Attentional modulation by signals of threat

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General Conclusions

Human behavior in a complex environment relies on mechanisms that enable the efficient selection of information that is relevant for survival. The selection of information that enters our visual system forms the foundation of all our decisions and actions. Since the amount of information in our daily environment is nearly unlimited, we have to filter out just those events that are most relevant to us. While theories of selective attention have generally assumed that selection is the result of an interplay of both stimulus-driven and goal-driven processes, more recently an important role has been attributed to events that have a high emotional value. Crucially, one of the most important adaptations for an organism to survive is the detection of emotionally relevant information.

Many studies have found evidence for the view that selective attention to competing stimuli is modulated by their threat value. Quick detection of threat has been observed even when the threatening stimuli are not part of the task goal and even when it is better to ignore them. Such fast threat detection seems especially relevant in situations where multiple stimuli in the environment demand attention. Some studies have shown that in addition to facilitated attention to threat, it takes longer to disengage attention from threat after it has been attended. It can therefore be argued that once threat has been selected, it holds attention such that a thorough processing of the event is possible and an appropriate response is selected. It appears as though attentional biases to threat are comprised of both facilitated attention and difficulty in disengagement, and these processes work together to promote a quick and appropriate behavioral response.

Eye movements measurements have added additional information to the mechanisms of attentional biases to threat. When a threatening event suddenly emerges in one's environment, it is important to not only select the most relevant information quickly, but also to immediately take action. Since eye movements are thought to reflect the locus of covert attention, saccades are able to provide a direct measurement of attentional competition between stimuli. Therefore, eye movements provide evidence for interference of threat with behavior. In **Chapter 3**, we showed that threatening stimuli influence oculomotor processing already at a very early stage. When an angry face was presented together with a neutral one, saccadic trajectories

curved away from the location of the angry face, indicating that the presence of threat interfered with oculomotor selection. Therefore, the threatening content of a face is automatically prioritized in the oculomotor system and biases behavior.

The study of attentional biases toward threatening information has consistently emphasized the role of individual differences. A large body of research has indicated, for example, that anxious individuals are more likely than controls to display attentional biases toward threatening information. Moreover, several studies only observed attentional biases to stimuli that were relevant to an individual's specific phobia. Likewise, it has been argued that the level of arousal that emotional stimuli elicit play a large role in eliciting attentional biases. Specifically, stimuli that are rated as higher in arousal, whether negative or positive, than competing stimuli in their environment are detected more quickly. Thus, whether an emotional event influences selective attention seems to rely on both the emotional state of the observer and the emotional value an individual applies to the event. An event is appraised as emotionally relevant when it has potential consequences for either aiding or hindering individual needs.

Importantly, a mutual factor in the studies described above is that all emotional stimuli consisted of pictures conveying an emotion. Perceptual differences between pictorial stimuli are inevitable, since they may vary in low-level features such as complexity and luminance. Therefore, it is hard to exclude the possibility that attentional effects are due to low-level feature differences among stimuli, instead of emotional content. Based on the results of behavioral studies described above, it is therefore still unclear whether a threatening stimulus can capture and hold attention exclusively due to its valence.

Consistent with behavioral studies employing pictures of naturally threatening stimuli, evidence from fear conditioning studies showed that stimuli that are associated with a threatening outcome are detected preferentially over neutral ones. In fear-conditioning, an initially neutral stimulus becomes aversive after association with a threatening outcome. Importantly, a fear conditioning paradigm has the advantage that the stimuli have intrinsically equivalent affective value prior to the experiment. The

only difference was that one of them was consistently associated with an unconditioned aversive stimulus. Therefore, the possibility that the attention effects were due to physical differences between the stimuli, rather than their emotional value, can be ruled out.

Fear-conditioned cues have been shown to interfere with ongoing behavior and are therefore thought to be detected voluntary, that is, even when they are irrelevant to current task goals. In **Chapter 4**, we showed that when performing a visual search task, the abrupt appearance of a cue previously associated with an electric shock attracts attention and interferes with the ongoing search task. Even though all stimuli in the display were initially completely neutral, the presence a stimulus with a learned fear association slowed response times more than a stimulus without a fear association. Thus, imminent threat can be considered highly behaviorally relevant and interferes with competing goals.

In **Chapter 5**, we provided additional evidence for oculomotor competition between threatening and neutral stimuli. When a saccade had to be directed to one of two locations indicated by an arrow, relative to a neutral cue, saccades were initiated faster to the location that was previously occupied by a threatening cue. Moreover, when a saccade had to be directed to the location opposite of the fear-conditioned cue, saccades were initiated slower, indicating slower disengagement of attention from a threatening relative to a neutral cue. In addition, more saccades landed on the location of the threatening cue when the saccade had to be directed elsewhere, indicating a difficulty of suppressing eye movements to its location. Therefore, a threatening event strongly competes with a goal-directed eye movement by evoking programming of involuntary eye movement to its location. The pattern of results supports the view that a fear-conditioned stimulus induces a reflexive shift of attention and interferes with temporary goals.

An attentional bias does not seem to be specific to threat, but can occur for all stimuli that are relevant to an individual's goal at a given point in time. For example, it may be crucial to quickly attend to signals of safety, compared to signals conveying neutral information, in order find a way out of a threatening situation. However, from

an evolutionary perspective, quick detection of threat seems to be of a particularly high relevance for an individual's survival, since threat usually requires direct action. In **Chapter 6,** we demonstrated that just like a threatening cue, a cue that predicted safety interrupted with the execution of a voluntary saccade to another location. However, there was no evidence of facilitated allocation of attention to the location of the safety cue compared to neutral cues. Quick facilitation of attention in early stages of processing seems specific to cues with a threatening value. The initial execution of a saccade to a location previously occupied by threat appears relatively fast and automatic and represents a direct change in behavior. In addition, other stimuli interfere with ongoing tasks when they are behaviorally relevant, but they seem to require additional processing.

Crucially, behaviorally relevant goals, and the assessment of how external events interrupt those goals, differ from individual to individual and from situation to situation. Emotions are therefore fundamentally tied to the concept of goal-relevance. A stimulus or event is appraised as emotionally relevant when it has potential consequences for either furthering or obstructing a person's goals. Obviously, these goals can include immediate survival goals, such as avoiding predators and other life-threatening events. Additionally, more complex and socially embedded goals need to be achieved, such as forming friendships with other individuals and attracting potential mates. Such goals are closely tied to an individual's well-being and reproductive fitness. In general, it can be argued that emotions put a tag of importance to an event, given the organism's currently active goals. Every type of goal seems relevant in its own specific situation, and one of the critical functions of fast emotion detection seems to separate the immediately important goals from the ordinary. Emotion adds value to events and provides bias in information processing that subsequently influences behavior