The eye on the needle

Eileen Kowler & Han Collewijn

Tiny gaze shifts, or microsaccades, have little function in the eye movement control system and were once thought to be suppressed during fine spatial judgements. A new study suggests that they are important for finely guided visuomotor tasks and may actively contribute to the acquisition of spatial information in the same way as do larger saccades.

A driver's nightmare, prowling a crowded parking garage looking for a space and late for an important appointment. Finally, you find a spot, but the parked cars on either side are so close to the dividing lines that there is barely enough room to maneuver. You slowly creep in, mindful of the door handles and mirrors jutting out from the cars on each side. You shift your gaze to the left, then right, and then left again, each shift of gaze coinciding with a small adjustment of the steering and advancement forward, until, finally, you're in the space with no dents or scratches anywhere. The ability to appropriately direct your gaze makes all the difference to your parking success. A recent study by Ko *et al.*[1] provides some new and surprising insights about how such gaze shifts contribute to vision. The authors studied eye movements while threading a needle, a familiar, but undoubtedly less stressful, finely guided visuomotor task (**Fig. 1a**).

Those troubled by nightmares of scratching cars while parking in impossibly narrow slots might wish for a different kind of visual system, one that offers a panoramic view of the scene with uniformly high-quality resolution of spatial detail, so we would not be forced to keep looking around. Alas, human beings must contend with the inhomogeneity of vision. Resolution of fine visual detail is available only in a small region surrounding the central locus of gaze[2,3]. Outside this region, visual resolution steadily deteriorates, which means we must rely on eye movements (specifically, the rapid jumps of the eye known as saccades) to scan the scene and allow us to apprehend the details of one portion of the image at a time.

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All this work that goes into planning saccades and shifting gaze would not be needed if spatial resolution, visual acuity, were of uniformly high quality across the visual field. Just such a situation applies to human vision when spatial details fall in the very center of the field, the central 0.5 degree, where acuity is remarkably good[2,3]. Thus, it is curious that human beings have the capacity to produce and control extraordinarily small saccades. Saccades as small as 5 min of arc, termed microsaccades, were first noticed in the human eye movement pattern in the 1950s during studies of eye movements made while maintaining fixation on a small stationary detail[4,5].

The microsaccades observed during fixation were initially thought to be reflexive corrections to fixation errors produced by slow, noisy oculomotor drift. This view was not supported, however, by findings that 'drifts' are really active movements (slow control) that use visual signals to keep the line of sight on target without assistance from saccades, which could be easily suppressed during fixation[4]. Microsaccades have also been thought to provide the motion of the image on the retina necessary to maintain vision (retinally stabilized images fade from view). However, no central role for microsaccades in maintaining visibility has been found, except perhaps in special cases in which efforts are made to hold the head still and targets are eccentric and of low contrast. In normal viewing, image velocities are fast enough to prevent fading without the need for microsaccades (reviewed in ref. 5).

The remaining plausible function for microsaccades is essentially the same as the function of larger saccades, namely, to take the line of sight from one chosen detail to another. If so, a useful role for microsaccades should be revealed in tasks that require the highest level of spatial resolution and involve serial comparisons of details across small regions of space[4]. A previous study[6] investigated this hypothesis by studying the role of microsaccades in the performance of finely guided visuomotor tasks; specifically, aiming a rifle or threading a needle. The study found no evidence to support a contribution of microsaccades. Saccades during the visuomotor tasks were larger than the typical microsaccades and saccades dropped out of the eye movement pattern just as the task was being successfully completed, when the crucial visual details were closest to each other. Another study[7] found the same result for a purely visual version of the needle threading task.

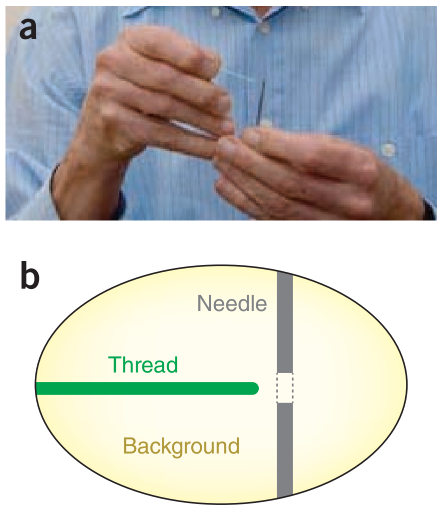

Figure 1 Two kinds of finely guided visuomotor tasks. (**a**) Threading a needle in the real world[6]. (**b**) Illustration of the display used in Ko *et al.*'s[1] study of virtual needle threading, showing the vertically oriented needle and the horizontal thread.

Ko *et al.*'s findings[1] challenge the conclusion that microsaccades are not useful in finely guided visuomotor tasks and provide a new view of the debate about what microsaccades, and saccades in general, contribute to visual processing. Ko *et al.*[1] made the insightful argument that the value of microsaccades should be most apparent, not when a task such as needle-threading was nearly completed, but rather in the few seconds prior, when visual comparisons across small distances were most critical. In Ko *et al.*'s[1] version of a needle-threading task (**Fig. 1b**), the 'needle' was a vertical bar with a narrow 'eye' displayed on a computer monitor. The 'thread' was a thin horizontal bar, located a half degree from the needle and moving toward it either at a slow, constant speed or (in a replication of previous conditions[6]) under the subjects' control. Ko *et al.* replicated previous results[6,7], finding that the frequency of microsaccades was smaller (by a factor of two) at the very end of the trial than at the beginning.

Ko *et al.*[1] then repeated the experiment, this time allowing the subject to adjust only the thread's vertical position and ending each trial when the thread was a scant 7 min of arc from the needle, when critical visual comparisons between thread and the eye of the needle were still very much underway. Saccades did not drop out of the eye movement pattern over time, but instead became smaller. By the end of trials (but before the thread intersected the needle), the frequency of occurrence of saccades smaller than 20 min of arc, which had been initially low (0.6 per s), increased to the level found during maintained fixation on stationary targets (about 1 per s). An increase in frequency was also found for a population of even smaller saccades (<10 min of arc); however, saccades this small were rare during either threading or fixation (0.2 per s).

Further analysis showed that the saccades were not simply random shifts of the line of sight, or movements designed to produce retinal image transients, but rather reflected the strategies of the task. Microsaccades (<20 min of arc) were made to look back and forth between needle and thread. In addition, any adjustments to the position of the thread were more likely to occur just after a microsaccade was made to look from the needle to the thread than after other possible transitions. After an adjustment in thread position, microsaccades were more likely to be directed to the thread (perhaps an attempt to evaluate the effect of the adjustment) than to the needle. These findings suggest that microsaccades are part of an active looking strategy, incorporating and reflecting the goals and plans of the task.

Ko *et al.*'s findings[1] are important because they show that microsaccades are used precisely the way large saccades are, namely, to bring the line of sight to visual details that are crucial for the immediate task. These findings are unexpected because when visual details are of sufficiently high contrast, not obscured by crowding from neighbors and separated by less than half degree on the retina, it should be possible to perform the task without saccades. A judiciously chosen central fixation location should have provided the vantage point needed to evaluate the relative position of the critical details (needle and thread) and permit the appropriate adjustments. Further research using controlled, rather than spontaneous, fixation behavior should elucidate whether microsaccades (specifically, those smaller than 15 min of arc) are actually necessary or helpful in accomplishing the present task. Ko *et al.*'s results[1] deal not with necessity, but with spontaneous behavior. Given the alignment task, the subjects preferred to make saccades. Why? What was the benefit of this strategy?

The same question can be raised about any saccade, regardless of size, when objects and details are large or vivid enough to be resolved using the visual periphery. Why bother to look around when vision is already good enough? One intriguing possibility is that the limitations that prompt the use of saccades in an environment where all the visual details are easy to see are cognitive, rather than visual. Perhaps we can only make one decision at a time. If so, saccades, be they micro or macro, are doing something in addition to improving spatial resolution. They are transforming the visual scene into a sequence of discrete views that focus our attention, decisions and plans on only one detail at a time[8]. Ko *et al.*'s experiment[1], which deals with the smallest of voluntary human movements, sheds light on the larger connections between vision, thinking and action that underlie real-world activities.

COMPETING FINANCIAL INTERESTS
The authors declare no competing financial interests.

1. Ko, H., Poletti, M. & Rucci, M. *Nat. Neurosci.* **13**, 1549–1553 (2010).
2. Rossi, E.A. & Roorda, A. *Nat. Neurosci.* **13**, 156–157 (2010).
3. Klein, S.A. & Levi, D.M. *J. Opt. Soc. Am. A* **4**, 1543–1553 (1987).
4. Steinman, R.M., Haddad, G.M., Skavenski, A.A. & Wyman, D. *Science* **181**, 810–819 (1973).
5. Collewijn, H., & Kowler, E. *J. Vis.* **8** (14):20, 1–21 (2008).
6. Winterson, B.J. & Collewijn, H. *Vision Res.* **16**, 1387–1390 (1976).
7. Bridgeman, B. & Palca, J. *Vision Res.* **20**, 813–817 (1980).
8. Ballard, D.H, Hayhoe, M.M., Pook, P.K. & Rao, R.P. *Behav. Brain Sci.* **20**, 723–742 (1997).

How hard is the CNS hardware?

Martin E Schwab

A study in this issue reveals gene expression differences between neurons that do, and those that do not, show recovery-associated growth after stroke. The differentially expressed genes may provide potential therapeutic targets.

Stroke hits unexpectedly, like lightning, striking the farmer in a field during a hot summer's day or the recently retired manager preparing for a stress-free life of enjoyment. Large strokes leave the sufferer hemiplegic and frequently, when the motor speech area is also affected, unable to speak, even when comprehension of language and cognitive abilities are intact. Recovery after large strokes is often very limited and quality of life is severely affected; many inhabitants of health care homes are, in fact, stroke victims. In this issue of *Nature Neuroscience*, Li *et al.*[1] find that a vigorous growth response occurs in spared neurons around the lesion and investigate the molecules mediating this growth. Outgrowth of new fibers and the formation of new connections over large parts of the motor and sensory cortex may provide the substrate for the establishment of new circuits that compensate for lost functions during the process of rehabilitation.

Ruptured blood vessels (hemorrhagic stroke) or aggregates of platelets and blood cells (thrombi) that clog important cerebral blood vessels (ischemic stroke) lead to local tissue destruction in the brain in a few hours. The destruction process is complex and can only be halted, in the case of clogged vessels,

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