Dispatches

Eye–Hand Coordination: Learning a New Trick

In many manual tasks, a specific repertoire of eye movements accompanies the actions. A new study has shown how this pattern changes as eye and hand become coordinated when learning a new skill.

Michael F. Land

During everyday activities — driving, making a sandwich or playing ping-pong — our eyes search ahead, trying to find the information that our hands and limbs need to carry out their tasks [1–4]. It has become clear in the last 20 years, since it became possible to monitor eye movements in freely moving people, that the eye-movement system does far more than respond reflexly to objects that catch the eye. In a skilled motor task, eye movement has a role that is different from the action itself, but thoroughly enmeshed with it [2]. For example, in driving on a winding road, one job of the eyes is to locate and track the inside lane edge (tangent point) of the next bend, as its location relative to the driver provides direct information about road curvature, and hence how much to turn the steering wheel [5]. There are many other examples where a precise eye movement strategy is a crucial component of the larger action. What has never been addressed before is how, during the acquisition of a skill, the motor and eye movement strategies co-evolve. This has now been done, as reported recently in *Journal of Neuroscience* [6].

Sailer, Flanagan and Johansson [6] devised a task which involved learning how to use a novel mouse-like tool to control the position of a cursor on a screen, in order to hit a series of consecutively appearing target boxes. The tool consisted of a freely held box with a handle at each end. Applying opposite rotational torque to the two handles moved the cursor up and down the screen, whilst pushing the handles towards or away from each other moved the cursor laterally (in fact the system was isometric, and the handles did not move). Making oblique cursor movements with the tool was evidently quite difficult and took some time to learn. The gaze movements and cursor movements of the subjects were monitored as they learned how to use the tool, and measures of success such as hit rate and path length to target were also measured. The learning process took a total of about 20 minutes.

The most interesting result was that, for most subjects, learning proceeded in three distinct stages: an exploratory phase in which the hit rate remained low; a skill acquisition stage in which the hit rate increased rapidly; and a skill refinement stage in which the rate increased more slowly. The three phases were characterised by very different patterns of both motor control (as shown by the cursor movements) and gaze movements.

During the exploratory phase most cursor movements and gaze movements were either horizontal or vertical, as the subjects learned to cope with one or other control dimension of the tool (Figure 1A). Gaze generally followed the cursor, with occasional glances to the target, and gaze saccades were generally small, 3–4°. At this stage it typically took about 20 seconds for the cursor to reach the target.

During the skill acquisition stage, the subjects slowly learned to move the cursor obliquely, and the hit rate increased to about one target every two seconds (Figure 1B). At the beginning of this second period, the eyes continued to track the cursor, although the pattern changed from gaze lagging behind the cursor to leading it by up to 0.3 seconds: gaze thus began to anticipate cursor position. At the same time, gaze saccades became larger, increasing from about 4° to 12°, as more were directed towards the target (successive targets were 18° apart).

During the skill refinement stage, gaze no longer tracked the cursor, but went straight to the next target, with either a single saccade, or with one large and one smaller saccade (Figure 1C).

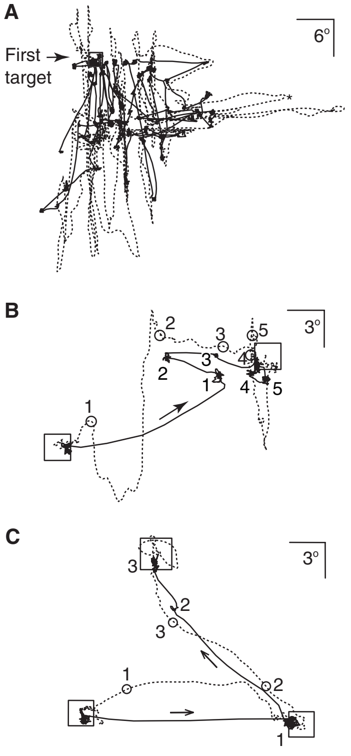

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Figure 1. Paths of gaze (solid line) and the cursor (dotted line) during three phases of the acquisition of the skill by one subject.

Squares are the targets. Numbers on the solid curves are gaze fixation positions, and numbers on the dotted paths are the points corresponding in time to the gaze fixations. (A) The very first attempt to locate a target during the exploratory phase, characterised by extremely ineffective vertical and horizontal movements of both eye and cursor. (B) The skill acquisition phase: although the cursor track is still predominantly horizontal and vertical, it reaches the target after only five gaze fixations. Fixations are now ahead of or level with the cursor. (C) The skill refinement stage: gaze goes straight to the next target, and the cursor follows in a more or less straight line. (Reproduced with permission from [6]; Copyright 2005, Society for Neuroscience.)

Hit rates increased slightly to just below one per second.

The role of gaze clearly changes as learning progresses. To begin with, the eyes follow the movements of the cursor. At this stage vision is being used to check on the effects of the rather inexpert control operations, and learning proceeds by associating particular manipulations with their visual consequences. During the skill acquisition stage, gaze begins to anticipate cursor movements and, as manipulation becomes more secure, vision is used to provide a series of local goals for cursor movements. Finally, with control of cursor direction established, it is sufficient for gaze to mark the target — the end point of the cursor movement.

To what extent does this study provide a model for the learning of eye-hand coordination in general? First, the task described here is being undertaken by adults who already have a full repertoire of eye movement strategies to deal with most contingencies in life, including new skill acquisition, so this is probably not like the early stages of eye-hand coordination in infancy — about which, it must be said, we know nothing. Another qualification to the generality of the study might be that the tool that had to be mastered here was made deliberately difficult to use, and this probably had the consequence of extending the initial exploratory period for longer than would have been the case with, for example, an ergonomically designed joystick.

That said, the description of the evolution of eye hand-coordination in this particular skill, with a gradual transition from a monitoring to an anticipatory role for the eyes, does sit very nicely with ideas about skill acquisition in other contexts. Many activities we learn after early childhood have components that require the visual calibration of a manual activity — how much to turn the steering wheel of a car, or the effects of a tennis stroke on a ball's trajectory. These imply a period when vision is mainly concerned with checking consequences, corresponding to the first two phases of the scheme proposed by Sailer *et al*. [6]. Equally, once the calibration has been established, vision is freed up to look ahead — to the next bend or the intended target of the next stroke. Vision now has a feed forward rather than a feedback role.

It has long been recognised that skill acquisition proceeds in stages. Psychologists distinguish the early attention-demanding stages in learning a new skill, from the later stages in which actions are automatized, and require little or no conscious intervention [7,8]. There are also theoretical models of the internal processes involved in motor control which allow for learning by comparing motor signals with sensory feedback, and which lead to predictive behaviour — the kinds of processes that seem to be at work here [9,10]. Other studies have considered the transformations involved in eye-hand coordination [11] and the possible neural substrates of motor learning [12].

The eye movement patterns demonstrated in the new study [6] have exposed some of the deeper processes that occur during skill learning, processes that could not have been foreseen just by observation of the actions themselves. With this information it should be possible to refine models of the learning process, both in terms of their computational mechanisms, and also the parts of the brain that are likely to be involved.

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Department of Biology and
Environmental Science, University of
Sussex, Brighton BN1 9QG, UK.
E-mail: M.F.Land@sussex.ac.uk

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Mitotic Spindle: Disturbing a Subtle Balance

Mitotic spindles maintain a roughly constant length in metaphase, so the forces between the spindle poles are balanced. A new study involving screening molecules believed to mediate this force balance has found that spindle length is relatively insensitive to perturbations of molecular motor force-generating activities, but more sensitive to perturbation of microtubule assembly regulators and chromosome cohesion.

David J. Odde

A central question in biology is how do individuals, organs, tissues, cells and even subcellular structures, such as the mitotic spindle, maintain control over their size, even as their constituents turn over rapidly. Theoretically, a slight imbalance in the assembly and