Distractor-induced blindness for orientation changes and coherent motion

Lars Michael [a,*], Guido Hesselmann [b], Markus Kiefer [c], Michael Niedeggen [a]

[a] Department of Psychology, Freie Universität Berlin, Habelschwerdter Allee 45, 14195 Berlin, Germany
[b] Department of Neurobiology, Weizmann Institute of Science, 76100 Rehovot, Israel
[c] Department of Psychiatry, University of Ulm, Leimgrubenweg 12, 89075 Ulm, Germany

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ABSTRACT

The conscious perception of simple visual stimuli can be modulated by the presence of distractors. In the motion blindness paradigm, the detection of coherent motion is impaired when task-irrelevant motion distractors are presented prior to the target. Aim of this study was to examine the feature specificity of the distractor effect. For this reason, targets were either defined by motion coherence ("motion blindness") or orientation changes ("orientation blindness"). In a series of three experiments we show that distractors have to share the feature characteristics of the target in order to reduce its detectability. However, independent inhibition sets for visual features can be activated if the targets' characteristics are ambiguous.

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1. Introduction

The processing of elementary visual features, such as motion and orientation, is not always operated pre-attentively, i.e., without requiring attentional resources (Joseph, Chun, & Nakayama, 1997; Raymond, 2000). In previous studies, we have demonstrated that the strength of perceived motion perception can be modulated by attentional mechanisms (Niedeggen, Hesselmann, Sahraie, & Milders, 2006), and that the detection of a coherent motion target is substantially impaired in a temporal selection task (Sahraie, Milders, & Niedeggen, 2001). In order to elicit these effects, two spatially separate rapid serial visual presentation (RSVP) streams are presented. In a local sequence the colour of a fixation point changes at 10 Hz. This central area is surrounded by a random dot kinematogram (RDK) whose dots follow a random walk. The random global motion is interrupted by short episodes of coherent motion for 100 ms. The subject's task is to attend to the colour "red" in the local stream and to detect a simultaneous coherent motion episode in the global stream (target motion). Thus, the colour change in the local stream serves as a cue to shift attention to the global stream. Task-irrelevant motion episodes presented prior to the cue serve as distractors.

Using this paradigm, we found that the detection of the target motion is severely impaired. The transient motion blindness (attention-induced motion blindness, AMB) was mostly expressed if cue and target were presented simultaneously, and recovered if

the cue-target SOA exceeds 200–300 ms (Sahraie et al., 2001). The experimental effect critically depends on the number of distractors presented: With increasing number of distractors, the motion blindness is more expressed (Hesselmann, Niedeggen, Sahraie, & Milders, 2006).

In a study using event-related brain potential we showed that this process is not correlated with a modulation in the sensory processing of the incoming stimuli (Niedeggen, Sahraie, Hesselmann, Milders, & Blakemore, 2002), but with a gradual increase of a frontally located inhibition process (Niedeggen, Hesselmann, Sahraie, Milders, & Blakemore, 2004). Based on these findings, we proposed that the transient motion blindness effect might be due to a central inhibitory process triggered by distractors which have to be ignored or suppressed (Hay, Milders, Sahraie, & Niedeggen, 2006; Hesselmann et al., 2006; Milders, Hay, Sahraie, & Niedeggen, 2004; Sahraie et al., 2001). According to our model, the occurrence of the cue leads to a release of this inhibition which appears to be a sluggish process so that motion blindness is fully released at approximately 300 ms.

The paradigm inducing motion blindness shares some characteristics with the attentional blink (AB): Here, stimuli are presented in one RSVP stream, and a predefined primary target (T1) has to be detected. The detection of an upcoming second target (T2) critically depends on its temporal distance to T1 (Shapiro, 1994). In most AB experiments, alphanumeric stimuli are used in the RSVP stream, and the target events are specified by instruction (i.e. digit or letter). Recent experiments on the attentional blink have shown that the detection performance also depends on distractor-like events (Zhang, Zhou, & Martens, 2009): According to the authors, a negative attentional set will be activated by pre-T1-stimuli with a high perceptual similarity to T2, and its

activation affects the T2 detectability significantly. For example, Ghorashi, Zuvic, Visser, and Di Lollo (2003) found that reaction times were longer, when distractors and target were similar (letters or tilted lines) compared with a dissimilar condition.

The effect of distractors has been associated with a negative attentional set which is categorically defined at an abstract level (Zhang et al., 2009). In their study, Zhang et al. showed that performance for a digit T2 is impaired when distractors share the semantic category (Arabic digits and Chinese number characters) but not when they are perceptually deviant (symbols). Similar results were reported by Folk, Leber, and Egeth (2008) who showed that a colour distractor produces an impairment of target detection when it matches the target colour. A more general top-down attentional set for colour singletons, however, should enable distractors of different colours to produce a decrement in target detection. These results are in line with experiments indicating that an irrelevant four character string, highlighted by colour, impaired the detection of a letter target when it contains also letters, but not when it consisted of digits or false-font characters (Maki & Mebane, 2006).

Our theoretical account on motion blindness has been detailed with respect to its temporal characteristics (Hesselmann et al., 2006). However, the central inhibition model has not been specified with respect to different feature characteristics. Since distractors and target share a common feature, the motion blindness paradigm did not allow to examine the prerequisites of the activation of attentional sets.

Therefore, we aimed to extend motion blindness to a further elementary visual feature, orientation. For this reason, the dynamic pattern was not defined by dots, but by small bars with identical orientation. Target as well as distractor events were defined either by a coherent motion episode or by a coherent flip in bar orientation, respectively (see Fig. 1). Adding a visual feature did not only allow us to test whether the distractor effect also extends to orientation. This also allows to examine to which extent the effect is driven by top-down processes.

In the first experiment, specific distractor effects of orientation flips on the detection of orienting targets were investigated. In the second experiment, we examined whether orientation changes might serve as potent distractors for orientation targets, but not for motion targets. In the third experiment, the target feature remained undefined, i.e., both motion or orientation targets could occur, and participants had to report which target they perceived. Under this uncertainty task, also the specificity of distractor features related to the features of the respective target was investigated.

2. Experiment 1

Although studies based on the attentional blink indicated a clear effect of distractors, its activation mechanism has not been fully explored. In one study, however, it has been reported that the presence of one single distractor was sufficient to reduce the detection rate for T2 significantly (Zhang et al., 2009).

Our previous studies on motion blindness have been more detailed in this respect. Based on our findings, we assume that the distractor inhibition – or negative set – will be activated in a gradual fashion. Evidence for this assumption was obtained in psychophysical and electrophysiological experiments (Hesselmann et al.,
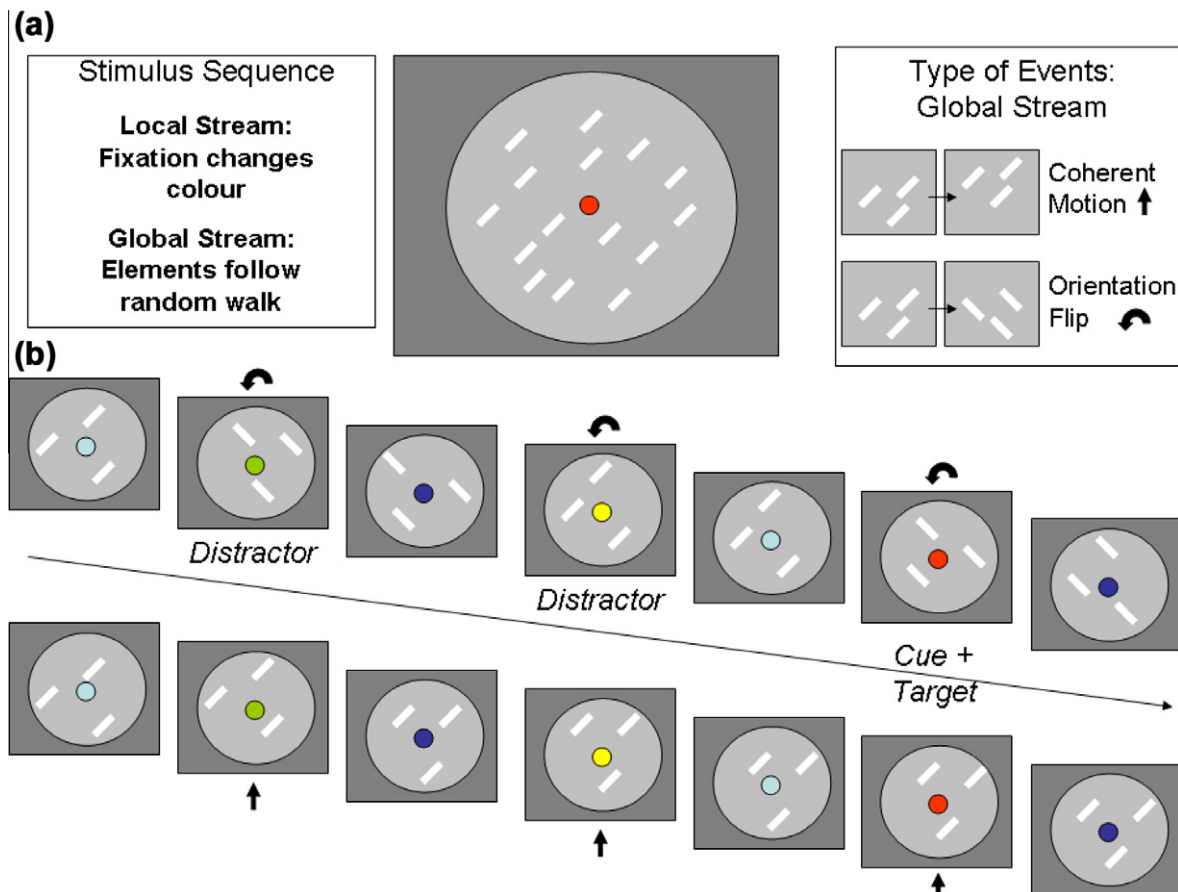

Fig. 1. Experimental paradigm. (a) Schematic diagram showing the properties of the local and global RSVP stream. (b) Schematic diagram illustrating the sequence of distractor and target events for coherent motion episodes (upper sequence) and orientation changes (lower sequence).

2006; Niedeggen et al., 2004). The probability for motion blindness significantly depends on the number of distractors presented prior to the onset of the cue. This effect was correlated with an effect in the event-related brain potentials (ERPs): Here, a linear increase of a frontal ERP component with increasing number of distractors was obtained.

In line with these findings, we predicted that the same mechanism will be triggered if motion stimuli will be substituted by orientation stimuli.

2.1. Methods

2.1.1. Participants

The sample consisted of 10 participants (nine females and one male) with an age-range of 16–31 years ($M = 22.00$ years, $SD = 5.37$ years) with normal or corrected-to-normal vision. All subjects were students of the Freie Universität Berlin which were recruited by advertisement. They received course credit after giving informed consent.

2.1.2. Procedure

Subjects were seated in front of a computer screen inside a sound-attenuated chamber. A chin rest was used to minimize head movements. The stimuli were presented on a 21-in. CRT monitor with a refresh rate of 100 Hz, using a Visual Stimulus Generator (VSG 2/5; Cambridge Research Systems Ltd., Kent, UK).

The task was similar to that used in our previous studies. Subjects viewed two separate rapid serial visual presentation streams (RSVP sequence: see Fig. 1). The local stream consisted of a 10 Hz colour change of the central fixation point (0.5° diameter). The used colours were of different luminance and easily separable. The fixation was centred in a grey circular patch (3.5° diameter) which was surrounded by 150 randomly distributed, white bars on a grey background (25° × 25°). Each bar was diagonally oriented, and defined by three dots (0.18° diameter). As shown in Fig. 1, all bars were oriented in the same direction. The global stream consisted of random distributed bars performing a random walk with casual changes of the bars' orientation. The onset of a change in orientation (diagonally left-to-right to diagonally right-to-left, or vice versa) was a global coherent event, thus all bars changed orientation simultaneously.

Subjects were instructed to keep fixation on the fixation point throughout the 3500 ms trials. Immediately after the detection of the cue (colour red) in the local stream, subjects had to switch attention to the global stream to detect the target (change in orientation). Changes in orientation prior to the cue had to be ignored, and served as distractors. The cue was presented between 1500 and 2500 ms after the beginning of the trial.

After each trial subjects had to indicate the detection of a target. In order to avoid temporal uncertainty distractors were not presented in an interval of 400 ms prior to the cue. The final distractor was presented 400–700 ms before the cue onset.

For each participant one block of trials was presented comprising 200 trials. In three experimental conditions, either zero, three or six orientation distractors were presented in the global stream (40 trials each). In two control conditions, each 40 additional trials without a target and without a cue were presented. All trials were presented in randomized order. For each participant, the mean detection rate was computed, and data were statistically analysed using a multivariate ANOVA.

2.2. Results and discussion

In control trials without colour cue, the participants correctly indicated the cue's absence (mean rate of correct rejection: 99.50%). In control trials without target, the mean rate of false

Table 1
Means and SEM (standard error of the mean, in parentheses) of motion detection rates as a function of the number of distractors.

Number of distractors	Percentage of detection
0	84.75 (1.69)
3	68.25 (3.98)
6	58.25 (4.60)

alarms was 12.25%. The result for the three experimental conditions (see Table 1) showed the expected parametric effect. The higher the number of presented orientation distractors prior to the cue, the higher was the resulting orientation blindness effect.

The ANOVA revealed a significant effect of the number of distractors ($F(2, 18) = 28.19$, $p < .001$, $\eta_p^2 = .76$), and a linear trend was found to be significant ($F_{1,9} = 37.959$, $p < .001$, $\eta_p^2 = .808$). Bonferroni-corrected pairwise comparisons showed significant differences for all pairs of conditions (0 vs. 3: $t(9) = 4.64$, $p = .001$; 0 vs. 6: $t(9) = 6.16$, $p < .001$; 3 vs. 6: $t(9) = 3.80$, $p = .013$).

These findings indicate that the effect established for the processing of motion stimuli can be extended to orientation changes. In both cases, the expression of the experimentally induced blindness is significantly modulated by the number of distractors sharing the feature of the target. Following the suppression model of the AMB effect (Hesselmann et al., 2006; Sahraie et al., 2001), we assume a similar inhibition mechanism: The processing of orientation changes in the global stream will be gradually more suppressed the more distractors are presented. It is unlikely that neural adaptation contributes to the effect: For the case of AMB we have previously shown that neither the temporal interval between the distractors and the target (Sahraie et al., 2001) nor the temporal interval between the distractors (Hesselmann et al., 2006) affected target detection.

3. Experiment 2

The data of Experiment 1 support the notion that the inhibitory process can be triggered by distractors sharing the features of the target (onset of coherent motion, or changes of orientation). However, we did not test whether deviant events in the pre-cue epoch will trigger a comparable process, even if they do not share the targets' features. Numerous studies have shown that such deviant events are able to trigger attentional processes automatically, and may affect the conscious processing of visual targets (Folk, Remington, & Johnston, 1992; Maki & Mebane, 2006).

Therefore, we tested whether the effects of motion and orientation blindness obtained in our experiments can be elicited by deviants which do not share the target's characteristic. The modification in the experimental setup (Fig. 1) allows us to compare the effect of feature-specificity: In Experiment 2, two visual features (transient motion episodes and changes in orientation) were simultaneously embedded in the global stream. Following our model, a distractor effect should only be obtained if the targets' feature is shared.

3.1. Methods

3.1.1. Participants

The sample consisted of new 10 participants (seven females and three males) with an age-range of 22–48 years ($M = 35.40$ years, $SD = 8.34$ years) with normal or corrected-to-normal vision. All subjects were students of the Freie Universität Berlin which were recruited by advertisement. They received given course credit after giving informed consent. One additional subject was excluded

from all further analysis because his false alarm rate (>80%) indicated that he could not detect the target events.

3.1.2. Procedure

In Experiment 2, the same temporal arrangement of targets and distractors as in Experiment 1 was used. As an additional feature, episodes of coherent motion were presented in the global stream. The elements in the display (diagonal bars) were displaced coherently either leftwards or rightwards for episodes of 100 ms.

Two separate blocks were presented to the participants: In each block, the cue had to be detected (red fixation in the local stream). In the 'orientation block', the participants had to decide whether the onset of the cue was accompanied with a change of orientation of the elements. In the "motion" block, the participants had to decide whether the onset of the cue was accompanied with a coherent motion of the elements. Additionally, they had to identify motion direction. In both conditions, episodes of coherent motion and/or changes in orientation prior to the cue had to be ignored. The participants were instructed to report the target detection after each trial by pressing a corresponding button on a four-button-box.

The motion signal was always defined by fully (100%) coherent motion. Motion direction was assigned to the distractor motion episodes following a quasi-random method, i.e., the random assignment of motion vectors to distractors on the level of single trials was controlled, and a high disproportionate distribution of vectors avoided. The direction of the last distractor was always different from that of the motion target to avoid possible motion contrast effects (Raymond & Isaak, 1998). In each motion and orientation block, 180 trials were presented in randomized order. Two experimental factors were defined. The distance between cue and target was either 0 ms or 200 ms (factor SOA). For each SOA, three different distractor conditions were defined (factor distractor type): Distractors were either defined by six episodes of coherent motion (20 trials), or by six orientation changes of the elements (20 trials), or by each three exclusive episodes of motion coherence and orientation switch (20 trials). According to its relation to the target, distractor type was defined as "congruent" (distractor identical with target), "incongruent" (distractor not identical with target), and "partially congruent" (motion and orientation distractors in one sequence). Furthermore, three control conditions were used in each block: Trials without target presentation, trials without presentation of the cue, and trials without distractors (each 20 trials).

The order of the blocks was balanced over subjects. For each participant, the mean detection rate was computed according to the experimental factors, and data were statistically analysed using a multivariate ANOVA.

3.2. Results and discussion

As in Experiment 1, subjects' performance was highly reliable: In control trials without colour cue, mean rate of correct rejection was 98.75%. In control trials without target, the mean rate of false alarms was 11.7%. Results of the experimental manipulations are presented in Fig. 2a. The ANOVA revealed a main effect of SOA ($F(1, 9) = 13.37$, $p = .005$, $\eta_p^2 = .60$), and a main effect of distractor type ($F(2, 8) = 7.55$, $p = .014$, $\eta_p^2 = .65$). As can be seen in Fig. 2a, the detection rate recovered at the higher SOA, and was less expressed for the incongruent distractors. Post hoc comparisons revealed that detection rate was significantly reduced for congruent distractors (congruent vs. incongruent: $t(9) = 2.83$, $p = .02$; congruent vs. partially congruent: $t(9) = 3.99$, $p = .03$). The latter effect, however, was significantly modulated by the target type (target × distractor: $F(2, 8) = 4.75$, $p < .044$, $\eta_p^2 = .54$).

Due to the higher-order interaction, experimental effects were analysed for the two target types separately. In the 'orientation' block, we obtained a significant main effect of SOA ($F(1, 9) = 10.07$, $p = .011$, $\eta_p^2 = .53$), as well as distractor type ($F(2, 8) = 13.47$, $p = .003$, $\eta_p^2 = .77$). Both factors did not interact. Post hoc comparisons showed that detection performance was significantly reduced in the congruent condition (congruent vs. incongruent: $t(9) = 5.42$, $p < .001$; congruent vs. partially congruent: $t(9) = 4.41$, $p = .02$), as well as in the partially incongruent condition (partially congruent vs. incongruent: $t(9) = 3.45$, $p = .07$). In the 'motion' block, the main effect of SOA was obtained, too ($F(1, 9) = 8.62$, $p = .017$, $\eta_p^2 = .49$). The factor 'distractor type', however, was only expressed for the short, but not for the long SOA (SOA × Distractors: $F(2, 8) = 4.57$, $p = .048$, $\eta_p^2 = .30$). Post hoc comparisons failed to show a significant difference between the congruent and incongruent condition ($t(9) = 2.14$, $p = .061$).

Taken together, the findings from Experiment 2 allow us to conclude that motion and orientation blindness is triggered by distractors defined by the same visual feature, and that the detection rate is most affected by homogenous distractor episodes. Hence, the blindness effects in this arrangement are triggered by *feature-specific* distractors. When features of the distractors are shared with the target, the target detection is severely impaired. Analogous to motion blindness, a similar phenomenon of orientation blindness could be observed, when orientation changes are defined as targets and orientation changes were presented prior to the cue.

The effect obtained for the 'partially congruent' distractors (three orientation and three motion stimuli in the pre-cue epoch) at the short SOA is in line with the idea of a cumulative inhibition (Niedeggen et al., 2004). The target's detectability is significantly increased if congruent and incongruent distractors are presented. Following our findings from Experiment 1, this effect is most likely due to a reduction of the number of congruent distractors. More specifically, we found evidence that deviants in the global stream which do not share the feature of the upcoming target do not trigger a distractor-inhibition process.

4. Experiment 3

Experiment 2 indicated that motion blindness is due to motion, and that orientation blindness is due to orientation distractors. The effect appears to be driven by top-down control processes: According to the instruction, a feature-specific task set is specifically activated. Distractors affect the maintenance of this task set.

This hypothesis leads itself to the question, whether a feature-specific inhibition can be triggered if the target's feature is not specified. In our previous studies, participants' a priori knowledge of the target characteristics allowed a differential processing of deviant events in the pre-cue epoch. According to Zhang et al. (2009), the system is enabled to inhibit a specific task set. Following the idea that the inhibition process is driven by top-down control, one might predict that a more general negative attentional set will get activated which inhibits a broader range of visual features. In this case, presentation of orientation changes will also affect the detection of a target motion, and vice versa (cf. Folk et al., 2008).

Experiment 3 is a close variation of Experiment 2, with exception that the target can either be a motion onset or an orientation change. The trials of the two blocks defined in Experiment 2 were mixed, and the target's feature was not specified. We examined whether the feature-specific distractor effect remains under these conditions.

4.1. Methods

4.1.1. Participants

The sample consisted of 10 participants (all female) with an age-range of 19–38 years ($M = 25.60$ years, $SD = 6.06$ years) with
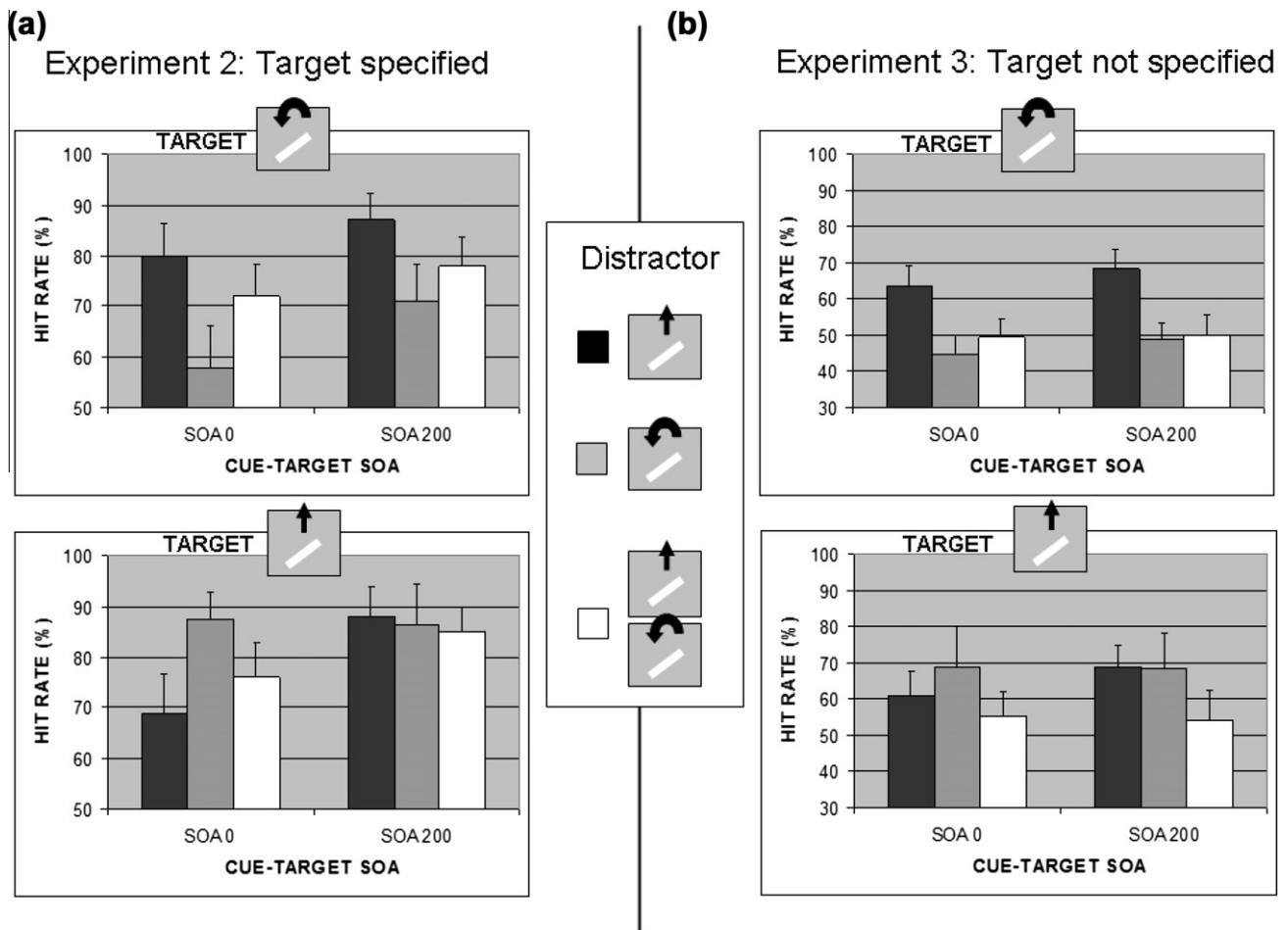
Fig. 2. Results for experiments 2 and 3. (a) Experiment 2: Target detection rates for trials with six coherent motion episodes (black bars), six orientation changes (grey bars) or three motion episodes and three orientation changes (white bars) presented prior o the cue. Error bars indicate standard errors of the means. Coherent motion targets (upper image) and targets consisting of orientation changes (lower image) were presented blockwise. (b) Experiment 3: The same target and distractor characteristics were used as in Experiment 2. Target features were presented at random.

normal or corrected-to-normal vision. All subjects were students of the Freie Universität Berlin which were recruited by advertisement. They received course credit after giving informed consent. Six additional subjects were excluded from further analysis due to high false alarm rates (>80%).

4.1.2. Procedure

In Experiment 3, the same temporal arrangement of targets and distractors as in Experiment 2 was used. The cue was defined by a red fixation, and targets were defined by a coherent change in orientation, or a coherent motion episode. However, the two block defined in Experiment 2 were summarized to one block and the instruction was changed. Participants were instructed that orientation changes or motion signals serve as a target. They had to indicate whether one of these events accompanies (SOA 0 ms) or follows (SOA 200 ms) the cue. The response did not require the identification of the target type but its mere detection. Distractor types were identical to those described in Experiment 2 (motion, orientation, motion and orientation). Homogeneity of distractor type (congruent, incongruent, or partially congruent) depended on the type of target, and was to be defined following the presentation of the target.

In each 120 trials, the trial was defined by a motion or an orientation target (factor Target). For each target, two SOA condition were constructed (factor SOA: 0 ms vs. 200 ms). For each SOA condition, three different distractor types were constructed (factor distractor type): Six episodes of coherent motion (20 trials), or six orientation changes of the elements (20 trials), or each three exclusive episodes of motion coherence and orientation switch (20 trials). Three additional control conditions were included (each 40 trials without target presentation, or without presentation of the cue, or without distractors). In total, 360 trials were presented.

All trials were presented in randomized order. For each participant, the mean detection rate was computed according to the experimental factors, and data were statistically analysed using a multivariate ANOVA.

4.2. Results and discussion

The control conditions revealed a higher difficulty of the task if the target feature remains uncertain: In control trials without colour cue, mean rate of correct rejection was 99.25%. In control trials without target, the mean rate of false alarms was 27%.[1]

The results of the experiments are shown in Fig. 2b. The ANOVA revealed that distractor type modulated the detection performance

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[1] To clarify the participants' strategies, we analysed false alarms rate in the "no target" condition. The statistics revealed no differences between the erroneous detection of a motion (13.5%) and orientation target (13%, $t(9) = 0.14$, $p = .89$). In addition, no differences between motion and orientation judgements were observed in the partially congruent conditions (each three motion and orientation distractors). Both results indicate that a congruent bias in the participants' response is unlikely to effect the experimental results.

(distractor type: $F(2, 8) = 5.93$, $p = .026$, $\eta_p^2 = .60$). This main effect was not modulated by any other factor. Pairwise comparisons demonstrated that the detection rate was significantly elevated for the incongruent target condition (incongruent vs. congruent: $t(9) = 3.27$, $p = .010$; incongruent vs. partially congruent: $t(9) = 3.48$, $p = .007$).

If data were analysed for the targets separately, we obtained the effect of 'distractor type' for orientation targets ($F(2, 8) = 6.78$, $p = .019$, $\eta_p^2 = .63$). Post hoc comparisons revealed a significant increase of detection performance in the incongruent distractor condition (incongruent vs. congruent: $t(9) = 4.62$, $p = .011$; incongruent vs. partially congruent: $t(9) = 4.99$, $p = .07$). The distractor effect was also obtained for motion targets ($F(2, 8) = 5.65$, $p = .020$, $\eta_p^2 = .58$). However, the effect was less expressed in this condition, and post hoc tests failed significance.

Two additional effects are prominent, when Fig. 2a and b are compared: (1) Detection rate was reduced if the target is not specified. In contrast to Experiment 2 (mean detection rate = 74%), the correct detection of motion and orientation targets is clearly reduced (57%). (2) SOA effect – prominent in Experiment 2 – is not expressed in Experiment 3. Both results indicate that the task became much harder for the participants, and that the recovery of behavioural performance takes longer than 200 ms.

The results of Experiment 3 are not in line with the predictions of a pure top-down model. Since the target feature was not specified via instruction, orientation and motion distractors were assumed to induce an inhibition process of comparable strength. However, in case of orientation targets we found clear evidence for a feature-specific inhibition. These findings will be discussed in detail in the general discussion.

Noteworthy is the higher difficulty of the task: 37.5% of participants had to be excluded from further analyses due to high false alarm rates. These participants reported high uncertainty concerning target occurrence as well as feature identity, but showed no tendencies to incorrectly detect one specific feature.

5. General discussion

The inhibitory effect of distractor processing has been shown to affect the detection of simple motion stimuli (AMB, attention-induced motion blindness, Sahraie et al., 2001). The series of three experiments described in this study shed new light on the nature of the inhibitory process, and the prerequisites for its elicitation. Our findings can be summarized as follows:

1. The inhibition process is not restricted to motion stimuli, but extends to the processing of orientation changes. In both cases, the strength of the inhibitory effect is modulated by the number of distractor events.
2. If the target feature is specified, the inhibition process is driven by distractors which share the targets feature.
3. The inhibition process is also activated if the target feature is not specified. Deviant events in the pre-cue epoch are more likely to serve as distractor if they share the feature of the upcoming target.

Our first result supports the notion that the inhibition process is not induced exclusively by motion signals – but also by other elementary visual features. For this reason, it is more appropriate to label the effect 'distractor induced blindness' rather than 'attention induced motion blindness'. The distractor effect identified in our paradigm is likely to contribute to the expression of the attentional blink, too. As shown in other studies, the expression of the attentional blink is modulated by visual events with semantic or perceptual similarity to the upcoming target (Olivers & Watson, 2006).

Following our results (see Experiment 1), this modulation might depend on the number of perceptually similar events.

However, the distractor effect that we report does not share the temporal characteristics of the attentional blink: Whereas distractor induced blindness usually recovers within 200–300 ms post cue onset (Hesselmann et al., 2006; Sahraie et al., 2001), the attentional blink is mostly expressed at 200–500 ms post T1 onset, (see Dux & Marois, 2009; Martens & Wyble, 2010). The differences are due to the dual-task characteristics of the attentional blink in which two targets (T1 and T2) compete for processing resources. In contrast, cue processing in distractor induced blindness does not interfere with the sensory processing of the target, and does not suppress its detectability (Niedeggen et al., 2004, 2006).

The mechanism eliciting the distractor effect is comparable to the negative attentional set (Zhang et al., 2009). According to the results by Zhang and colleagues, an inhibition will be triggered by distractors which are perceptually and/or semantically similar to the target. In line with our findings (Experiment 2), a mere perceptual salience is not sufficient to elicit the process. The authors also identified a fronto-central ERP negativity elicited by the presentation of a distractor, which resembles the latency and topography of the distractor-evoked negativity obtained in our previous ERP work (Niedeggen et al., 2004). Based on their findings, Zhang et al. (2009) concluded that a category-specific negative attentional set is established by the distractor which delays the attentional allocation to T2.

Following our results, this hypothesis will have to be modified in several respects: (1) Experiment 1 confirmed that the negative attentional set is activated by distractors cumulatively. A single distractor embedded in a rapid serial presentation is rather unlikely to affect the target detection. The effect obtained by Zhang et al. (2009), is primarily due to the short temporal interval between distractor and T1 presentation. (2) The temporal effect of the inhibition induced by distractors is restricted, and decays with increasing the interval between the last distractor and the onset of the cue (Hesselmann et al., 2006). (3) Results from Experiment 3 suggest the inhibition of feature-specific task sets although they can in principle also be explained by bottom-up mechanisms similar to findings obtained for the attentional blink.

For the attentional blink, one study suggests the existence of bottom-up mechanisms driven by features of the distractors: The enumeration of coloured dots was severely impaired when the dots shared their colour with distractor letters in the RSVP stream (Olivers & Watson, 2006). In this case, colour was not a defining feature for the dot pattern. Therefore, a bottom-up mechanism was assumed which inhibits items that share features with the distractors.

A similar mechanism could in principle explain the results in our study. It is possible that the inhibition process can be mediated by bottom-up mechanisms if the target is not fully specified. Top-down mechanisms cannot filter irrelevant distractors with a high salience, and are therefore forced to operate by disengagement from salient events (Belopolsky, Schreij, & Theeuwes, 2010). Repeated disengagement driven by the presentation of highly salient motion or orientation distractors may lead to a specific inhibition of the respective feature and, finally, to an impairment of target detection if there is a match with the target's features. Alternatively, it is also plausible that more than one negative attentional set will be activated if the target is not specified. In terms of a 'task set', simultaneous activation (Kiesel, Kunde, & Hoffmann, 2007) and inhibition (Kiefer & Martens, 2010; Mayr, Diedrichsen, Ivry, & Keele, 2006; Mayr & Keele, 2000) of different features has been demonstrated. Following these findings, motion distractors will inhibit a motion task set, and orientation distractors a corresponding orientation task set. This interpretation is more favourable since a bottom-up approach would also imply a modulation of sensory

processing of distractors and targets. However, such a modulation was not observed in our previous ERP data (Niedeggen et al., 2002, 2004).

Finally, we have to focus on the visual features used in our experiments. Although both are highly salient, their inhibitory effect was different: Data of Experiment 2 indicates that the feature specific inhibition process triggered by orientation distractors is not fully released after 200 ms. Additionally, Experiment 3 showed that the feature specificity is apparently more expressed for orientation as compared to motion distractors. The differences are presumably due to two facts: In contrast to a motion coherence signal, the orientation change serves as a more rapid event which does not require the temporal integration of the elements' spatial information. Moreover, the two visual signals are processed in different areas in the visual cortex. Motion coherence is primarily processed in a specialised cortical area, V5/MT (Newsome, Britten, & Movshon, 1989). In contrast, orientation sensitivity is already found in the primary visual cortex, and extends to several areas within the extrastriate cortex (McDonald, Seymour, Schira, Spehar, & Clifford, 2009). These differences might contribute to a faster, more specific, and more sustained activation of a negative attentional set by orientation changes.

In sum, our results indicate that the inhibitory distractor effect which impairs the detection of simple visual targets can be driven by two types of basic visual features, motion and orientation. The proposed inhibitory process shares some characteristics of a negative attentional set (Zhang et al., 2009), and we conclude that it plays an important role in the generation of related phenomena, such as the attentional blink.

Acknowledgments

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