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# Scanning of Natural Visual Scenes: How Cognitive and Sensory Mechanisms Work Together to Control Saccades

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The ability to use saccadic eye movements to bring the line of sight to targets of choice in natural visual scenes is truly one of the most remarkable motor skills human beings possess. We manage to look precisely where we want while scarcely being aware of making any effort to control the movements. How do we do it? Consider the specific challenges presented by any scanning task:

The natural targets for saccades are spatially-extended objects. At the same time, the line of sight must land at a single spatial position within the object. This single landing position is not determined by deliberate effort: when we scan a scene it's objects we think about looking at – faces, flowers or coffee cups – not tips of noses, petals or rims. Presumably, some involuntary sensory or sensorimotor process operates on the visual information within the chosen target and computes a single saccadic landing position. Yet, computation of the landing position cannot be completely immune to volition because for us to be able to look where we wish, any influence of visual signals from irrelevant backgrounds must be eliminated.

Recent research in our laboratory has shed light on how volitional and involuntary mechanisms work together to direct saccades accurately in natural visual scenes. This work has supported a two-stage model of saccadic control, in which selection of the target object by means of attentional allocation precedes a spatial-pooling process that computes a central location within the attended object. This central location then serves as the target for the saccade. These assertions are supported by the following experimental results:

(1) Saccades are preceded by a shift of spatial attention to the target. Concurrent measurements of saccadic and perceptual performance, analyzed by means of attentional operating characteristics (AOCs), have shown that making a saccade to one location impairs the perceptibility of targets at other locations. The attentional cost of saccades proved to be surprisingly modest: accurate perceptual identification of targets at non-goal locations required only a 10–20% increase in the latency of saccades (Kowler, Anderson, Dosher and Blaser, 1995). Analogous experiments requiring the concurrent perceptual identification of two targets showed comparable interference, which increased the closer the targets were to one another. Such interference would aid saccadic localization because it shows that attending to one target effectively inhibits the processing of nearby targets and reduces their potential for attracting the line of sight (Bahcall and Kowler, 1995).

(2) Saccades land at precise locations within spatially-extended targets. This level of precision has been demonstrated when subjects direct saccades to the "target as a whole" rather than to any specific place within it. Saccadic precision is excellent, with standard deviations of landing positions equal to about 6% of eccentricity, a value only slightly greater than the SDs observed in analogous perceptual localization tasks. The precision of saccades is unaffected by increases in target size (Kowler and Blaser, 1995) and decreases in target contrast.

(3) Saccades directed to spatially-extended targets land close to (but not precisely at) the center-of-gravity. This was observed for different types of targets, i.e., patterns of random dots (McGowan *et al.*, 1996), and outline drawings of a variety of simple shapes. Statistical analyses of landing positions obtained with the random dot patterns show that landing position was determined by pooling information across the form, with no differential weighting of dots according to location (i.e., near *vs.* far eccentricities; boundary *vs.* central locations). Differential spatial weighting did not account for the small but reliable departures of landing position from the center-of-gravity.

We conclude that effective, and relatively effortless, saccadic localization of targets in natural scenes is accomplished by allocation of attention to the target object followed by a spatial-pooling process that computes the target's center of gravity. The link between saccades and attention means that no special selection process is needed to determine the saccadic goal. Saccades will be directed to the object you are interested in at the time the movement is triggered, with no additional set of decisions required. The modest attentional costs of saccades means that saccadic localization will interfere only minimally with the concurrent perceptual or cognitive processing of objects at locations other than the saccadic goal. The high level of saccadic precision observed with a wide variety of spatially-extended targets shows that lower-level sensory and sensorimotor mechanisms contribute negligible noise to the localization process. This low level of noise opens the way for cognitive decisions (conveyed, perhaps, by shifts in the distribution of attention) to play the major role in determining landing position. All in all, the mechanisms responsible for directing saccades appear to be remarkably suited to meet the requirements of natural scanning: accurate and precise localization achieved with minimal demand on cognitive resources.

## References

Bahcall, D. and Kowler, E. (1995) Attentional interference at close spatial separations. *Investigative Ophthalmology and Visual Sciences Supplement. 36*, S901.

Kowler, E., Anderson, E., Dosher, B. and Blaser, E. (1995) The role of attention in the programming of saccades. *Vision Research, 35*, 1897-1916.

Kowler E. and Blaser, E. (1995) The accuracy and precision of saccades to small and large targets. *Vision Research, 35*, 1741-1754.

McGowan, J., Kowler, E., Sharma, A. and Chubb, C. (1996) Precise saccadic localization of random dot targets. *Investigative Ophthalmology and Visual Sciences Supplement 37*, S524.