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**Flow and quiet eye: the role of attentional control in flow experience.**

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Abstract

This report was designed to investigate the role of effective attention control in flow states, by developing an experimental approach to the study of flow. A challenge-skill balance manipulation was applied to self-paced netball and basketball shooting tasks, with point of gaze recorded through mobile eye tracking. Quiet eye was used to index optimal control of visual attention. While the experimental manipulation was found to have no effect, quiet eye was associated with the experience of flow. Furthermore, mediation revealed an indirect effect of quiet eye on performance through flow experience. This study provides initial evidence that flow may be accompanied by changes in visual attention, suggesting that further investigation of visual attention may elucidate the cognitive mechanisms behind flow experience.

Keywords: quiet eye; challenge; flow; peak performance

**Does attentional control underpin the flow experience? A preliminary examination**

Flow is an intrinsically motivated, optimal mental state which has attracted particular interest from sport psychologists because of its link with peak performance (Jackson & Csikszentmihalyi, 1999; Koehn & Morris, 2012). Sport also affords an ideal environment in which to study flow as it provides challenging tasks with clear goals and measurable performance outcomes (Jackson & Csikszentmihalyi, 1999). However, a significant challenge is to identify the cognitive mechanisms through which flow may provide beneficial effects (Swann, 2016). Consequently there is a need to apply both experimental manipulations (Moller, Meier & Wall, 2010) and direct measurement techniques that can provide an insight into the functional benefits of flow. This study aims to adopt such an experimental approach, utilising eye tracking technology to assess potential attentional mechanisms that might underpin the state.

Attentional control requires the ability to maintain top-down attention to only goal relevant stimuli (dorsal network; Corbetta & Shulman, 2002), and resist the distracting influence of stimulus driven attention (ventral network; Corbetta & Shulman, 2002). But while those in flow describe a heightened task focus and prolonged concentration (Jackson & Csikszentmihalyi, 1999) indicative of optimal attentional control, this is yet to be measured empirically. Support comes from the computer gaming literature, where immersion in the task (a state similar to flow1) has been characterised by efficient control of visual attention (Cheng, 2014; Jenette et al., 2008). Additionally, recent neuroimaging research has implicated the role of higher order attentional processes in the flow experience (Ulrich, Keller & Grön, 2016). The efficient control of top-down visual attention is also linked to superior performance in sporting tasks (Mann, Williams, Ward & Janelle, 2007) with one particular measure, the quiet eye (QE; Vickers, 1996) providing an objective index of optimal attentional control. The QE, the final fixation to a target prior to movement execution, is proposed as facilitating the organisation of neural networks for controlling movement (Vickers, 2009). A longer QE duration has been linked with expertise and superior performance across a range of interceptive and far aiming tasks (see Lebeau et al. 2016 for a recent meta-analysis) and reflects an efficient top-down control of attention (Vine & Wilson, 2011). As such it may provide a potential mechanism through which to explain the association between flow and peak sport performance.

In order to study flow experimentally, it is necessary to create the conditions for flow to occur. Lab-based experimental approaches have been utilised within gaming research by manipulating the challenge-skill balance (Keller & Bless, 2008), identified by Nakamura and Csikszentmihalyi (2002) as a crucial precursor to flow. Csikszentmihalyi’s (1975) flow theory predicts that flow occurs when there is a perceived balance between challenge and skill. If the task is too easy (skills outweigh challenges) then boredom or apathy occurs, but if the task is overly difficult (challenges outweigh skills) the individual feels stress or anxiety. Controlling this balance provides the best route to manipulating flow (Moller et al., 2010), but is yet to be applied in a sporting task.

Our overarching aim was therefore to assess the potential role of optimal attention control - indexed by quiet eye duration - as a flow mechanism. Basketball free throw shooting was chosen as our primary task of interest as it has a validated QE (Vickers, 1996; Wilson, Vine & Wood, 2009), plus a similar three-point shooting task has previously been utilised to show measurable changes in flow (Pates, Cummings, & Maynard, 2002). Netball shooting was chosen as a suitable comparison task for the purpose of generalising any positive findings (Swann, 2016). We manipulated the challenge-skill balance by providing participants with shooting targets to achieve, ranging from too easy to too hard. In line with flow theory (Csikszentmihalyi, 1975), it is predicted that moderate goals will present an optimal challenge, making flow more likely. We also predicted best performance in this condition, due to more focused attention, indexed by longer quiet eye durations.

**Methods**

**Participants**

Eighteen basketball players (2 female; *M*age = 23.88 years; *SD* = 7.56; mean experience = 10.8 years; *SD*=7.75) and seventeen netball players (all female, *M*age = 20.00 years; *SD* = 0.97; mean experience = 11.50 years, *SD*=2.10) were recruited. All participants attended testing individually, and signed consent forms, with details of the study explained to them verbally and in writing. University ethics committee approval was obtained prior to participant recruitment.

**Apparatus**

For the basketball task, free throws were taken at a standard net, at NBA regulation height (3.05m) and distance (7.24m), with a regulation basketball. For netball, shots were taken at a standard netball post, at a height of 3.05m, as recommended by England Netball. There is no netball equivalent of the basketball free-throw. Therefore a shooting distance of 3.2m was chosen based on previous use in flow research (Pates, Karageorghis, Fryer & Maynard, 2003) and discussion with netball players who identified it as a typical but challenging shooting distance.

Participants’ eye movements were recorded using an ASL (Applied Science Laboratories; Bedford, MA) Mobile Eye Tracker, which comprises a pair of glasses carrying a forward facing scene camera and an eye camera using dark pupil tracking (±0.5° visual angle; 0.1° precision), recording at 33Hz. Motor movement was recorded with a digital camera (Casio Exilim EX-Z850, 33fps) positioned at a right angle to the participant, to record the whole shooting movement.

**Measures**

**Flow.** State flow was measured using the Flow Short Scale (FSS, Rheinberg, Vollmeyer & Engeser, 2003), a questionnaire widely used in gaming research (Engeser & Rheinberg, 2008). This short measure was chosen as repeated administrations of long measures may have induced fatigue. This scale also provides a simple unitary measure, reflecting the goal of identifying flow rather than investigating aspects of the experience. The FSS measures flow through ten questions scored on a 7-point Likert scale, loading onto two factors, absorption in the activity and fluency of performance, or a global flow factor. Statements such as ‘*I feel just the right amount of challenge*’ are rated for accuracy, with responses ranging from ‘*Very much’* to *‘Not at all’.* Note, lower scores on this scale reflect higher felt flow. A reliability analysis gave Cronbach’s α of .86 for the overall scale.

**Quiet eye period.** The QE period is defined as the final fixation directed to a single location in the visuomotor workspace, within 3° of visual angle, for a minimum of 100ms. The onset of the QE begins at the initiation of the final fixation before the final movement occurs, with an offset when the gaze fixation deviates from the location by 3° of visual angle or more for 100ms (Vickers, 2007). Based on previous research key gaze locations for basketball were defined around the basket and backboard (Vickers, 1996; Wilson, et al., 2009). For netball, key gaze locations were defined as on or just above the net (within 1°), as no backboard is used. A relative QE duration was then computed as a percentage of movement time to account for variations in throwing strategy (Lebeau et al., 2016). The definition of the shot phase (from the first video frame showing upward motion of the ball to the first frame where the ball left the participant’s fingertips) described by Vickers (1996) allowed this to be standardised across both sports.

**Performance.** The performance measure was based on a scoring system used by Hardy and Parfitt (1991) where 5 was given for a clean basket, 4 for rim and in, 3 for backboard and in (omitted for netball), 2 for rim and out, 1 for backboard and out (omitted for netball) and 0 for a complete miss.

**Procedure**

After reading the participant information sheet and signing the consent form, participants were fitted with the ASL eye tracker which was calibrated over 5 points on the basketball hoop or markers on the wall. Participants were given 20 shots to familiarize themselves with the task and with the equipment. Recording checks were performed at the start of every block of shooting, and re-calibrated where necessary.

Participants performed five blocks of 10 shots, with instructions designed to give varying levels of challenge: a target of 2, 4, 6, 8 or 10 baskets out of 10. The order of the blocks was counterbalanced across participants. If the target was reached in fewer than 10 shots, participants were asked to continue with the remaining shots. After each block of shots participants sat and filled out the Flow Short Scale.

**Data Analysis**

Gaze and movement data were analysed using Quiet Eye Solutions software (Quiet Eye Solutions Inc.) which allows gaze and motor videos to be time locked and played simultaneously. Quiet eye duration was calculated for all of the 50 shots taken by each participant. Due to tracking issues data from one participant was completely excluded, plus 62 of the remaining 1700 shots (3.65%) across all participants. As there was found to be no difference between basketball and netball in FSS scores, *F*(1,30)=0.10, *p*=0.76, *ω*²=-.029; QE percentage *F*(1,15)=1.67, *p*=.216, *ω²*=.038; or performance, *F*(1,32)=.70, *p*=.41, *ω²*=-.009, sports have been combined in the subsequent analyses.

Repeated measures ANOVAs were used to test the effect of goals on flow, QE and performance with a Greenhouse-Geisser correction applied when the assumption of Sphericity was violated. ANOVAs were followed by Bonferroni corrected paired t-tests in all cases. As performance data was not normally distributed, a related samples Friedman’s analysis of variance by ranks was conducted. The effect size partial omega squared (*ω2*) was calculated for *F*-tests, Cohen’s *d* for t-tests and Cramer’s *V* for *χ2* tests. Pearson’s correlation analyses were used to examine the relationships between flow, performance and quiet eye. To investigate the order of these relationships, mediation analyses were conducted using the PROCESS macro for SPSS (Hayes, 2012).

**Results**

**Experimental Manipulation**

To examine the effect of the goals manipulation on flow, a one-way repeated measures ANOVA was conducted on FSS scores, revealing no significant effect, *F*(4,132)=1.81, *p*=.13, *ε*=.68, *ω*²=.023 (Table 1).

**QE percentage**

To test the effect of the goals manipulation on visual attention, a one-way repeated measures ANOVA was conducted on relative QE scores. There was found to be a significant main effect of goals, *F*(4,60)=3.47, *p*=.01, *ω²*=.132 (Table 1), however, Bonferroni corrected comparisons showed no significant pairwise differences (all *p*s > .05).

**Performance**

To examine the effect of goals on performance, a related samples Friedman’s analysis of variance by ranks was conducted. There was found to be no difference in performance scores, *χ2*(4)=8.04, *p*=.09, *V*=.479 (Table 1).

[Table 1 near here]

**Relationships**

Correlational analyses were conducted to examine the relationship between variables, independent of experimental manipulation. There was found to be a significant correlation between FSS and relative QE, *r*(125)=-.20, *p*=.03; between flow score and performance, *r*(174)=-0.47, *p*<.001; but no relationship between relative QE and performance, *r*(125)=-.01, *p*=.87. A mediation model with QE as the independent variable, performance as the dependent variable and flow score as the mediator was also tested to examine these relationships further. Based on 10,000 samples, bootstrapped confidence intervals indicated a significant indirect effect of .003, 95% CI= .000 to .006.

**Discussion**

This study aimed to investigate the cognitive mechanisms behind the flow state through assessing changes in visual attention during a self-paced sporting task. Based on flow theory (Csikszentmihalyi, 2000), our first hypothesis postulated that moderate goals would facilitate greater flow, however results did not indicate a difference in flow scores across conditions. In comparison to FSS scores obtained from a variety of tasks (Engeser & Rheinberg, 2008), values in this study were only in a mid-range (mean per item=3.12 on a 1-7 scale), indicating the task may not have been sufficiently absorbing. Higher scores on the FSS have been obtained in tasks that allowed a longer period of engagement (Engeser & Rheinberg, 2008). Similarly, previous flow research with basketball (Pates et al., 2002) has utilised three-point shooting which provides a more continuous task, whereas the necessarily stop-start nature of free throws may have prevented flow occurring.

Alternatively, goals given by the experimenter may have been superseded by the general task goal of scoring a basket (e.g., due to goal commitment/acceptance; Locke, Shaw, Saari & Latham, 1981). As a result the given goal may have had limited influence on the perceived challenge-skill balance. Despite the difficulties encountered here, it is our hope that these findings will contribute to successful methodologies in the future. More fruitful approaches may require stronger influences on the perceived challenge-skill balance and more continuous tasks to be suitably absorbing. For instance, given the propensity for flow in video games (Engeser & Rheinberg, 2008), virtual reality sporting environments may provide a highly engaging task, as well as allowing control over task constraints and hence better manipulation of the challenge-skill balance.

Our second hypothesis predicted that increased flow experience would relate to enhanced QE, which was partially supported. As the goals manipulation was unsuccessful, a correlation analysis indicated a significant relationship between the objective measure of attention (relative QE) and flow scores. Although the effect was small (*r*=.20), this is perhaps unsurprising when attempting to relate subjective experience to measurable changes in gaze behavior. Inferring possible causal relationships is difficult given the relational analyses, but mediation analysis may provide initial indications as to causal direction. A small indirect effect of QE on performance through flow score was found. Rather than flow leading to improved attention and subsequently performance, this suggests that optimal QE may have enhanced flow, creating better shooting performance. If this model is supported in future investigations, it may highlight the efficacy of deliberate focusing of visual attention for facilitating flow.

Despite difficulties with experimental manipulations, these results provide initial evidence that visual attention may play an important role in understanding the mechanisms responsible for flow. In particular changes in quiet eye, a behavior associated with top-down attention control (Vine & Wilson, 2011), may indicate that the extreme focus reported during flow (Jackson & Csikszentmihalyi, 1999) is due to goal-directed influences on attentional selection. Given the findings from mediation, future research may wish to further investigate attentional changes as a possible cause of flow. If this were to be supported, it would highlight the practical efficacy of deliberate focusing strategies for finding flow. Techniques like quiet eye training (Vine & Wilson, 2011) that promote goal-directed control may create an attentional state that is conducive to flow.

A key concern with this research approach relates to finding flow - an elusive experience - in a laboratory setting. Whilst sport research often focuses on more extreme, career-defining instances, Csikszentmihalyi (2000) discusses the importance of ‘micro’ flow, which can occur in everyday activities. The type of experience measured in this study is likely to be akin to ‘micro’ flow, but nonetheless may be representative of attentional changes across all instances of the state. Despite this experimental concern, the ability to manipulate flow in a laboratory setting is an important first step for developing practical applications and addressing mechanisms.

**Conclusion**

 In summary, this study utilised an experimental approach to the flow experience to assess changes in visual attention. Results indicated that the goal manipulation was unsuccessful, but the relationship between flow and relative QE provided tentative evidence for the importance of visual attention during flow. These findings suggest that experimental methodologies and direct measurement techniques may hold promise for better understanding flow in sport, and should continue to be developed, despite the inherent difficulty in capturing this elusive experience in the laboratory (Moller et al., 2010).

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Table 1: Mean (SD) flow, quiet eye, and performance scores across conditions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Target | 2 | 4 | 6 | 8 | 10 |
| FSS | 3.29 (0.78) | 3.01 (0.64) | 3.19 (0.89) | 3.00 (0.92) | 3.18 (0.99) |
| Performance | 3.44 (0.70) | 3.42 (0.75) | 3.36 (0.80) | 3.58 (0.66) | 3.44 (0.68) |
| QE % | 60.80 (25.47) | 60.90 (25.41) | 63.77 (28.04) | 76.72 (19.04) | 73.28 (19.15) |

Footnotes

1. The state of immersion refers to being fully present and absorbed in an experience and is a common occurrence during gaming. However, it differs from flow in that it can also occur in passive experiences (such as TV viewing) whereas flow requires an active engagement in the task.