# Is a 'quiet eye' all it takes to be successful? Comment on Vickers

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TA COMMENTARY

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ABSTRACT

Inspired by the pioneering work of Joan Vickers, Quiet Eye (QE) research has gained increased attention from researchers in disciplines ranging from Sports Science to Neuroscience. A recent target article by Vickers (2016) provides an overview of QE research relating to expert performance, oculomotor control, attention, anxiety, and child development. In this commentary, we provide a neuroscientific perspective on QE and optimal oculomotor control and discuss their possible underlying brain mechanisms. We focus primarily on the role of the parietal-frontal network and question its involvement in visuomotor transformations and processing of an efference copy. To address these issues, we discuss the potential benefits of adapting transcranial magnetic stimulation techniques to QE research. In addition, a brief perspective on QE research in patients with neurodegenerative disorders and aging is provided.

Keywords:
attention – goal-directed reaching – gaze – efference copy – visuo-motor transformation – parieto-frontal network

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## Introduction

First of all, we would like to compliment Joan Vickers with the Quiet Eye (QE) research she inspired so many researchers with. Her recent review paper on issues related to QE research (Vickers, 2016) provides an excellent platform for examining both the behavioral and neural aspects of oculomotor control. The cortical circuits controlling oculomotor function and upper limb movements are highly interconnected. Oculomotor control (in general) and QE (in particular) are believed to be mediated by a parieto-frontal network. However, little is known about the nature of interactions between key areas of this network as well as between this parieto-frontal network itself and other brain structures important for controlling the planning and execution of goal-directed movements such as the basal ganglia and cerebellum. Other aspects of QE literature that have been addressed in Vickers' paper aim to tackle the link between QE, memory and attention as well as the use of QE training as a means to improve oculomotor control in patient populations. Our commentary will focus primarily on questions related to brain mechanisms underlying QE and discuss future target groups that could benefit from QE training. Throughout this commentary, we will formulate some challenging research questions we do not know yet fully the answers for.

## Potential brain mechanisms

One possible explanation for the benefits of long QE durations on successful motor performance is that it provides the necessary time for organizing the neural structures that are responsible for planning and controlling actions. Visually-guided movements require sensory information about the target to be extracted and transformed into an appropriate motor command. Thus the amount, or quality, of visual information about the target appears critical in this sensorimotor transformation process. A possible mechanism underlying QE effects on motor control is that a longer fixation duration provides more time to prepare the motor command, send it forward and process online feedback, but also allows to gain more detailed visual inputs about the target through the fovea. Another likely mechanism is that longer QE duration may provide the generation of a better-defined efference copy of the intended movement.

*Can stable gaze (and longer QE duration) prior to movement initiation be taken as a prerequisite for optimal visuo-motor transformations?* A large number of transcranial magnetic stimulation (TMS) studies in humans corroborate the view that a cortical circuit connecting the posterior parietal cortex (PPC) to the premotor cortex subserves sensorimotor transformations underlying reaching movements (Davare, Andres, Clerget, Thonnard, & Olivier, 2007; Davare, Rothwell, & Lemon, 2010; Koch et al., 2010; Tunik, Frey, & Grafton, 2005; for a review, see Davare, Kraskov, Rothwell, & Lemon, 2011). This circuit connects the medial part of the intraparietal sulcus (mIPS) and parieto-occipital junction (POJ) to the dorsal premotor cortex (PMd). Using state-of-the-art dual-coil TMS paradigms, it has recently been shown how transfer of visuo-motor information is processed in parieto-frontal networks during grasping movements (Davare et al., 2010). It is also possible to probe POJ-M1 connections with dual-coils paradigms during reaching movements (Vesia, Bolton, Mochizuki, & Staines, 2013). Since optimal visuo-motor transformations are expected to optimize the definition of the motor plan before movement initiation, the use of dual-coils TMS paradigms would provide an elegant way to address this question.

*Is QE associated with the formation of an efference copy?* There is evidence to suggest that visuo-motor transformations occur in the parieto-frontal pathways through the generation of an efference copy (Loh, Kirsch, Rothwell, Lemon, & Devare, 2010; Medendorp, Goltz, Crawford, & Vilis,2005). The efference copy is necessary for optimal transformation of the target coordinates from a gaze-centered into a hand-centered reference frame (Medendorp et al., 2005; for a review, see Vesia & Crawford, 2012). In the context of eye-hand coordination, for example, information about the efference copy of eye motor commands can be used for defining hand motor commands. In addition, the efference copy generated by networks projecting onto the frontal eye field (FEF) may be effective for optimizing fixation on the target. Evidence from functional magnetic resonance imaging (fMRI) studies describing expert vs. novice differences in brain activity during sport-related anticipation could provide some hints about the brain network involved in this process (Wright, Bishop, Jackson, & Abernethy, 2011; Wright & Jackson, 2007). Interestingly, evidence from those studies suggests that early stage occlusion during anticipation results in increased activation across both posterior and anterior components of the action observation network rather than the cerebellum and the basal ganglia. Importantly, interactions between areas of the action observation network (see Rizzolatti & Sinigaglia, 2010, for a review) and the parieto-frontal network can be studied with TMS.

## Future target groups

Beyond pinpointing specific mechanisms underlying the QE phenomenon at the neural level, future QE research should focus particularly on the investigation of special target groups.

Expert versus novices: QE training is expected to enhance performance of goal-directed movements by optimizing preparatory gaze. Modulation in brain activation from novice (untrained) to expert (trained) performance in young and older adults should be investigated. Besides training-induced changes in preparatory gaze, QE training is expected to optimize information processing and interregional communication between areas of the parieto-frontal network as well as between the parietal-frontal network itself and subcortical brain structures (e.g., the cerebellum, a candidate region for formation of efference copy). Yet, very little research has been conducted to explore the association between performance gains and practice-related changes in the reorganization of the aforementioned brain network. The question also remains open about the specific mechanisms that might be most affected by QE training. Documenting shifts in brain activation from unskilled to skilled performance before and after QE training by using fMRI and TMS would allow addressing these issues.

*Aging and pathological functioning:* Recent research suggests that generic oculomotor training might have a positive impact on postural stability in people with cerebellar ataxia (Bunn, Marsden, Giunti, & Day, 2015) as well as on gait in progressive supranuclear palsy (Zampieri & Di Fabio, 2009). In several studies, optokinetic stimulation and gaze stabilization were used as elementary components in vestibular rehabilitation to improve static balance (Bunn et al., 2015; Chen, Hsieh, Wei, & Kao, 2012; Morimoto et al., 2011). Crowdy, Kaur-Mann, Cooper, Mansfield, Offord, and Marple-Horvat. (2002) investigated the effect of rehearsal of eye movements on locomotor performance in cerebellar patients. They reported an improvement of stepping regularity and accuracy in the two cases and a decrease in stance and double support phase durations in one patient only. Improved oculomotor control was shown by a reduced occurrence of saccadic dysmetria, measured as a significant increase in the ratio of single to multi-saccadic eye movements. An earlier study of Crowdy Hollands, Ferguson, and Marple-Horvat (2000) showed that the amount of locomotor problems observed in cerebellar patients during visually guided stepping is linked to the severity of their oculomotor abnormalities. Despite the heterogeneity in level of dysfunction between the participants, a significant improvement in the accuracy of steps as a result of eye movement rehearsal was found compared to repeated walking alone. All studies mentioned above investigated the effect of generic oculomotor training on balance and lower limb functionality. Given the importance of visually guided goal-directed aiming in aging and in pathological functioning such as Multiple Sclerosis and Parkinson, it is remarkable that, to the best of our knowledge, no research has been conducted on this topic.

## Conclusion

While our commentary makes some assumptions about the brain network underlying QE, the actual brain structures responsible for processing sensory information during longer QE durations are yet to be uncovered. This issue could be addressed by using neuroimaging techniques such as fMRI, electroencephalography (EEG), and TMS. These three techniques are complementary because they allow not only to define these brain networks (fMRI and EEG) but also to determine the causal role of each brain area in sensory processing, movement planning and execution (TMS). To date, no studies using a combination of these techniques has been conducted to highlight the brain mechanisms underlying preparatory gaze behavior and QE in goal-directed movements. Furthermore, inference about the effect of age on the neural mechanisms underlying the benefits of QE on movement performance and training is therefore imperative.

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## Data Availability Statement

All relevant data are within the paper.

## References

Bunn, L. M., Marsden, J. F., Giunti, P., & Day, B. L. (2015). Training balance with opto-kinetic stimuli in the home: A randomized controlled feasibility study in people with pure cerebellar disease. *Clinical Rehabilitation, 29*, 143-153. doi: 10.1177/0269215514539336

Chen, P.-Y., Hsieh, W.-L., Wei, S.-H., & Kao, C.-L. (2012). Interactive wiimote gaze stabilization exercise training system for patients with vestibular hypofunction. *Journal of NeuroEngineering and Rehabilitation, 9*, 77. doi: 10.1186/1743-0003-9-77

Crowdy, K. A., Hollands, M. A., Ferguson, I. T., & Marple-Horvat, D. E. (2000). Evidence for interactive locomotor and oculomotor deficits cerebellar patients during visually guided stepping. *Experimental Brain Research, 135*, 437-454. doi: 10.1007/s002210000539

Crowdy, K. A., Kaur-Mann, D., Cooper. H. L., Mansfield, A. G., Offord, J. L., & Marple-Horvat, D. E. (2002). Rehearsal by eye movement improves visuomotor performance in cerebellar patients. *Experimental Brain Research, 146*, 244-247. doi: 10.1007/s00221-002-1171-0

Davare, M., Andres, M., Clerget, E., Thonnard, J. L., & Olivier, E. (2007). Temporal dissociation between hand shaping and grip force scaling in the anterior intraparietal area. *The Journal of Neuroscience, 27*, 3974-3980.

Davare, M., Kraskov, A., Rothwell, J. C., & Lemon, R. N. (2011). Interactions between areas of the cortical grasping network. *Current Opinion in Neurobiology, 21*, 565-570.

Davare, M., Rothwell, J. C., & Lemon, R. N. (2010). Causal connectivity between the human anterior intraparietal area and premotor cortex during grasp. *Current Biology, 20*, 176-181. doi: 10.1016/j.cub.2009.11.063

Koch, G., Cercignani, M., Pecchioli, C., Versace, V., Oliveri, M., Caltagirone, C., Rothwell, J., & Bozzali, M. (2010). In vivo definition of parietomotor connections involved in planning of grasping movements. *Neuroimage, 51*, 300-312. doi: 10.1016/j.neuroimage. 2010.02.022

Loh, M. N., Kirsch, L., Rothwell, J. C., Lemon, R. N., & Davare, M. (2010). Information about the weight of grasped objects from vision and internal models interacts within the primary motor cortex. *The Journal of Neuroscience, 30*, 6984-6990. doi: 10.1523/JNEUROSCI.6207-09.2010

Medendorp, W. P., Goltz, H. C., Crawford, J. D., & Vilis, T. (2005). Integration of target and effector information in human posterior parietal cortex for the planning of action. *Journal of Neurophysiology, 93*, 954-962.

Morimoto, H., Asai, Y., Johnson, E. G., Lohman, E. B., Khoo, K., Mizutani, Y., & Mizutani, T. (2011). Effect of oculo-motor and gaze stability exercises on postural stability and dynamic visual acuity in healthy young adults. *Gait and Posture, 33*, 600-603. doi: 10.1016/j.gaitpost.2011.01.016

Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror circuit: Interpretations and misinterpretations. *Nature Review Neuroscience, 11*, 264-274. doi: 10.1038/nrn2805

Tunik, E., Frey, S. H., & Grafton, S. T. (2005). Virtual lesions of the anterior intraparietal area disrupt goal-dependent on-line adjustments of grasp. *Nature Neuroscience, 8*, 505-511.

Vesia, M., Bolton, D. A., Mochizuki, G., & Staines, W. R. (2013). Human parietal and primary motor cortical interactions are selectively modulated during the transport and grip formation of goal-directed hand actions. *Neuropsychologia, 51*, 410-417. doi: 10.1016/j.neuropsychologia.2012.11.022

Vesia, M., & Crawford, J. D. (2012). Specialization of reach function in human posterior parietal cortex. *Experimental Brain Research, 221*, 1-18. doi: 10.1007/s00221-012-3158-9

Vickers, J. N. (2016). Origins and current issues in Quiet Eye research. *Current Issues in Sport Science, 1:101*. doi: 10.15203/CISS_2016.101

Wright, M. J., Bishop, D. T., Jackson, R. C., & Abernethy, B. (2011). Cortical fMRI activation to opponents' body kinematics in sport-related anticipation: Expert-novice differences with normal and point-light video. *Neuroscience Letters, 500*, 216-221. doi: 10.1016/j.neulet.2011.06.045

Wright, M. J., & Jackson, R. C. (2007). Brain regions concerned with perceptual skills in tennis: An fMRI study. *International Journal of Psychophysiology, 63*, 214-220. doi: 10.1016/j.ijpsycho.2006.03.018

Zampieri, C., & Di Fabio, R. P. (2009). Improvement of gaze control after balance and eye movement training in patients with progressive supranuclear palsy: A quasi-randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 90*, 263-270. doi: 10.1016/j.apmr.2008.07.024