

In my mind's (quiet) eye: a perceptual-cognitive approach to the Quiet Eye – comment on Vickers

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Introduction

The quiet eye (QE; Vickers, 1992, 1996) has become a widely researched phenomenon across a variety of sports and motor tasks (for reviews, see e.g., Vickers, 2007, 2009, 2016). It is currently considered a critical action-related variable, being a major factor of perceptual-cognitive expertise that differentiates experts from non-experts (e.g., Mann, Williams, Ward, & Janelle, 2007). It is therefore surprising that our insight into its functioning, into the underlying mechanisms of the QE, has remained scarce to date. While research on the QE has grown, covering cross-sectional research designs (e.g., expert novice paradigm with QE as dependent variable; e.g., Vickers, 1992) as well as longitudinal research designs (e.g., learning paradigm with QE

ABSTRACT

In her article on the origins and current issues in quiet eye (QE) research, reviewing an impressive body of research, Vickers (2016) concludes amongst others that it is important to understand the neural and other processes underlying the QE. Interestingly, the debate on the mechanisms of the QE has received growing interest only recently, with hypotheses from two main theoretical approaches (i.e., cognitive and ecological ones) evolving. What is missing as part of this discussion, however, are perceptual-cognitive approaches and their potential explanatory value with respect to the QE. Following a short summary of the current debate on the theoretical underpinnings of the QE and the main hypotheses that have been proposed so far, we introduce a perceptual-cognitive approach to the QE, and discuss recent findings that point to a perceptual-cognitive explanation of the QE.

Keywords:

effect anticipation – effect representation – mental representation – CAA-A

as independent variable; e.g., Vine & Wilson, 2010), focusing on behavioral, cognitive, and neural aspects, the discussion of the theoretical underpinnings has taken a back seat until recently (e.g., Gonzalez et al., 2015).

Current debate on how the QE works

Following Vickers (2009), Klostermann (2014) and Gonzales and colleagues (2015) have augmented the discussion on what exactly is reflected by the QE. So far, cognitive and ecological approaches (formerly known as motor and action approach: Meijer & Roth, 1991) have been introduced as theoretical accounts for the specific mechanisms of the QE.

The most prominent suggestion so far has evolved from the cognitive domain and draws on the schema theory (Schmidt, 1975). According to this hypothesis, the QE serves to program movement parameters in order to prepare subsequent movement execution (*programming hypothesis*; e.g., Williams, Singer, & Frehlich, 2002). In contrast to the cognitive approach, the ecological approach draws on the theory of direct perception (Gibson, 1979). According to the *affordance hypothesis* (e.g., Oudejans, van de Langenberg, & Hutter, 2002), the QE reflects the attuning of affordances prior to their realization, not requiring any cognitive engagement. Aiming at an integrative approach, Klostermann (2014) has recently introduced the *inhibition hypothesis*, with reference to Neumann (1992). According to this hypothesis, alternative parameter specifications are inhibited during the QE, allowing one parameter specification to come into effect. In sum, several hypotheses have been proposed as potential explanations for the QE, focusing on seemingly dichotomous aspects of the motor action. Surprisingly, while hypotheses from both the cognitive and the ecological domain exist, theories from the perceptual-cognitive domain and their potential explanatory value have not been discussed in the light of the QE so far. It might, however, prove valuable in the explanation of what the QE is and how it works.

A perceptual-cognitive approach to the QE

Following what is often referred to as a crisis in the motor domain (Abernethy & Sparrow, 1992; Schack & Ritter, 2013; Summers, 1998), with researchers from cognitive and from ecological approaches agreeing that they disagree, a third class of approaches has gained in importance not only in movement science and psychology, but as well in cognitive robotics (for an overview, see Schack & Ritter, 2013): Perceptual-cognitive approaches discuss motor control in the light of action-based cognition. Specifically, the goal-directedness of actions, the anticipation of perceptual effects, and effect representations are of particular importance for action control according to this class of approaches (for an overview, see Schack & Tenenbaum, 2004a, 2004b).

According to perceptual-cognitive approaches (e.g., theory of anticipative behavioral control: Hoffmann, 1993; simulation theory: Jeannerod, 2001) and the original idea of a bidirectional link between an action and its effects (i.e., ideomotor theory: James, 1890), actions are primarily guided by cognitively represented perceptual effects. Drawing on seminal work of Bernstein (1967) and his idea of a model of the desired future, motor actions can be considered as being stored in memory as well-integrated representational networks or taxonomies comprised of perceptual-cognitive units that guide action execution (cf. cognitive action architecture approach/CAA-A; for an overview, see Schack, 2004; Schack & Ritter, 2009). Moreover, these networks of *basic action concepts* (BACs) are suggested to change throughout the process of motor learning, resulting

in action-related structure formation through perceptual-cognitive scaffolding. From research conducted in the realm of the CAA-A (e.g., Schack & Mechsner, 2006), experts as compared to novices hold structured representations with groupings of BACs reflecting the functional phases of the motor action (cf. Göhner, 1992, 1999; Hossner, Schiebl, & Göhner, 2015). Recently, action representations have been shown to functionally adapt in the direction of an elaborate representation during motor learning, thereby relating more so to biomechanical task demands (Frank, Land, & Schack, 2013).

With respect to the QE and the ongoing theoretical discussion, we think that it is important to consider as well perceptual-cognitive approaches. Drawing on Bernstein's (1967) notion of the desired future and the cognitive action architecture approach (Schack, 2004), the QE may be considered as reflecting the time to create a model of the desired future across all levels of action organization and across all perceptual-cognitive components (nodes) of the action architecture. Accordingly, the desired effects are planned based on the action effect representation available, and thus serve to select, execute, and control an action. From this point of view, it might be the effect anticipation based on the effect representation available that is reflected by the QE. Recent research indicates that the representational networks of a motor action develop alongside of the QE during learning (Frank, Land, & Schack, 2016). Participants trained on a golf putting task over the course of three days. Putting performance, the mental representation structure of the putt, and the QE were measured prior to and post practice as well as after a retention interval. In contrast to a no practice control group, both representational networks as well as QE durations developed functionally alongside of performance improvements over the course of learning. Interestingly, the degree of elaborateness in representation structures related to the length of QE durations after learning, with better developed representation structures relating to longer QE durations. This finding extends research on differences in QE behavior by providing insight into QE changes over the course of practice, with the QE developing alongside of representational networks of motor action in long-term memory, relating to one another after learning. From these findings, the more elaborate information-processing during movement preparation, as expressed by longer QE durations, seems to be related to more elaborate underlying effect representations in long-term memory.

This finding supports the notion that the QE reflects cognitive processing (e.g., Gonzalez et al., 2015; Klostermann, Kredel, & Hossner, 2014; Williams et al., 2002). More importantly, however, this study provides initial evidence that the QE reflects critical action-related information processing based on the effect representation available. To that effect, the QE is likely to reflect a predictive, perceptual-cognitive mode of control initiating a cognitively demanding process of motor planning. In contrast to the programming hypothesis, however, it may be not the parameterization of motor commands in the first place, but the anticipation of perceptual effects that are crucial to successful motor planning and execution. Although the results indicate

that the more elaborate information processing during movement preparation is based on more elaborate mental representations in long-term memory, it must be noted that we did not directly test for underlying mechanisms in the study reported above. Future studies are needed to look more closely at the causality of this relationship, and the mechanisms of the QE.

Conclusion

This commentary covered a short summary of the current debate on the theoretical underpinnings of the QE and the main hypotheses that have been proposed so far, followed by the proposition of a perceptual-cognitive approach to the QE. In contrast to merely cognitive or merely ecological approaches, this approach takes into account cognitive as well as ecological aspects, by focusing on the cognitively represented perceptual effects of the action. Accordingly, the anticipation of these effects is suggested to be reflected during the QE. In order to advance the current discussion on the theoretical underpinnings of the QE, researchers (including ourselves) should put more effort into designing studies that tackle the underlying mechanisms of the QE and its components (e.g., duration, onset, offset) in more depths and in relation to the action, thereby disentangling various explanations and testing competing hypotheses against each other. Crossing boundaries between seemingly distinct theoretical approaches from movement science, cognitive psychology, and neuroscience will necessarily result in controversial but hopefully as well fruitful discussions toward more integrative accounts of the QE phenomenon.

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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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