Homo economicus in visual search

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Humans rely on visual search to detect food, predators and mates. Decades of research in visual search behavior has focused on the role of sensory information [1,2] such as salience of the target, amount of background clutter quantified by number and heterogeneity of distracting objects, and recently target frequency effects [3]. In contrast, the role of reward outcomes in visual search behavior is relatively unknown. Here we investigate how sensory information (based on the visual representation of target present and absent displays, and target frequency) combines with reward outcomes (points gained or lost for correct vs. incorrect responses) to influence decision making and target detection performance in a visual search task.

We asked subjects to detect an oddly oriented line (of a known orientation) in briefly flashed pictures containing a number of parallel lines. We measured target detection performance as a function of the target frequency (50%, 10%, 2%) and the reward scheme. We experimented with two reward schemes: in experiment A, the reward was ‘Neutral’, i.e. false alarm and miss errors were equally penalized (loss of 50 points) and correct detections and correct rejections were equally rewarded (gain of 1 point). In experiment B, missing a target was penalized much more seriously (-900 points) than a false alarm (-50 points), and correct detection was rewarded more (+100 points) than correct rejection (+1 point). We call this the ‘Airport’ reward scheme to mimic an airport scenario where missing a bomb hidden in a suitcase is prohibitively expensive compared to false alarms that result in relatively quick manual inspection.

We present four main findings: 1) Rare targets are missed even when the target is salient (a drop in detection rates from close to 80% down to 30% as the target frequency decreases from 50% to 2%, replicating the results of [3]). 2) Contrary to previous studies [3,4], we find a rapid and optimal influence of reward on sensory decision making and detection rates – humans behave as reward-maximizing agents and decide whether the target is present or not based on whichever maximizes their expected reward. Hence, the poor detection performance for rare targets can be corrected by changing the reward scheme. 3) A quantitative model based on reward-maximization accurately predicts human detection behavior in different target frequency and reward conditions. We use this model to illustrate how reward schemes can be designed to obtain high detection rates for any target frequency. 4) We conclude with a neurally plausible model of how subjects quickly learn the optimal decision criterion in different target frequency and reward schemes. Potential applications of our findings include improving detection rates in life-critical searches for rare targets (e.g., bombs in airline passenger bags, cancers in medical images).

References