Functions of a quiet and un-quiet eye in natural tasks – comment on Vickers

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TA COMMENTARY

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ABSTRACT

The Quiet Eye (QE) is an interesting phenomenon that has implications for the links between cognition and eye movements as well as for the question of how we examine these links in real world tasks. The gaze behaviour observed in sports and other active tasks is varied in form and function. Although fixation duration has a specific definition in laboratory tasks, in sport and naturalistic actions it is not as easy to interpret. I discuss what we can learn from gaze in natural behaviour and how both quiet and "un-quiet" eyes may have highly specific functions in different tasks.

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It is an intriguing possibility that one of the factors determining expertise in sport is our overt visual attention. Research into the Quiet Eye (QE) has now spanned many different situations (Vickers, 2016). The finding that a final fixation with a long duration is associated with sporting success has been replicated both within and between individuals (Mann, Williams, Ward, & Janelle, 2007). In this commentary, I will describe how progress in this field relates to what we know about the functions of gaze in the laboratory and in real world actions.

The un-quiet eye

The irony of any paper about the QE is that the eye is not really "quiet" at all. Our illusion of continuity is so strong that many people express surprise when watching the darting saccades that are common in most visual tasks. In the laboratory, fixations tend to last somewhere between 100 ms and 500 ms during tasks like reading or image viewing (Rayner, 2009). Even during fixations the eyes are subject to "fixational eye movements" such as microsaccades (forming a continuum of oculomotor activity with saccades; Martinez-Conde, Otero-Millan & Macknick, 2013). It has recently been reported that experts make larger microsaccades when watching video clips of table tennis, indicative of increased attention to items in the periphery (Piras, Raffi, Lanzoni, Persiani, & Squatrito, 2015).
In the laboratory, saccades are a readily-interpreted response to the limits of the fovea. Thus, fixations are an indication of where people are extracting information from and what they are doing with this information. Longer fixation durations are normally indicative of more difficult – or less efficient – information processing. As a result, expertise in such tasks is often associated with shorter rather than longer fixation durations. For example, novice or less-skilled readers have greater average durations (Rayner, 2009). Gegenfurtner, Lehtinen and Säljö (2011) conclude in their meta-analysis that experts generally

make *shorter* fixations when looking at visual information. To understand this apparent discrepancy with QE research it is helpful to consider studies of active vision from outside the lab.

From the lab to the golf course

QE research presents several challenges compared to conventional lab-based cognitive psychology. Researchers must deal with a participant who is free to move, and technical limitations mean that analysis is often dependent on video coding. QE research has succeeded in overcoming these challenges, along with research into natural gaze behaviour by Land, Hayhoe and colleagues (e.g., Land & Hayhoe, 2001). With mobile eye trackers cheaper and more user-friendly than ever before, the number of researchers investigating gaze in active tasks is only going to increase.

Despite the difficulties, I (as well as others) have argued that it is crucial to study visual behaviour outside the constrained situation of the psychological laboratory (Foulsham, 2015; Tatler, Hayhoe, Land, & Ballard, 2011). In Foulsham, Walker and Kingstone (2011), we compared gaze in people walking outdoors with those watching videos of the same scene while sitting in the laboratory. People fixated task-relevant features such as the path more frequently in the real world than on video. Participants also moved their eyes less within the head frame-of-reference when walking in the real world, perhaps due to their freedom to make head movements and the participant's locomotion through the environment. There are interesting parallels here with QE research. It may be that, when walking, we are all "experts", skilled at dwelling in the right place at the right time (for "non-experts", see Kretch, Frenchak, & Adolph, 2014, who measured gaze in infants learning to walk). The study of gaze in walking also makes clear that defining "fixations" in real world actions is more difficult than when the head is fixed in laboratory conditions. This is partly due to the lower temporal resolution of mobile eye trackers, but also because of difficulties with excluding smooth pursuit, tracking gaze, and reflexive movements which keep the eyes central while the head is moving. The spatial (within 3 °) and temporal (> 100 ms) limits of QE gaze may seem somewhat arbitrary, and it will be interesting to see whether advances in technology can lead to a more physiologically precise definition.

Figure 1 shows an example of the range of gaze behaviour made during real tasks. In this (unpublished) study, several golfers were recorded on a real course executing different shots. QE-type behaviour could be detected in the fixations on the ball and club before striking the ball. However, a range of other interesting behaviours were on display during the pre-shot routine. Golfers often looked at targets between the tee and the desired position on the fairway, a scanning process which continued during practice swings. Before and after the shot, gaze was used for other purposes: to guide the hands when manipulating ball or tee, or to track the ball in motion. The visual information being acquired and the processing occurring is different in each case, and difficult to study within the laboratory.

The function of eye movements in natural tasks

The variation in gaze during sports is no surprise if one looks at the literature from natural behaviour. The key insight from these experiments is that gaze is highly specific to a particular task and sub-task (Foulsham, 2015; Land & Hayhoe, 2001). For example, during Land's tea-making experiments, some fixations were associated with guiding the hand when reaching; others with manipulating items (e.g., putting the lid on the kettle); and others with monitoring a state of the environment (e.g., waiting for the kettle to fill). That participants can seamlessly switch between the appropriate types of gaze behaviour demonstrates a high level of learned control. Such control, and exquisite timing, must also be hallmarks of the trained athlete.

The examples from natural behaviour teach us that it is only possible to fully interpret the function of gaze patterns, and measures like fixation duration, within a more detailed description of the task and the motor acts involved. Expertise and extended processing are normally associated with shorter fixations in laboratory tasks, where stimuli and processing difficulty can be controlled, and it is easier to draw conclusions about a single fixation. In sport, walking and tea making, longer gazes are often associated with the monitoring of dynamic information in the environment, as well as with over-learned, predic-

Figure 1: Point of gaze (circular cursor) at three moments during a golf shot. The function of fixation may be quite different when picking up a tee (left), lining up before a shot (middle) and tracking the ball after the shot (right).

tive behaviour which allows skilled actors to deploy gaze early. It is important that researchers are now probing the QE experimentally, in order to determine the functional consequences of a longer final look (Gonzalez et al., 2015; Vine, Lee, Walters-Symons, & Wilson, 2015). As with other natural behaviours, the timing of QE onset and offset, and therefore also of "un-quiet" periods, is likely to be the crucial factor. Ultimately, the discoveries from such experiments will be specific to particular sports and actions, and the QE must fit within a more detailed description of the task at hand.

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