Conscious and Unconscious Processing in Visual Spatial Selection

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Overview

This thesis examines the mechanisms underlying visual spatial attentional selection. Spatial attentional selection can be driven in either a top-down or a bottom-up way. Whereas top-down processes in spatial selection are voluntary, intentional and goal related, bottom-up processes are involuntary, unintentional and unrelated to a goal. Although top-down attentional selection is a voluntary process, errors can still be made. For example, imagine searching for a red book in a full bookshelf. Due to the top-down attentional set to look for a red book, all red items will capture your attention. This is called contingent capture (Folk et al., 1992; 1994). In contrast, bottom-up capture is an automatic process that is triggered by objects or events in the environment that are highly salient, such as a red book between only green books (Theeuwes, 1992, 1994a; 1994b). Both modes of attentional selection have in common that selection can occur with (overt attention) or without the eyes (covert attention).

This thesis consists of two parts. The last two chapters cover studies in which we investigated the interactions between bottom-up and top-down overt attentional selection. The first part covers studies in which we examined unconscious covert attentional selection processes. The Introduction of this thesis will only address this latter topic.

Intuitively, one assumes that objects have to be visible to be selected. However, research has shown that a highly salient object may get selected without consciously perceiving it (Theeuwes, et al., 1998). Or, one can select an object that cannot be consciously perceived due to the method of presenting. For instance, when a visual stimulus is rapidly followed by a second stimulus, the mask, perception of the first stimulus is disrupted. In Chapter 1 an overview of studies are described that investigated spatial attentional selection in the absence of awareness. In particular, the review focuses on studies investigating unconscious bottom-up attention. A possible neural network underlying unconscious attentional orienting is suggested.

In Chapter 2 it was investigated whether an abrupt onset cue that is not consciously perceived can trigger an attentional shift to its location. In this study, spatial cues were presented subliminally. After a short or a long delay, the target appeared either at the cued or at the uncued opposite location. Typically, in a spatial cueing task with visible cues, facilitation at the short delay and inhibition (IOR) at the long delay is obtained (Posner and Cohen, 1984). Note that this biphasic pattern is only observed when attention is captured in a bottom-up fashion. Our findings show the classic biphasic pattern but now with cues that were not consciously perceived. It is concluded that subliminal cues have the ability to capture attention in a bottom-up fashion. It was suggested that a direct subcortical route from the retina to mechanisms essential for attention (retinotectal pathway), such as the superior colliculus was responsible for unconscious attentional orienting.

Chapter 3 investigated whether subliminal spatial cues can affect the oculomotor system. To test the hypothesis that unconscious attentional orienting is mediated by the retinotectal pathway, the experiment was performed under monocular viewing conditions. Monocular viewing allows examining temporal-nasal hemifield asymmetries in behavior which presumably result from the anatomical asymmetry in the retinotectal pathway. The results showed that the subliminally presented spatial cues affected the oculomotor system. Relative to the neutral condition, saccade latencies to the validly cued location were shorter and saccade latencies to the invalidly cued location were longer. Although we did not observe an overall IOR effect, there was a temporal-nasal asymmetry effect for those observers who showed an IOR effect when both hemifield were collapsed. More specifically, consistent with the notion that processing via the retinotectal pathway is stronger in the temporal hemifield than in the nasal hemifield an IOR effect was found for cues presented in the temporal hemifield but not for cues presented in the nasal hemifield. It was concluded that unconsciously processed spatial cues affect the oculomotor system, possibly via the retinotectal pathway.

Chapter 4 investigated whether a subliminal distractor affected eye-movement metrics, like saccade trajectories and endpoints. Deviations of saccade trajectories are known to arise from competition between target and distractor related activity within the oculomotor system, such as competing activations in the superior colliculus (McPeek et al., 2003). In this study, observers made eye movements upwards and downwards while a subliminal distractor was presented in the periphery. Results showed that the subliminal distractor affected saccade metrics like endpoint and trajectory suggesting that subliminal visual information evokes competition in the oculomotor system.

In chapter 5 it was examined whether subthreshold occipital transcranial magnetic stimulation (TMS) can have a facilitory and inhibitory effect on target processing in a spatial cueing task. Observers performed a classic spatial cueing task in which a target was presented in one of two peripheral placeholders. At different points in time, a subthreshold single pulse was delivered at the occipital pole of one hemisphere. The stimulated area corresponded with the retinotopic location of the placeholder in the visual field contralateral to the TMS. Results showed that subthreshold TMS 150 ms or 200 ms before stimulus onset facilitates visual processing: observers responded faster to targets in the visual field contralateral to the TMS compared to targets in the visual field ipsilateral to the

TMS. Moreover, enhanced visual processing of the cue as a result of TMS amplified the cue validity effect. This resulted in stronger facilitation when the cue was valid and stronger interference when the cue was invalid. It was concluded that TMS induced cortical excitability at primary visual cortex is the mechanism that enhanced visual processing.

Whereas the exogenous spatial cueing task is an established task to investigate bottom-up attentional capture, the oculomotor capture task is excellent for research on bottom-up driven capture of the eyes. In this task a salient distractor is presented simultaneously with an equiluminant color change of the target. Observers are asked to make a speeded saccade to the color change. Typically, in this task in about 10 to 30% of the trials, the initial saccade is directed to the distractor instead of to the target. In Chapter 6 we examined whether the time course of oculomotor capture differs between bottom-up and contingent capture. For this reason, we manipulated the relevance of a salient onset distractor. In two experiments the onset distractor could either be similar or dissimilar to the target, or the onset was presented at the target location or at a non target location. Error saccade latency distributions showed that early in time, oculomotor capture was driven purely bottom-up while later in time top-down information decelerated the oculomotor system. These findings revealed the interaction between bottom-up and top-down processes in oculomotor behavior.

The interaction between bottom-up and top-down information was also investigated in the study described in Chapter 7. In this study, we investigated the time-course of oculomotor competition between bottom-up and top-down selection processes using saccade trajectory deviations as a dependent measure. Besides manipulating target distractor similarity, we also manipulated saccade latency by offsetting the fixation point at different time points relative to target onset. In this task, observers made a vertical saccade to a target while a distractor was presented next to the saccade path. The results showed that deviations for both short and long latencies were modulated by target distractor similarity. When saccade latencies were short, saccades deviated away less from a similar than from a dissimilar distractor and when saccade latencies were long the opposite pattern was found. This study shows that competition between saccadic goals was subject to two different processes with different time courses: one fast activating process signalling the saliency and task relevance of a location and one slower inhibitory process suppressing that location.

In sum, the present thesis provides evidence that bottom-driven spatial attention can be dissociated from consciousness. Consequently, this supports the idea that spatial attentional selection can occur in the absence of top-down control settings. Furthermore, the present thesis shows that bottom-up capture differs in time-course from contingent capture. Whereas bottom-up capture is a fast and transient process, contingent capture is a slower process that integrates top-down information with bottom-up salient information to guide the attentional and oculomotor system.