Tackling Quiet Eye issues on a functional level – comment on Vickers

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TA COMMENTARY

ABSTRACT

Joan Vickers (2016) pinpoints the Quiet Eye´s (QE) relation to superior learning and performance in numerous motor tasks. On this basis, this commentary emphasises that future research should particularly focus on underlying mechanisms to increase our understanding of the QE phenomenon. To this end, we suggest to pursue a functional approach that tackles the QE on a behavioural level by advancing theoretical as well as methodological aspects. Consequently, (a) an *inhibition hypothesis* will be outlined that supposes the QE to "shield" the parametrisation of the optimal task solution against alternative movement variants; (b) an algorithmic approach to the study of gaze behaviour will be introduced that maximises data quality and minimises manual analysis effort; and (c) a peripheral perspective on the QE will be depicted suggesting QE functionalities beyond foveal information processing.

Keywords:
perception-action coupling – gaze behaviour – inhibition hypothesis – peripheral vision – eye tracking technology

Over the last decades, positive effects of a gaze strategy called the Quiet Eye (QE) have been found for motor performance on an inter- and intra-individual level. As elaborated by Vickers (2016), this phenomenon highlights the relevance of the tight coupling between perception and action for superior motor behaviour. The QE´s functionality has been shown for a large range of motor tasks like dart throwing and golf putting (for a recent overview, see Rienhoff, Tirp, Strauss, Baker, & Schorer, 2016); and, first and foremost, Joan Vickers has a large share in unravelling this phenomenon (Vickers, 2007). However, a number of recent studies revealed that the relation between the QE and performance is not as monotonic as suggested (for recent overviews, see Gonzales et al., 2015, Wilson, Causer, & Vickers, 2015). Thus, instead of isolating the QE in further motor tasks or of searching for QE correlates on a neural level – as both suggested by Vickers (2016) – we would find it more fruitful to elaborate theoretical frameworks on the behavioural level that allow to experimentally test specific predictions in order to extend our understanding of the mechanisms underlying the QE. This commentary will outline such a framework by suggesting an explanation on a functional level, presenting respective empirical and measuring methods and providing an outlook on future research questions by introducing a "peripheral perspective" on the QE.

An inhibition hypothesis

In QE literature, different mechanisms are offered for the explanation of the phenomenon's functionality (for a recent overview, Gonzalez et al., 2015). The explanatory power of these mechanisms, however, seems to be limited to specific

demands (e.g., online vs. offline control) and constraints (e.g., situations of increased anxiety) of the motor task (Klostermann, 2014; Klostermann, Kredel, & Hossner, 2013). As, from our point of view, this state of diversity is rather unsatisfactory, we have elaborated a functional mechanism that parsimoniously accounts for the broad variety of current research findings. Drawing on Neumann's (1990) functional approach to the study of attention, this mechanism features an inhibition function such that the QE supports the parametrisation of the optimal solution for a given perceptual-motor task by inhibiting alternative movement parametrisations. Based on this hypothesis, predictions were established that offer an explanatory potential for the current state of research. This is especially true for the classical finding of prolonged QE durations in experts as motor learning is rather accompanied by an economisation of behaviour which would imply a shortening of the QE period with growing expertise rather than its lengthening. In contrast, on the basis of *the inhibition hypothesis*, it is assumed that expertise is hallmarked by a densely explored task space, resulting in increased inhibition demands and, thus, in a prolongation of the QE interval.

On an empirical level, results in favour of the *inhibition hypothesis* could be presented as an experimentally evoked increase in task demands over movement preparation (Klostermann et al., 2013) and movement execution (Klostermann, Kredel, & Hossner, 2014) affected the efficiency of long QE durations (see also Williams, Singer, & Frehlich, 2002). However, further research is required that specifically addresses the suggested "shielding" of the optimal movement variant, for instance, by experimentally varying inhibition demands.

Regarding the theoretical level, it needs to be added that the assumed inhibition mechanism needs further specification. Since the functionality of the attentional selection-for-action mechanism proposed by Neumann (1990) is fundamentally rooted in the idea that, in a real world, humans can achieve only one action goal at a time, it seems to make a lot of sense to marry the proposed inhibition function with current theoretical approaches on the effect-relatedness of motor control processes, in particular, with the idea of internal forward models (e.g., Wolpert & Miall, 1996) which would be perfectly match concepts focusing on prediction also in the domain of human vision (e.g., Enns & Lleras, 2008). However, details of this marriage have still to be sorted out in order to come up with clear-cut predictions that are open for empirical testing.

Advanced designs and technologies

For the rigorous study of functional mechanisms underlying the QE phenomenon, first, research designs needs to be shifted from the classical correlational to an experimental approach allowing for the independent manipulation of the QE duration as well as other variables derived from the respective explanatory framework. To this end, we have introduced an experimental paradigm which is based on the external pacing of a throwing movement and the temporally aligned presentation of cues (i.e., the target disc) being able to experimentally manipulate the QE duration (e.g., Klostermann et al., 2013).

Second, to perform meaningful inference statistics, compared to classical QE studies which are based on a manual allocation of a gaze vector to an area of interest, a massive increase of trials per participant and condition and of participants per group is inevitably. Consequently, we have proposed a technological shift towards an automated vector-based gaze analysis, which uses light-weight and high-frequency mobile eye-tracker hardware embedded in a motion-capture system enabling us to synchronously capture gaze behaviour and kinematics of the participant (Kredel, Klostermann, & Hossner, 2015). To allow for a thorough automation of the eye-tracking data collection and data analysis, gaze needs to be represented mathematically (i.e., as a gaze vector), which requires to track the position and orientation of the eye tracker in real-time inside a laboratory frame-of-reference. Beyond, we implemented a custom software application fusing the kinematic and eye-tracking data (i.e., eye rotation angles) thereby providing additional functionality for the automated management of experimental setups. With this system, the highly subjective and tedious manual data analysis can be replaced by an automated, objective data-to-stimulus assignment process since the gaze vector can be automatically assigned to static or moving objects with known positions related to the laboratory frame-of-reference (e.g., a target that has to be hit). Additionally, due to the simultaneous recording of the participants´ movement behaviour, this gaze analyses can be directly related to respective performance variables.

A peripheral perspective

Most notably, the advanced analysis procedure sketched before is not limited to a one-to-one assignment of a single stimulus to a foveal gaze point. In fact, it can be extended by mathematically specifying the biological characteristics of the visual periphery around the calculated gaze vector allowing for a many-to-many assignment of stimuli to foveal and peripheral regions. Obviously, this procedure offers a useful approach for the further disentanglement of potential QE mechanisms by extending the analysis beyond the collection of foveal data.

The necessity to extend the study of functional gaze strategies beyond the boundary of foveal vision is certainly true for situations in which crucial information can originate from a number of locations as it is the case, for instance, in combat or team sports. For example, in karate where the attacks can be realised with both arms and legs, the defender needs to monitor several cues at the same time. As, due to tight time constraints, it may be dysfunctional to fixate relevant cues in consecution, a central fixation in-between these locations and using peripheral vision might be more beneficial (Williams & Elliot, 1999). In a recent study, we were able to show that participants when monitoring four moving targets over a longer

period of time used exactly such a "pivot-point" gaze strategy (Vater, Kredel, & Hossner, 2016). Since, due to the motion sensitivity in the peripheral visual field, participants were able to detect motion changes even at large eccentricities, these results suggest a general functionality of a visual stabilisation. Thus, the QE might not only be beneficial in situations that require precise foveal information processing. Instead, a long final fixation might also be functional in situations that require an "anchoring strategy" – on the basis of the inhibition hypothesis, for shielding the optimal movement variant (e.g., the most precise pass to the best positioned teammate) against inferior alternatives. Hence, it seems worth considering to extend the purview of QE research beyond the boundary of foveal information processing as it has been exclusively done so far (cf. Vickers, 2016, Table 1: QE location).

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Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

All relevant data are within the paper.

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