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Visual attention and optimal decision making

Humans can be instructed to look at a fixation point and attend to different locations in space using high contrast visible cues such as a box or an arrow. Typically, performance in a variety of perceptual and tasks including target detection, discrimination and identification is superior when a target appears at the cued (attended) location than when it appears at an uncued (unattended) location. In addition, performance improves as the number of cued (attended) locations is reduced. These performance benefits are typically attributed to an enhancement of perceptual processing at an attended location and a deterioration of the perceptual processing at the unattended locations (Luck et al., 1996; Bashinski & Bacharach, 1980; Hawkins et al., 1990; Downing et al., 1988). The attentional enhancement/deterioration effects are due to a fixed amount of limited resources that has to be divided among the attended locations at the cost of the unattended locations. One limitation of these analyses is that they do not consider the stochastic nature of neural coding and perceptual decisions. Inclusion of noise in the processing of visual information allows for performance benefits by virtue of exclusion of irrelevant noisy information and/or more optimal weighting of different information sources, and without the need to invoke the concept of limited resources. Models based on signal detection theory and optimal observer analysis (SDT, Green & Swets, 1966) specify how to best integrate noisy information to reach decisions in the presence of cues and allow to calculate the expected performance changes based on these principles. In these models (e.g., Shaw, 1983, Kinchla, 1995, Palmer et al., 1994; Eckstein, 1998) attention allows the observer to give more weight to relevant information and reduce the weight to irrelevant information. We will discuss how the optimal observer framework can account for a number of important attention results in the visual search literature including the decreasing target detection performance with increasing number of distractors, the dichotomy between feature and conjunction search displays (Treisman & Gelade, 1980; Eckstein, 1998) and the cueing effect with partially valid cues (Posner, 1980; Eckstein et al., 2002). In addition, we present results suggesting that a similar differential weighting attentional mechanism might be responsible for improved saccade accuracy when a target object appears at an expected location (or with an object that typically co-occurs) in a natural scene vs. when it appears at an unexpected location (Chun, 2000). We finally argue that as the field moves towards integrating psychological and neurophysiological approaches to the study of attention, signal detection theory based models are particularly well suited to bridge studies of the effect attention on behavior and neural activity.