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Distractor-induced blindness for orientation changes and coherent motion

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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.

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

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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 distracters 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.,

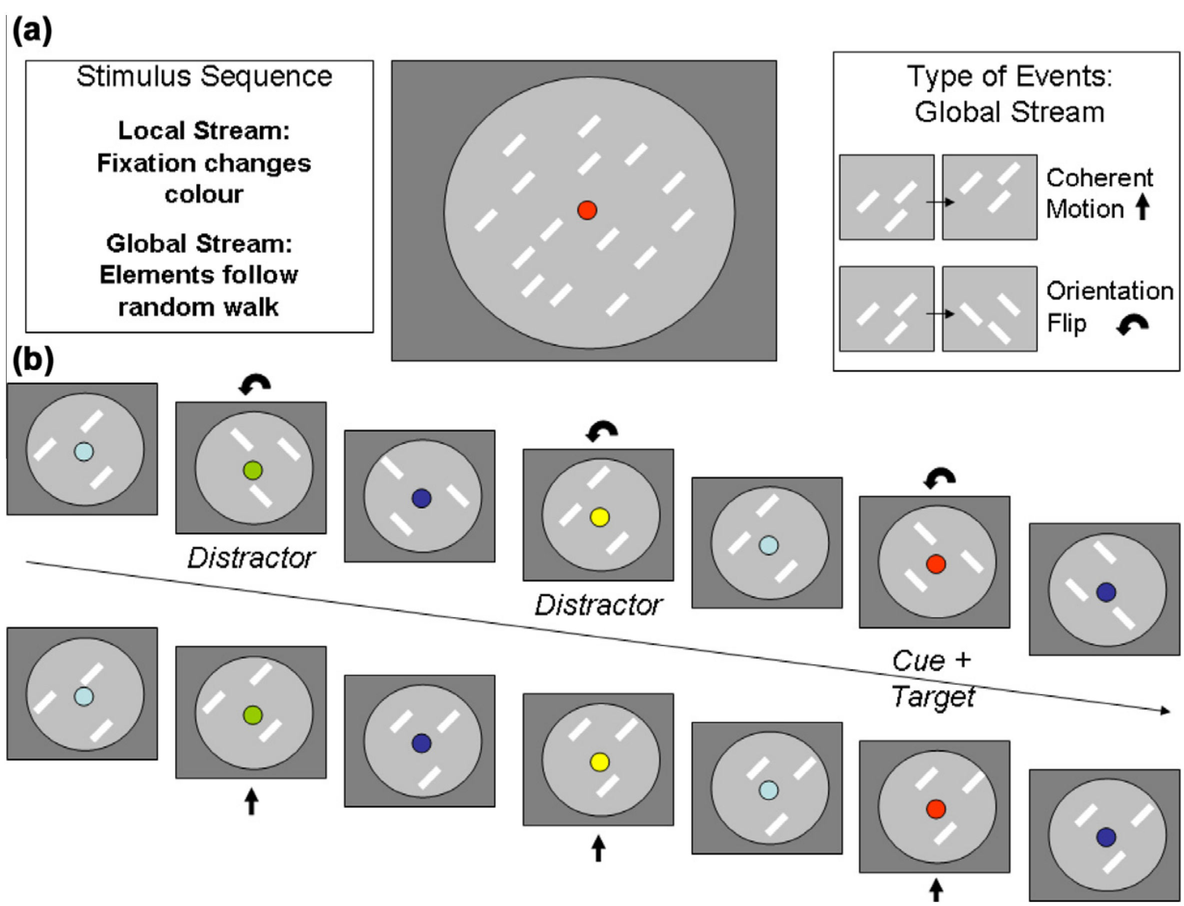

Fig. 1. Experimental paradigm. (a) Schematic diagram showing the properties of the local and global RSVP stream. (b) Schematic diagram illustrating the sequence of distractor and target events for coherent motion episodes (upper sequence) and orientation changes (lower sequence).