A sense for value

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Summary

We often underestimate how incredibly complex and ambiguous our environment is, and the sheer amount of information that is constantly bombarding our senses. To be able to effectively navigate and interact with such a complex and constantly changing environment, the ability to filter out irrelevant input and select only the most relevant and useful information is of paramount importance not only to cope with the richness and complexity of the environment, but to be able to survive and thrive in it.

Traditionally, selective attention has been described to rely on two fundamental strategies: On the one hand, stimulus-driven attention ensures that salient stimuli in the environment are rapidly detected, and if necessary, reacted to. On the other hand, voluntary, goal-driven attention permits the explicit, voluntary direction of the attentional focus in tune with specific goals and intentions. Traditionally, the question of which stimuli would be attended and further processed, and which ignored was considered to ultimately depend on the integration and interplay of these two strategies.

However, in the recent years a significant amount of evidence has emerged demonstrating that these are not the only strategies that our attentional system has at its disposal. Indeed, there is a growing number of studies demonstrating how past experiences also play an important role in guiding attention, allowing us to for instance, to recognize recurring patterns and regularities in the environment, and to use this information to direct our attentional resources. Importantly, many of

these studies have shown that there influence of past experiences on attention is not limited to permit the recognition of environmental patterns and regularities, but extends to the ability to consider the subjective value of the different stimuli, that is, the extent to which objects and events in the environment signal a possible benefit or threat to the individual survival and well-being of the observer.

From this perspective, the purpose of the studies contained in this dissertation was to examine the extent to which stimuli associated with both threats and rewards influenced the allocation of attentional resources, and to describe some of the most immediate effects of these value-driven attentional biases on perception and behavior. Additionally, the examination of threat- and reward-driven attentional effects under highly comparable experimental conditions serves to highlight the fact that, despite the undeniable differences in terms of the subjective experiences associated with threatening and rewarding events, being able to effectively cope with both is crucial for the survival and well being of the individual, and thus it is only reasonable to expect that our attentional systems are tuned to detect and react to stimuli with a subjective value, regardless of whether they are beneficial or aversive.

Chapter I provides an overview of scientific literature describing how certain objects and stimuli in our environments become attentional priorities not because of their physical salience, or because they are intentionally being sought after, but because they represent a potential threat and reward to the observer, that is, because of their subjective

value. This chapter goes on to describe key characteristics of the attentional effects elicited by value-associated stimuli elicit, namely, their speed and automaticity, their robustness and persistence over time, and the fact that they directly interact with both stimulus- and goal-driven attentional biases, either competing or boosting their effects depending on the specific circumstances of their interaction.

Chapter II describes the first experimental study conducted to assess the attentional effects of value-associated stimuli, specifically, a threat-associated stimulus. In this study, the presence of a certain neutral stimulus was associated with the delivery of a mild, but unpleasant electric shock, and this stimulus was then used in a task evaluating spatial attention. This study revealed that, even if the threat-associated stimulus was neither physically salient nor useful to perform the spatial attention task, stimuli presented at the same location of the threat-associated signal were detected and discriminated faster and more accurately. Notably, this improved speed and optimized sensory processing at the location of the threat cue persisted for an extended period of time.

Extending these findings, **Chapter III** begins by replicating the previously described attentional effects of threat-associated stimuli using the same experimental design, except for the fact that that the informative stimulus in the experiment was associated with a monetary reward, rather than with an electric shock. After confirming that attentional biases to signals of both threat and reward result in the same attentional effects, that is, faster response times and increased

perceptual sensitivity, this chapter moves on to describe a third experiment employing a reward-associated stimulus, with one additional manipulation in the design: In contrast to the previous studies, where the location of the value-associated stimulus did not provide any useful information for the spatial attention task, in this experiment the value-associated cue not inly signaled the availability of a monetary reward, but also that the target of the spatial attention task would be located at the opposite side of the display. This manipulation set the conditions to be able to examine the competition of a value-driven attentional bias (in this case, reward) directing attention towards the informative stimulus, and a goal-driven bias leading it away from the same stimulus. Results of this experiment suggest that a key factor determining which attentional bias would prevail in this competition was the duration of the lapse between the value-associated cue and the target stimulus to be identified. Specifically, results indicated that the value-driven bias rapidly takes precedence over voluntary attentional control if the lapse between cue and target is short, but that the voluntary goal-driven bias can regain control of attention if a longer time period is allowed. To close, this chapter presents an additional experiment conducted in an attempt to replicate the just described competition effects, this time with a threat-associated stimulus. However, this last experiment failed to replicate the reward-driven attentional effects previously describes , and only provided evidence suggesting that perceptual sensitivity is increased at shorter delays between cue and target stimuli.

Chapter IV describes a study designed to further explore the extent to which value-driven attentional biases compete with voluntary attentional control. This study investigated the extent to which eye movements would be sensitive to a reward-driven bias, and whether this bias, once established, would interfere with voluntary oculomotor control at a later stage of the experiment, during which the stimuli would no longer signal the availability of a reward. During the initial stage of the experiment, in which participants were instructed to make eye movements towards stimuli associated with different reward magnitudes, stimuli associated with a high reward (compared to low and no reward) led to faster and more accurate eye movements. Notably, at the later stage of the experiment, where the instruction was to look in the opposite direction from such stimuli, the presence of the stimulus previously associated with a high reward would still attract saccades, leading to increased incorrect movements, and slowing down the initiation of saccades. Furthermore, the combined analysis of incorrect saccades as a function of their latency revealed that the largest proportion of incorrect saccades was observed for the saccades with the shortest latency, further supporting the idea that value-driven attentional biases predominate shortly after the detection of the value-associated stimulus, but that this dominance can be overcome by voluntary control with longer delays.

Finally, **Chapter V** makes an overview of the most important findings of the described experiments, and discusses how could these findings be contextualized within available theories of attention.