevance as acquired during the experiment, the baseline condition (mask response) was performed as the first block of the experiment, unlike in Experiment 2, where it was performed after the target-response blocks.

The effects of task relevance that were found in Experiment 2 might have also been affected by the differences between masks in constancy, gestalt, and symmetry. Therefore, introducing a stable, symmetrical, clear-cut gestalt was expected to boost effects of task relevance for the new lines mask, possibly reversing Nd-mask when lines were relevant stimuli.

Methods

Participants
Participants were again students of the University of Lübeck, tested in a single session. Of the 12 participants originally tested, 1 had to be excluded due to equipment malfunction. Therefore, analysis of behavior will include data from 11 participants. Two other participants had too many EEG artifacts, leaving 9 participants for EEG analysis, which were 6 men and 3 women, mean age 24 ± 2 years.

Stimuli and Procedure
There were two changes from Experiment 2. First, the mask-response block was presented as the first block rather than in between the target-response and the prime-response blocks. Second, primes and targets on the one hand and masks on the other hand were completely crossed, by using the new lines mask: Primes and targets were, in a given block, either arrows or lines, and masks were, in random order, either the arrows mask, as before, or the lines mask, produced by overlaying the left and right lines, in a way completely analogous to the arrow stimuli (see Figure 2).

EEG Recording, Data Processing, and Data Analysis
Methods were identical to Experiment 2.

Results

EEG Potentials
Grand means from PO8 are displayed in Figure 8 for all five conditions. The difference waveshapes of arrows mask minus lines mask are displayed in the lower panels of Figure 6, in each panel compared to mask response as the baseline condition. ANOVA results are illustrated by the horizontal bars beneath the waveshapes and are additionally compiled in Table 2.

Nd-mask was present in the baseline condition (mask response), starting getting significant at 125 ms and continuing until 500 ms, though interrupted by two epochs of lacking significance (200–250 ms and 300–350 ms).

Figure 8. Grand average of EEG potentials evoked in Experiment 3, recorded from right posterior-lateral site PO8, where the effects of mask were largest. Data are pooled across prime directions (identical and opposite to target). Negative voltage is plotted upward. Time zero denotes onset of the primes, except for mask response, where time zero denotes onset of the mask, which was the only stimulus. Mask onset was at 13 ms in target response and prime response; additionally in target response the imperative arrows were presented at 120 ms. Analyses were done on six epochs of 25 ms from 4 ms to 150 ms, and on nine consecutive epochs of 50 ms, from 154 ms to 600 ms. Epochs are marked by gray shade of the horizontal bar when effects of mask were significant. Lighter shade denotes inverse effects, that is, less negativity evoked by the arrows mask. In all panels, solid lines are from trials with the arrows mask and dashed lines from trials with the lines mask. The additional stimuli used in the two prime-response blocks (right half) as primes preceding the mask and in the two target-response blocks as primes preceding the mask and as targets following the mask are depicted in the middle, either arrows or lines.
Table 2. Statistics from Analyses of PO7 and PO8 Recordings in Experiment 3

<table>
<thead>
<tr>
<th>Mask response</th>
<th>Prime response to arrows</th>
<th>Prime response to lines</th>
<th>Target response to arrows</th>
<th>Target response to lines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mask</td>
<td>Mask × Condit.</td>
<td>Mask</td>
<td>Mask × Condit.</td>
</tr>
<tr>
<td>1–25</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>26–50</td>
<td>0.7</td>
<td>0.1</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>51–75</td>
<td>0.0</td>
<td>1.3</td>
<td>3.8 (.09)</td>
<td>0.8</td>
</tr>
<tr>
<td>76–100</td>
<td>0.1</td>
<td>0.3</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>101–125</td>
<td>1.5</td>
<td>4.6 (.06)</td>
<td>14.1 (.006)</td>
<td>11.4 (.01)</td>
</tr>
<tr>
<td>126–150</td>
<td>19.5 (.002)</td>
<td>5.2 (.05)</td>
<td>10.1 (.01)</td>
<td>6.8 (.03)</td>
</tr>
<tr>
<td>151–200</td>
<td>45.9 (.000)</td>
<td>7.8 (.02)</td>
<td>11.1 (.01)</td>
<td>27.9 (.001)</td>
</tr>
<tr>
<td>201–250</td>
<td>0.8</td>
<td>7.3 (.03)</td>
<td>1.2</td>
<td>0.0</td>
</tr>
<tr>
<td>251–300</td>
<td>7.0 (.03)</td>
<td>16.4 (.004)</td>
<td>1.9</td>
<td>0.0</td>
</tr>
<tr>
<td>301–350</td>
<td>3.2</td>
<td>1.4</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>351–400</td>
<td>6.2 (.04)</td>
<td>1.0</td>
<td>0.4</td>
<td>2.0</td>
</tr>
<tr>
<td>401–450</td>
<td>6.7 (.03)</td>
<td>2.3</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>451–500</td>
<td>5.3 (.05)</td>
<td>11.0 (.01)</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>501–550</td>
<td>1.3</td>
<td>7.2 (.03)</td>
<td>3.6 (.09)</td>
<td>0.3</td>
</tr>
<tr>
<td>551–600</td>
<td>0.6</td>
<td>11.6 (.009)</td>
<td>4.0 (.08)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Analyses were done within each specified window (rows) separately for each of the five tasks (corresponding to Figure 8) and for each of the four target-response and prime-response tasks against the mask-response task (corresponding to the lower panels of Figure 6). Compiled are F values obtained for main effects of Mask (arrows vs. lines) from the separate analyses and obtained for Mask × Condition from the combined analyses (where the two levels of conditions are the task under analysis and the mask-response task). When p ≤ .05, the F values are printed in bold. Degrees of freedom are 1/8 for all effects.

When arrows were relevant, Nd-mask started at 150 ms in the prime-response task, already at 100 ms in the target-response task, and continued up until 600 ms in both tasks, interrupted by a shorter (400–450 ms in target response) or longer (300–450 ms in prime response) epoch of in significance. Unlike in Experiment 2, Nd-mask was not larger in these arrows-relevant conditions than in the baseline condition. The only significant Mask × Condition interaction (125–200 ms, Figure 6, lower right panel) was due to Nd-mask being smaller in prime response than in mask response, rather than larger. The apparent tendency for Nd-mask being larger than in mask response at 200–300 ms (Figure 6, lower panels) was far from significance (Table 2).

When lines were relevant, the arrows mask evoked less negativity than the lines mask (except for the N1 time domain), beginning at P1 latency (75–125 ms in target response, 100–125 ms in prime response), and continuing in the target-response task from 200 ms to 550 ms throughout, particularly marked when compared to Nd-mask of the baseline condition (Figure 6, lower left panel). Only N1 was distinctly more negative with the arrows mask than with the lines mask, with significant effects from 125 ms to 200 ms both in the target response and in the prime response task.

**Overt Behavior**

**Response time.** In mask response, responses tended to be slower to the arrows mask than to the lines mask (450 ms vs. 433 ms; F[1,10] = 3.6, p = .09).

**Target response (Figure 7, lower left panel).** Responses were slower to arrows than to lines (Stimulus: F[1,10] = 16.6, p = .002). Responses were also slower to congruent than to incongruent primes, F(1,10) = 11.9, p = .006, but this was true for arrows only (Prime × Stimulus: F(1,10) = 9.5, p = .01; effect of prime for arrows: F[1,10] = 13.3, p = .004; effect of prime for lines: F[1,10] = 0.0, n.s.) and was true for the arrows mask only (Prime × Mask: F[1,10] = 6.7, p = .03; effect of prime for the arrows mask: F[1,10] = 32.8, p < .001; for the lines mask, F[1,10] = 0.3). The latter effect meant for the arrow stimuli that inverse priming was large with the arrows mask (simple effect of prime: F = 21.4, p = .001) and reduced to insignificance with the lines mask, F = 2.8, p = .13, and for the line stimuli that priming was inverse with the arrows mask, F = 10.1, p = .01, but tended to become straight (noninverse) with the lines mask, F = 2.3, p = .16.

Responses to either stimulus, arrows or lines, were delayed when the stimulus was preceded by its own mask (Stimulus × Mask: F[1,10] = 7.6, p = .02), that is, responses to arrows were slow when preceded by the arrows mask (simple effect: F[1,10] = 6.8, p = .03) and responses to lines tended to be slow when preceded by the lines mask, F(1,10) = 4.2, p = .07.

**Errors.** In mask response, error rates did not differ between arrows mask and lines mask (mean 3.9%, F[1,10] = 0.4, n.s.).

In target response (Figure 7, bottom left panel), responses to either stimulus, arrows or lines, were more often erroneous when the stimulus was preceded by its own mask (Stimulus × Mask: F[1,10] = 10.8, p = .008). Further, prime effects differed between the two stimuli (Stimulus × Prime: F[1,10] = 4.6, p = .06): With arrows, errors tended to be more frequent when primes were identical (simple effect: F[1,10] = 3.5, p = .09), whereas with lines, errors tended to be more frequent when primes were opposite, F(1,10) = 3.1, p = .11.

In prime response, identification was worse when prime stimuli were followed by their related masks (Prime × Mask: F[1,10] = 7.9, p = .02; Mask: F[1,10] = 6.4, p = .03; Prime × Mask: F[1,10] = 17.4, p = .002). This was true both for arrow primes (arrows mask: 54% incorrect responses; lines mask: 22%; F[1,10] = 14.5, p = .003; 54% was not different from chance, t = −1.8, p = .11, whereas 22%, of course, was, t = 3.7, p = .004) and for line primes (lines mask: 51% incorrect responses; arrows mask: 41%; F[1,10] = 7.3, p = .02; 51% was not different from chance, t = −0.7, p = .51, whereas 41% was, t = 2.5, p = .03).

**Discussion**

A new lines mask was introduced that was related to the line stimulus in the same way as the arrows mask was to the arrow...
stimulus. By this, the control stimuli were matched to the arrow stimuli as far as possible. Yet, Nd-mask was still obtained in favor of the arrows mask in the mask-response condition. This Nd-mask did not significantly increase further when arrows were used as relevant stimuli but decreased when lines were used as relevant stimuli, even to the point that Nd-mask was reversed, that is, more negativity was evoked by the lines mask. In contrast to this relevance-related variation, the N1 peak was consistently larger at 150–200 ms with the arrows mask than with the lines mask, with the phasic time course of this effect reminiscent of the results quoted above from Kemenans et al. (1993) and Reinvang et al. (2002). Thus, this N1-related part of Nd-mask appears to be purely exogenous and to differ from the sustained Nd-mask effect on which this article is focused.

Behavioral results for arrows were similar to the previous experiments. Behavioral results for lines showed a distinct new pattern, militating against the notion that the point of reversal from straight priming to inverse priming is linked to the transition from conscious to nonconscious perception (Eimer & Schlaghecken, 2002; Klapp & Hinkley, 2002). Rather, priming was inverse when line primes could be identified better than chance (when masked by arrows) and stopped being inverse when line primes could not be identified any more (when masked by lines).

Comparison of Nd-Mask between Experiments 2 and 3

Figure 9 provides a summary of the Nd-mask results obtained in Experiments 2 and 3. For comprehensive analysis, Nd-mask was measured from 200 ms to 500 ms, and Experiment was added as a between-subjects factor to the ANOVA design. Only the Mask × Experiment effect will be reported, reflecting differences of Nd-mask between experiments. Degrees of freedom were 1,19. Nd-mask did not differ between experiments for the mask-response condition, $F = 1.9$, n.s., but was smaller in Experiment 3 than in Experiment 2 in all other conditions, most clearly when lines were targets, $F = 39.9$, $p < .001$, where Nd-mask even reversed polarity in Experiment 3, but also in prime response to lines, $F = 6.6$, $p = .02$, in prime response to arrows, $F = 10.7$, $p = .004$, and as a tendency in target response to arrows, $F = 3.7$, $p = .07$.

During the N1 time range (125–200 ms), Nd-mask was constantly present in all conditions of both experiments. Its amplitude was identical between experiments for the mask-response condition and for the lines-relevant conditions, $F < 0.3$ throughout, but was smaller in Experiment 3 than in Experiment 2 for the arrows-relevant conditions (target response: $F = 5.9$, $p = .03$; prime response: $F = 8.2$, $p = .01$).

General Discussion

Summary of Results for Nd-Mask

Masks containing arrow-like elements evoked more posterior negativity than other masks in all three experiments. This Nd-mask consisted of two components: a slow potential, lasting from about 100 ms to about 500 ms, and a short phasic enhancement of N1 (125–200 ms). The latter effect might be mainly determined by physical differences between the stimuli, as will be argued below. Of more interest, therefore, is here the slow potential that obviously was affected by task relevance of the stimuli used for the mask, most marked in Experiment 3 where Nd mask even

Figure 9. Mean Nd-mask amplitudes in Experiments 2 (solid lines) and 3 (dashed lines) for Nd-mask proper, measured at 200–500 ms (upper panel), and for Nd-mask at the N1 component, measured at 125–200 ms (lower panel). As denoted on the right side of each panel, negative Nd-mask values indicate that potentials were more negative with the arrows mask than with lines masks, and positive Nd-mask values indicate that potentials were more negative with lines masks than with the arrows mask. As denoted at the x-axis of the lower panel, the leftmost value is from the mask-response task, the two following values from the target-response tasks, and the two rightmost values from the prime-response tasks. The two values within each of these tasks are from the two blocks where arrows or lines, respectively, are task relevant.
reversed, to attain more negativity with the non-arrows mask than with the arrows mask. On the other hand, also this component appeared to include an exogenous component, underlying the ever-present difference between stimuli in the mask-response condition.

**Phasic Enhancement of N1**

In all conditions of Experiment 3, N1 was larger with the arrows mask than with the lines mask. Most probably, this is a simple exogenous effect. N1 is usually larger to foveal than to peripheral stimuli (e.g., Miniussi, Rao, & Nobre, 2002) and this mechanism might apply here: The arrows mask occupies space directly at fixation whereas the lines mask leaves this space empty. Therefore, it makes sense that this difference in N1 was relatively small when arrows were primes and targets because, by covering fixation anyway, these stimuli attenuate this difference between masks. By the same reasoning, masks did not differ in this respect in Experiments 1 and 2, because both the scrambled-lines mask and the arrows mask occupy space directly at fixation.

**Effects of Stimulus Relevance on Nd-Mask**

By its topography, its time course, and its eliciting conditions, the effect of task relevance on Nd-mask resembles effects of relevance reported previously for other stimuli, for example, selection negativity for relevant spatial frequencies (Martinez et al., 2001) and “relevant orientation distractors —related negativity” evoked by contralaterally presented distractors sharing relevant elements with the target (Hopf et al., 2004, p. 1831). Somewhat differently, parallels may be drawn between Nd-mask and the N170-type potential evoked by familiar objects (Gauthier, Curran, Curby, & Collins, 2003; Tanaka & Curran, 2001). Of particular interest under the present perspective is the negative shift following the N170 in those studies. This shift was similar to Nd-mask in its time course and topography, lasting for hundreds of milliseconds. The authors of those studies did not distinguish between N170 and the ensuing shift, relating this complex to holistic processing of the clear and familiar gestalt of those objects. There is ongoing debate whether the N170 evoked by familiar objects is the same component as N170 evoked by faces (Carmel & Bentin, 2002; Xu, Liu, & Kanwisher, 2005), but the slow continuing negativity largely remained out of focus. In fact, in several studies, this slow negativity behaved differently from N170. For example, whereas N170 is somewhat larger for inverted than for upright faces (Eimer, 2000; Itier, Taylor, & Lobaugh, 2004; James, Johnstone, & Hayward, 2001; Rossion et al., 1999; Sagiv & Bentin, 2001), the following slow negativity is distinctly larger for upright than for inverted faces when both are nontargets (Eimer, 2000, Figure 1; Sagiv & Bentin, 2001), that is, possibly when gestalt processing occurs spontaneously. Further, whereas N170 is larger for faces than for flowers, both stimuli equally evoke more slow consecutive negativity than unidentifiable patterns (Sagiv & Bentin, 2001). Whereas N170 was not affected by task relevance of the faces, the consecutive negativity became larger when faces were task relevant (Carmel & Bentin, 2002).

Thus, a viable conclusion emerging from those results and the data from the present study is that Nd-mask reflects perception of the distinct gestalt inherent in the mask. The difference between the arrows mask and lines masks even in the mask-response baseline condition might thus reflect just this difference in gestalt, namely, saliency, rather than being due to elementary features of the stimuli. Thus, also this “exogenous” component might actually be an “endogenous” one. Increases of Nd-mask when arrows were task relevant then reflect the fact that the arrows gestalt is in participants’ focus of attention, and the finding that Nd-mask was throughout smaller in Experiment 3 than in Experiment 2 reflects the fact that the control stimulus now likewise had a clear gestalt. As long as this gestalt was not task relevant, there still remained a head start for the well-known arrows gestalt, but, if becoming task relevant, the clear gestalt of the control stimulus was even able to reverse the Nd-mask effect. Thus, the advantage of this gestalt conception is that both the constant advantage of the arrows and the effects of relevance can be subsumed under one concept.

**Effects on Behavior**

Though ancillary with respect to variations of Nd-mask, priming effects on response times and errors, as well as identification performance with the different prime-mask combinations, are of some interest for the ongoing discussion about the mechanisms effective in masked priming (Eimer & Schlaghecken, 2002; Klapp & Hinkley, 2002; Lleras & Enns, 2004; Praamstra & Seiss, 2005; Verleger et al., 2004). Results will be discussed separately for the arrow stimuli, used in several studies since Eimer and Schlaghecken (1998), and for the lines stimuli, which have not been used in this context so far.

**Arrow Stimuli**

With arrows as stimuli, inverse priming as first described by Eimer and Schlaghecken (1998) was obtained in all three experiments: Responses were delayed and error rate increased when target arrows were identical to the preceding primes. The extent of inverse priming was modified by the look of the mask and by refresh rate of the screen.

**Effects of mask.** In all three experiments, the inverse effect of arrow primes was smaller when primes were followed by the lines mask (both the scrambled-lines mask used in Experiments 1 and 2 and the structured lines mask used in Experiment 3) than when followed by the arrows mask. This reduction of inverse priming might have occurred either because only the arrows mask produced a percept opposite to the prime (Lleras & Enns, 2004; Verleger et al., 2004) or because the lines masks did not mask as efficiently as the arrows mask such that the ongoing perceptual impression created by the prime could overcome the inhibitory process (Schlaghecken & Eimer, 2002). In favor of the latter assumption, primes could indeed be identified above chance with the lines masks in all three experiments. However, this does not necessarily disconfirm the alternative assumption that may assume that prime visibility is a less decisive factor than the percept created by the prime-mask interaction.

In favor of this argument was identification performance in Experiment 2: Participants systematically judged primes masked by the arrows mask to point to the other direction than the primes actually did. This weak but systematical tendency is well compatible with the idea that the arrows mask creates a weak percept opposite to the primes. A tendency of similar size in Experiment 3 did not become significant, so the status of this finding is still uncertain. Related to this argument, like some
previous data (Lleras & Enns, 2004; Verleger et al., 2004) the present data were at best moderately compatible with the notion (Klapp & Hinkley, 2002) that inverse priming is linked to nonconscious perception and straight priming to conscious perception. Indeed, whereas, confirming this notion, in all three experiments the lines mask both made inverse priming insignificant and made primes better visible than chance, on the other hand, even with prime visibility of 78% in Experiment 3, prime effects did not even tend to become straight, thus behaving in the allegedly nonconscious mode.

Effects of screen refresh rate. Inverse priming on response times was larger when primes were presented for 17 ms than for 14 ms. This effect is actually compatible with both hypotheses because primes might need a certain perceptual strength, either to evoke inhibition or to produce perceptual interaction with the mask.

Line Stimuli
Lines as primes were identified better than chance in most cases (about 40% errors): when masked by the arrows mask (Experiment 2 and Experiment 3) and when masked by scrambled lines (Experiment 2). It was only with the structured lines mask (Experiment 3) that identification was at chance level. Effects of line primes on response times ran parallel to identification performance: There was inverse priming in most cases, namely, when line primes were masked by the arrows mask (Experiment 2 and Experiment 3) or by scrambled lines (Experiment 2). Only when line primes were masked by the structured mask was priming not inverse any more. Thus, primes that could be identified better than chance caused inverse priming. This result makes a strong point against the above-quoted notion that inverse priming is linked to nonconscious perception and straight priming to conscious perception: Line primes had effects opposite to this rule. Moreover, the effects of line primes are not particularly compatible with both mentioned accounts of inverse priming with arrow stimuli. Increases of inverse priming when line primes became visible is in contrast to what the inhibition hypothesis had argued with arrow primes: There it was argued that the continuing visible percept would overcome inhibition. The active mask and object-updating hypotheses had argued that inverse priming comes into play by elements of the mask resembling the prime. However, the structured lines mask in Experiment 3, which was the one mask that contained these elements most clearly, in the same manner as the arrows mask does for arrows, did not induce inverse priming, whereas those masks that did not clearly contain elements of the line primes (arrows mask and scrambled-lines mask) did induce inverse priming. Thus, obviously, existing hypotheses on inverse priming are arrow biased and therefore too narrow to account for the full range of phenomena.

Nd-Mask and Inverse Priming
The present findings provide some support for the prerequisites of the arguments made both by Verleger et al. (2004) and by Lleras and Enns (2004) to account for inverse priming. Verleger et al. had argued that inverse priming occurs because arrows are special stimuli, automatically inducing direction-related processing, such that the mask that consists of left and right arrows evokes bidirectional processing. Indeed, Nd-mask indicated that arrow-type stimuli are processed differently from stimuli that possess less structured and less well-known gestalts. Lleras and Enns had argued that inverse priming occurs because the task-relevant features that are contained in masks undergo privileged processing. Indeed, Nd-mask was enhanced by task relevance.

So indeed, when arrows were primes and targets, Nd-mask and inverse priming varied in parallel: More negativity was obtained with the arrows mask than with the lines masks, and correspondingly inverse priming was larger with the arrows mask than with lines masks. Thus, it might appear that Nd-mask can be used as a predictor for the amount of inverse priming.

However, Nd-mask and inverse priming dissociated when lines were used as primes and targets: Again, Nd-mask reflected gestalt quality and task relevance, being larger when lines were masked by lines than when lines were masked by arrows. However, as noted in behavioral results, the amount of inverse priming varied in an unexpected way, being smaller when lines were masked by lines than when lines were masked by arrows. This effect was just contrary to the effects predicted by gestalt, relevance, and inhibition hypotheses, therefore also contrary to the effects to be predicted on the basis of Nd-mask.

Conclusion
In conclusion, the determinants of inverse priming continue to be insufficiently understood. Arrows undergo special processing (Verleger et al., 2004) as reflected by Nd-mask, mask relevance does matter to processing (Lleras & Enns, 2004) as reflected by effects of stimulus relevance on Nd-mask, and prime visibility certainly is an important factor (Eimer & Schlaghecken, 2002). However, these factors met with problems when having to account for the effects with lines masked by double lines. In correspondence to slow posterior negative shifts that have been described in other contexts, Nd-mask probably reflects perception of clear gestalts of visual stimuli.

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(Received July 27, 2004; Accepted April 6, 2005)