QUANTIFYING EXTERNAL FOCUS OF ATTENTION IN SAILING BY MEANS OF ACTION SPORT CAMERAS

ADAPTED FROM –


- FIGURE 4.1. A sailor heading upwind wearing an action sport camera, while pulling the kicking strap.
ABSTRACT

The aim of the current study was twofold: (1) to validate the use of action sport cameras for quantifying focus of visual attention in sailing and (2) to apply this method to examine whether an external focus of attention is associated with better performance in upwind sailing. To test the validity of this novel quantification method, we first calculated the agreement between gaze location measures and head orientation measures in 13 sailors sailing upwind during training regattas using a head mounted eye tracker. The results confirmed that for measuring visual focus of attention in upwind sailing, the agreement for the two measures was high (intraclass correlation coefficient \( ICC = 0.97 \)) and the 95% limits of agreement were acceptable (between \(-8.0\%\) and \(14.6\%\)). In a next step, we quantified the focus of visual attention in sailing upwind as fast as possible by means of an action sport camera. We captured sailing performance, operationalised as boat speed in the direction of the wind, and environmental conditions using a GPS, compass and wind meter. Four trials, each lasting 1 min, were analysed for 15 sailors each, resulting in a total of 30 upwind speed trials on port tack and 30 upwind speed trials on starboard tack. The results revealed that in sailing – within constantly changing environments – the focus of attention is not a significant predictor for better upwind sailing performances. This implicates that neither external nor internal foci of attention was per se correlated with better performances. Rather, relatively large interindividual differences seem to indicate that different visual attention strategies can lead to similar performance outcomes.

KEY WORDS

Sailing;
Visual attention;
Eye-head orientation;
Motor control;
Environmental conditions
INTRODUCTION

The execution of a variety of motor skills have been shown to benefit from external foci of attention relative to internal foci of attention, that is, attention to movement effects or to body movements, respectively (e.g., Wulf, 2007a, 2007b; Wulf & Prinz, 2001). These motor skills range from simple balance tasks on, for instance, a stabilometer (McNevin, Shea, & Wulf, 2003; Shea & Wulf, 1999) to more complex tasks, such as simulated baseball batting tasks (Gray, 2004). Among more complex tasks, research has provided ample evidence that an external focus is advantageous for sports such as golf putting (e.g., Wulf & Su, 2007), basketball shooting (e.g., Zachry, Wulf, Mercer, & Bezdics, 2005) and dart throwing (e.g., Marchant, Clough, & Crawshaw, 2007).

Environmental predictability provides a basis for classifying these motor skills. That is, golf putting, basketball shooting and dart throwing are rather closed skills on the open/closed skill continuum and require consistent patterns of performance in stable and predictable environments (Schmidt & Lee, 2011). More specifically, in these tasks often the action-relevant objects are not in motion (e.g., golf ball) or self-controlled (e.g., dart arrow). Despite the extensive knowledge of the role of focus of attention on the skills outlined above, relatively little is known about the impact of an external focus of attention on performance in more open skills. In particular, it remains to be determined to what degree attentional focus contributes to skills that include complex body movements, objects in motion, or unpredictable environments (Raab, 2007), such as windsurfing or sailing.

Evidence supporting the assumption that an external focus of attention is also beneficial for skills that include complex body movements stems from work by Freudenheim, Wulf, Madureira, Pasetto, and Corrêa (2010) and Stoate and Wulf (2011). Both studies examined the effect of attentional focus instructions on swimming speed, both including internal and external focus instructions, and a control condition. The results indicated that external focus instructions (e.g., “putting the water back/down”) were associated with faster swimming times. This finding is in agreement with anecdotal evidence reported by Wulf (2007a) after practicing power jibes. In windsurfing, a power jibe requires well-timed body movement during its various phases accompanied by the precise timing of flipping the sail. In addition, windsurfers often have to adapt their balance to an unpredictable environment (e.g., choppy water, gusty wind). In such situations, windsurfers need to pay close attention to the water, the wind, their body and their surfboard. In her anecdotal report, Wulf argues to have preferred focusing on movement effects rather than focusing on body movements as this seemingly led to better performances (Wulf, 2007a, p. 35). In contrast to Wulf’s attentional strategy on the water, Schücker, Knopf, Strauss,
and Hagemann (2014) recently reported that internal foci of attention may not necessarily have a negative impact on performance, but might be advantageous instead. They examined 32 runners on a treadmill and found that in some situations an internal focus of attention (i.e., “how the body feels during exercise”) did not disrupt movement efficiency during running. Schücker et al. therefore questioned whether external foci of attention are more beneficial than internal foci under all circumstances.

Notably, several factors might contribute to successful performance in competitive sports. Among these factors are motor skills (e.g., van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008), sports equipment (e.g., Roberts, Jones, Harwood, Mitchell, & Rothberg, 2001), environmental conditions (e.g., Dicks, Davids, & Button, 2009) and perceptual cognitive skills (e.g., Mann, Williams, Ward, & Janelle, 2007) including visual search and attentional focus (for a comprehensive overview, see e.g., Pluijms, Cañal-Bruland, Kats, & Savelsbergh, 2013). While more and more research is being conducted to examine the factors associated with athletes’ decision processes during successful performance, research to date has inclined to focus on ball games (beach volleyball, e.g., Cañal-Bruland, Mooren, & Savelsbergh, 2011; tennis, e.g., Huys et al., 2009; soccer, e.g., Savelsbergh, van der Kamp, Williams, & Ward, 2005) rather than sports such as sailing (for exceptions, see e.g., Pluijms, Cañal-Bruland, Hoozemans, & Savelsbergh, 2015; Pluijms et al., 2013). In sailing, it is still relatively unexplored to what degree the aforementioned factors underpin decision-making in skilled performers.

Given the lack of research on the role of attentional focus in open skills (e.g., Raab, 2007) and hence continuously changing environments, the present study aimed at examining the relationship between focus of attention and performance in sailing. The underlying rationale to examine attentional focus in sports is the relationship between eye movements, attention and motor performance. It is well-established that attention can move independent of eye movements (Posner, 1980); yet, eye movements occur with an obligatory shift of attention (e.g., Deubel & Schneider, 1996; Shepherd, Findlay, & Hockey, 1986). In other words, “attention is free to move independent of the eyes, but eye movements require visual attention to precede them to their goal” (Hoffmann, 1998, p. 120). The partial interdependence between eye movements and attention allows researchers to predict performance by measuring eye movements when examining expertise differences. It is therefore that focus of attention is often conceptualised and quantified by visual gaze (e.g., Doshi & Trivedi, 2009; Land, 1992; Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008; Proudlock & Gottlob, 2007; Schmitow, Stenberg, Billard, & Hofsten, 2013; Yu & Smith, 2013), typically measured using head mounted eye-trackers.

Vansteenkiste, Cardon, Philippaerts, and Lenoir (2015) recently denoted the challenging and time-consuming task of collecting gaze behaviour with head-mounted eye-
trackers, reflecting a disadvantage for applying such methods in daily practice in sports. For this matter, we were interested in quantifying sailors’ visual foci of attention by means of action sport cameras (i.e., based on sailors’ head orientation) instead of head mounted eye trackers (i.e., based on sailors’ head-eye orientation). Though the use of action sport cameras has the advantages of being easier to handle, less time consuming and cheaper – therefore being very attractive to coaches, athletes and sports practitioners alike – it might also result in significantly less accurate and precise estimates of attentional focus. To test this, in a first step, we validated the use of action sport cameras as a method to capture attentional focus. To this end, we calculated measures of agreement between gaze location measures and head orientation measures using footage of a head mounted eye tracker (for similar approaches and studies, see Land & Tatler, 2001; Proudlock & Gottlob, 2007) during upwind sailing in a laser dinghy. We did so in a representative performance environment so that sailors had full visual information and the opportunity to perceive information to guide their goal-directed actions allowing them to demonstrate functional responses likewise they would in the actual performance context (see e.g., Brunswik, 1956; Pinder, Davids, Renshaw, & Araújo, 2011; Pluijms et al., 2013). One of the benefits of a representative performance environment is that achievement is based on comparable information sources (i.e., perceptual cues or other stimuli) – and athlete’s responses remain the same – to those in a competitive performance environment. Achievement – in this case – refers to the adaptation of an organism to a specific environment (Brunswik, 1956).

In a second step, we tested whether an external focus of attention may relate to better sailing performance by asking 15 skilled sailors to each sail four trials upwind as fast as possible while measuring attentional focus by means of action sport cameras. According to the “constrained action hypothesis” (see McNevin et al., 2003; Wulf, 2007b), an external focus of attention facilitates motor performance, because it promotes automatic control of movement. “Adopting an external focus allows unconscious, fast, and reflexive processes to control the movement, with the result that the desired outcome is achieved almost as a by-product” (Wulf, 2007b, p. 9). In contrast to an external focus, adopting an internal focus of attention is associated with more conscious control of movement, thereby constraining “normal” automatic control processes. To test whether an external focus of attention may relate to better performance in open skill sports, we chose upwind sailing as it is considered an open skill including continuous movements such as tacking, hiking, and trimming. Tacking is defined as turning the “boat sharply into the wind from a close-hauled position, so that it momentarily points straight into the wind with sail(s) flapping and then continues until its sail(s) fill again with wind from the opposite side” (“Glossary of sailing terms,” 2007, p. 1079). Hiking stands for “sailing the dinghy more or less upright, with feet hooked under foot straps [. . .], body weight supported about mid-thigh by the side deck [. . .] and upper body
extended to greater or lesser degree over the windward side” (“Glossary of sailing terms,” 2007, p. 1078.). Trimming is making fine adjustments to the main sail (see “Glossary of sailing terms,” 2007). To be able to link attentional focus measures to sailing performance, we captured performance, operationalised as boat speed in the direction of the wind (i.e., dependent variable), and environmental conditions such as wind speed using marine electronics (i.e., GPS, compass, wind meter).

**STEP 1. CAN ACTION SPORT CAMERAS BE USED TO PROVIDE A VALID MEASURE OF ATTENTIONAL FOCUS?**

We were interested in quantifying sailors’ visual foci of attention by means of action sport cameras (i.e., based on sailors’ head orientation) instead of head mounted eye trackers (i.e., based on sailors’ head-eye orientation). To this end, we calculated measures of agreement between gaze location measures and head orientation measures using footage of a head mounted eye tracker in a representative task and environment, namely upwind sailing in a laser dinghy.

**METHODS**

**PARTICIPANTS**

We used previously collected eye tracking data of 13 skilled sailors who were participants in an experiment examining visual search, movement behaviour and boat control during the windward mark rounding (see Pluijms, Cañal-Bruland, Hoozemans, & Savelsbergh, 2015).

**APPARATUS**

To validate the use of action sport cameras to quantify focus of attention in sailing, we used video footage of a head mounted eye tracker. A head mounted eye tracker (Applied Science Laboratories) simultaneously records data from two cameras: (1) an eye camera that records the eye being tracked and (2) a scene camera that records the environment concurrently being observed by the sailor. Head mounted eye trackers are considered the gold standard for the assessment of visual search behaviour in the field. We cannot rule out that participants may have felt constrained by wearing the head mounted eye tracker, although during the debriefing most participants reported to have experienced the eye tracker as unobtrusive. That being the case, we were especially interested to validate the use of action sport cameras, since they have the
advantage of being easier to handle for participants.

PROCEDURE

In approaching the windward mark roundings that were analysed and reported in Pluijms, Cañal-Bruland, Hoozemans, and Savelsbergh (2015), participants had also sailed upwind legs without and with opponents during regular training sessions wearing the head-mounted eye tracker. These video samples were used to calculate the agreement between gaze location measures (interleaving eye and scene camera) and head orientation measures (only using the scene camera).

VARIABLES

The measurement agreement between the two methods was based on the viewing percentage to either internal or external areas of interest during upwind speed trials. Internal areas of interest were defined as the sail, the deck or trimming lines. External areas of interest were defined as all other locations and were complementary to internal areas of interest (i.e., water, clouds, opponents, horizon).

DATA ANALYSIS

We coded each frame twice (i.e., using both methods) to either an internal or external area of interest. First the frame was coded internally or externally using the precise gaze location of the head mounted eye tracker (i.e., head-eye orientation). Second, the same frame was coded internally or externally using the centre of the scene image (i.e., only sailors’ head orientation). We calculated the intraclass correlation coefficient (ICC) between the two measurements, quantified the measurement error using the 95% limits of agreement, and visualised the heteroscedasticity of the errors using a Bland and Altman plot (e.g., de Vet, Terwee, Mokkink, & Knol, 2011; Nevill, 1996; Nevill & Atkinson, 1997). For each participant, we compared 1000 frames (i.e., ± 35–60 s depending on the quality of the eye-tracking footage) during upwind sailing. This time-window was the minimum amount of frames in which every participant only sailed upwind as fast as possible in one stretch, and hence no other situations were included (such as the start or windward mark rounding). However, we cannot rule out that participants may demonstrate different visual search behaviour during a longer period of time. We continued our analyses with the viewing percentage to external areas of interest because an external focus directed to movement effects has been shown to be advantageous.
Difference in viewing % to external areas of interest (EH - H)

Mean viewing % to external areas of interest
- **FIGURE 4.2.** A Bland-Altman plot showing the sailors’ mean viewing percentages to external areas of interest (averaging the viewing percentages of both measurement methods for each participant), plotted against the differences between the two measurement methods for the estimated viewing percentages to external areas of interest. As regards the limits of agreement: The middle dotted line is the mean difference (3.2% ±5.7), the upper dotted line (95%) is the mean difference +1.96 × SD (14.6%), and the lower dotted line (−95%) is the mean difference −1.96 × SD (−8.0%); EH: eye-head orientation; H = only head orientation.
RESULTS

The mean viewing percentage (for all 13 participants) to external areas of interest according to the head mounted eye-tracker (eye-head orientation) was 53.4% ($SD = 26.9$); the mean viewing percentage to external areas of interest based on the centre of the scene image was 50.2% ($SD = 28.0$) (see also Table 4.1). The agreement (intra-class correlation coefficient; two-way mixed; absolute agreement) between the two measurement strategies for the 13 participants was high (de Vet et al., 2011), $ICC = 0.97$, 95% confidence interval (CI) [0.90 to 0.99], $p < 0.001$. The 95% limits of agreement for the percentage viewing time to external areas of interest were between −8.0% and 14.6% ($SD = 5.7$%), and the Bland and Altman plot showed homoscedastic errors (see Figure 4.2), indicating a small positive offset for the head orientation measures compared to the eye-head orientation measures.

Table 4.1. The viewing percentages to external areas of interest for the two measures based on the eye-tracking footage; in the fourth column the differences between the two measurement methods per participant.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Viewing % to external areas of interest – using head-eye orientation</th>
<th>Viewing % to external areas of interest – using only head orientation</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.2</td>
<td>42.5</td>
<td>-2</td>
</tr>
<tr>
<td>2</td>
<td>67.7</td>
<td>61.0</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>68.5</td>
<td>58.2</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>93.1</td>
<td>91.0</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>25.0</td>
<td>21.4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>69.1</td>
<td>53.6</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>23.7</td>
<td>21.9</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>15.7</td>
<td>13.6</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>25.7</td>
<td>19.6</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>81.0</td>
<td>86.3</td>
<td>-5</td>
</tr>
<tr>
<td>11</td>
<td>34.7</td>
<td>31.5</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>61.6</td>
<td>58.9</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>88.4</td>
<td>93.3</td>
<td>-5</td>
</tr>
<tr>
<td>Mean</td>
<td>53.4</td>
<td>50.2</td>
<td>3.2</td>
</tr>
<tr>
<td>SD</td>
<td>26.9</td>
<td>28.0</td>
<td>5.7</td>
</tr>
<tr>
<td>SE Mean</td>
<td>7.5</td>
<td>7.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

To help the reader interpret these limits, if a sailor’s estimated viewing percentage is, for example, 20.0% to external areas of interest (coded by only using the centre of the scene image), it is possible that this sailor could gaze an estimate as low as 12.0% (20.0% − 8.0%), or as high as 34.6% (20.0% + 14.6%) to external areas of interest (using the method based on eye-head
orientation). From these measurements errors we conclude that the validity of the measurement strategy of assessing the visual focus of attention using only an action sport camera (i.e., based only on sailors’ head orientation) is acceptable (e.g., de Vet et al., 2011), at least for determining visual focus of attention to our defined internal or external areas of interest during upwind sailing.

STEP 2. IS AN EXTERNAL FOCUS OF ATTENTION ASSOCIATED WITH FASTER UPWIND SAILING PERFORMANCE?

In order to test and apply our new method we quantified focus of attention by asking 15 differently skilled sailors to sail upwind as fast as possible. We were interested to examine whether an external focus of attention was associated with a faster performance in upwind sailing.

METHODS

PARTICIPANTS

Fifteen participants ($M = 27.7, SD = 14.9$ years; 11 males, 4 females) volunteered to take part in the experiment. Participants were recruited via the Royal Netherlands Yachting Union and InnoSportLab The Hague. Seven expert sailors either sailed in the highest Dutch squad (professional level) or were members of the national youth teams of the Netherlands (talent teams; under 21 years of age). The remaining eight intermediate sailors were defined as all sailors with- out sailing experience at an international level, and reported to sail regattas in a laser on club-level once a week. The ethics committee of the local institution approved the experiment, and participants gave written consent prior to participation.

APPARATUS

Participants performed upwind speed trials in a laser dinghy with a laser standard sail. The same dinghy with the same laser standard sail was used for every participant in our experiment, because we only measured with winds smaller than 25 knots (i.e., to safeguard the equipment). All participants (including the four females) were experienced sailing a laser with a standard sail. Note that during Olympic races and World Championships women sail a laser radial (i.e., shorter mast and reduced sail area), allowing lightweight sailors to sail in heavy winds (also above 25 knots). Visual focus of attention was recorded with an action sport camera (video camera glasses; CAMsports Coach, 720 p, 30 fps). A Pi Garda logger (Cosworth Electronics) with compass
(Tacktick) and wind meter (Tacktick), positioned at the bow of the laser, was used to log the dinghy’s position, speed (GPS, 5 Hz), wind direction, and wind speed (for a similar approach, see Pluijms, Cañal-Bruland, Hoozemans, & Savelbergh, 2015).

PROCEDURE

The experiment was executed at two test locations in the Netherlands on two different days. The two test locations were without strong tidal currents and similar with respect to larger landmarks in the vicinity. On arrival, participants received instructions about the experiment, that is, sailing upwind as fast as possible. Participants were instructed to perform two upwind speed trials on port tack and two upwind speed trials on starboard tack (i.e., four upwind speed trials per participant; 60 trials in total). Port is the side of a boat that is on the left when one is facing forward, starboard is the side of a boat that is on the right when one is facing forward. Participants were tested individually, each speed trial lasted one minute. After participants had finished the experiment, they were debriefed individually.

OUTCOME VARIABLE

The outcome variable was assessed by the component of the boat speed (in knots over ground) in the direction of the wind (also called Velocity Made Good upwind: VMG). A boat cannot sail directly upwind. Therefore, sailors – when trying to sail upwind as fast as possible – need to balance between gaining speed, for example, by making optimal use of the wind and shortening the travelled distance by keeping the boat close to the wind direction. That is, in upwind sailing, when steering too much into the wind the boat may lose speed, but travel a shorter distance; instead, when steering away from the wind, the boat may gain speed, but travel a larger distance.

PREDICTOR

External visual focus of attention

Visual focus of attention was defined as the percentage of viewing time to either internal or external areas of interest. Visual focus of attention was coded frame-by-frame (with 30 frames per second and trials of 60 s = 1800 frames per trial) based on the centre of the scene image of the action sport camera. Internal areas of interest were defined as the sail, the deck or trimming lines. External areas of interest were defined as all other locations (i.e., water, clouds, horizon). For further analysis, we used the total number of frames coded as “attention to external areas of
“interest” as a percentage of the total number of frames within a trial (1800 frames).

**COVARIATES**

**Environmental conditions**

Wind speed was handled as a covariate in the analyses and defined as the average wind speed for each trial.

**Expertise level**

Expertise level was handled as a covariate in the analysis and defined as either expert or intermediate sailor.

**DATA ANALYSIS**

First, multicollinearity among the covariates was explored. The covariates expertise level and wind speed were highly correlated ($\rho = -0.671$, $p < 0.001$). That is, expert sailors sailed with an average wind speed of 18.9 knots ($SD = 3.5$) compared to intermediate sailors who sailed with an average wind speed of 12.7 knots ($SD = 5.2$). To prevent the negative effect of multicollinearity in the multiple regression model, expertise level was excluded from further analysis because wind speed had the highest correlation with the outcome variable VMG ($r = 0.867$, $p < 0.001$) (see also Tu & Gilthorpe, 2011).

Secondly, generalised estimating equation (GEE) regression analyses were performed to examine whether visual focus of attention predicted performance. GEE is a regression analysis method that can be used when participants are measured repeatedly and accounts for the dependency of the repeated measures (Liang & Zeger, 1993). The working correlation structure for the GEE regression analyses was set to exchangeable and the regression analyses were conducted using IBM SPSS Statistics 22.0.0.0 (IBM Corp., 2013). First, we used a simple regression to examine the association between viewing percentage to external areas of interest and performance (VMG). Second, we added wind (knots) as a covariate. In case the regression coefficient of viewing percentage to external areas of interest changed more than 10% (Greenland, 1989; Kleinbaum, Kupper, Muller, & Nizam, 1988) when adding wind to the regression model, this indicated that wind substantially biased the association between viewing percentage to external areas of interest and performance and was hence kept in the regression model. Finally, we checked whether the interaction between viewing percentage to external areas of interest and wind modified the association between viewing percentage to external areas of interest
- FIGURE 4.3. The viewing percentage to external areas of interest of all trials (n = 59) plotted against the VMG in knots; wind speed day 1: 19.9 ± 0.9 knots; wind speed day 2: 9.1 ± 1.5 knots.
and performance. One trial was excluded from the GEE analyses because of missing GPS data; therefore, no performance measure (VMG) for this trial could be calculated. After exclusion of the aforementioned trial, 59 trials were analysed in the GEE analyses.

RESULTS

The results of the regression analyses are summarised in Table 4.2. Simple regression showed that the viewing percentage to external areas of interest was not a significant predictor of performance (VMG) (see model 1, Table 4.2). Although wind (knots) appeared to considerably (>10%) change the crude regression coefficient of viewing percentage in the multiple regression, the adjusted regression coefficient of viewing percentage was still not significant (B = 0.001, 95% CI [−0.006 to 0.008]) (see model 2, Table 4.2). Also, wind appeared not to modify the association between viewing percentage to external areas of interest and performance as the interaction between wind and viewing percentage to external areas was not significant (see model 3, Table 4.2). As reported in Table 4.2, wind by itself, of course, appeared to be significantly associated with performance. Additionally, in Figure 4.3 we plotted the viewing percentage to external areas of interest of all trials (n = 59) plotted against the VMG in knots illustrating the large interindividual differences divided over the two measurement days.

Table 4.2. Performance (VMG) predicted as function of the viewing percentage to external areas of interest and environmental conditions (wind) using generalised estimating equations (GEE). Presented are the regression coefficients (B), their standard errors (SE B), 95% confidence interval (CI) and P-value. The results are presented with only viewing percentage as predictor (model 1), with wind included as covariate (model 2), and with the interaction between viewing percentage and wind (model 3).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
<td>Lower limit 95% CI</td>
</tr>
<tr>
<td>Constant</td>
<td>2.34</td>
<td>0.36</td>
<td>1.63</td>
</tr>
<tr>
<td>Viewing % to external areas of interest</td>
<td>0.004</td>
<td>0.005</td>
<td>-0.005</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.18</td>
<td>0.44</td>
<td>-1.04</td>
</tr>
<tr>
<td>Viewing % to external areas of interest</td>
<td>0.001</td>
<td>0.004</td>
<td>-0.006</td>
</tr>
<tr>
<td>Wind (kts)</td>
<td>0.17</td>
<td>0.24</td>
<td>0.13</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.39</td>
<td>0.62</td>
<td>-1.60</td>
</tr>
<tr>
<td>Viewing % to external areas of interest</td>
<td>0.005</td>
<td>0.008</td>
<td>-0.01</td>
</tr>
<tr>
<td>Wind (kts)</td>
<td>0.19</td>
<td>0.001</td>
<td>0.11</td>
</tr>
<tr>
<td>Viewing % to external areas of interest * wind (kts)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>
DISCUSSION

The purpose of the current study was to validate the use of action sport cameras for quantifying focus of visual attention in sailing and to apply this method to examine whether an external focus of attention is related to better performances in upwind sailing. To assess the validity of this novel quantification method, we first calculated agreement measures between gaze location and head orientation measures using footage from a head mounted eye tracker. The ICC of the comparison of head orientation versus eye-head orientation was high, and the limits of agreement were acceptable, indicating that the action sport camera is a valid tool to assess attentional focus in upwind sailing. To the best of our knowledge, this is the first study to validate the use of action sport cameras in order to quantify visual focus of attention in sport settings. Coaches and sailors may use this user-friendly and practical tool to measure visual focus of attention instead of using a head mounted eye tracker, often challenging and time-consuming to operate. Moreover, (waterproof) action sport cameras are relatively inexpensive and hence offer an excellent opportunity to measure multiple sailors simultaneously and repeatedly within unpredictable environments. It follows that this procedure makes a novel contribution to applied sport-scientific research in general and may be of service to further our understanding of perceptual expertise also in other open skills.

In a second step, we applied the validated method to quantify focus of visual attention by asking 15 differently skilled sailors to sail upwind as fast as possible. We were interested to examine whether an external focus of attention was associated with better performances in upwind sailing. A total of 59 upwind speed trials were analysed. Our results showed that focus of attention did not predict sailing performance. This applied to both external and internal foci of attention. Obviously, our findings are not in line with extensive research showing positive effects of external foci of attention on performance in closed skills (e.g., Wulf & Prinz, 2001; Wulf, 2007a, 2007b). A potential explanation might be that for many complex motor actions, athletes also rely on perceptual information picked-up via other senses, such as touch (Pluijms, Cañal-Bruland, Bergmann Tiest, Mulder, & Savelsbergh, 2015), the auditory (e.g., Koelsch, Schröger, & Tervaniemi, 1999) and the vestibular systems (for an overview, see Gray, 2008). Hence, our findings do not necessarily contradict positive effects of external foci of attention on performance in closed skills (e.g., Wulf & Prinz, 2001; Wulf, 2007a, 2007b), they rather complement and extend these by focusing on open skills in unpredictable environments. If anything, our findings seem to question the generalisability of beneficial effects of external foci of attention to more open skills. Given that only very few researchers have undertaken efforts to quantify visual focus of attention in less predictable environments (for exceptions, see Abdollahipour, Wulf, Psotta,
& Palomo Nieto, 2015; Freudenheim et al., 2010; Schücker et al., 2014; Stoate & Wulf, 2011), more research is needed to establish whether a particular focus of attention is especially effective in enhancing performance in open skills.

Furthermore, we argue that a possible explanation for our findings may reside in the variance of viewing percentages to external areas of interest between participants (Figure 4.3). In other words, large interindividual differences may account for the finding that focus of attention did not predict sailing performance. This variance may be seen as echoing adaptive behaviour during exploration of the performance context (e.g., Davids, Button, & Bennett, 2008). For example, on the same day with approximately the same wind speeds (9.1 ± 1.5 knots) one participant had viewing percentages to external areas of interest ranging from 11.4% to 87.3% with a VMG of 2.3 ± 0.4 knots (averaged across four trials), whereas another participant had viewing percentages to external areas of interest ranging from 8.6% to 38.7% with a VMG of 2.2 ± 0.4 knots (averaged across four trials). In other words, even though wind conditions were identical for these two sailors and VMG was practically identical for all trials, the foci of attention between trials differed largely. In fact, the data plotted in Figure 4.3 nicely illustrates that using different foci under the same circumstances can lead to same performance outcomes, and also that using similar foci under the same circumstances can lead to differences in performance. The role of degeneracy might help to explain the differences in anticipatory behaviour. Degeneracy is defined as “the ability of elements that are structurally different to perform the same function or yield the same output” (Edelman & Gally, 2001, p. 13763) For example, body movements may differ, that is, many different patterns of muscle contraction may yield equivalent outcomes; or with reference to upwind sailing, information obtained from one sensory modality (e.g., tactile information from legs and feet) may overlap that obtained by others (e.g., visual information from the sail) (Edelman & Gally, 2001).

In addition, the interaction coefficient between viewing percentage to external areas of interest and wind speed was not significant. This indicates that sailors did, for example, not focus more to external areas of interest when sailing with higher wind speeds than with lower wind speeds. This is certainly interesting because it could be expected that with higher wind speeds sailors may be more likely to focus externally, for example, to pick-up wind shifts from the waves well in advance. We refrain from over-interpreting this non-significant interaction, given that we have not systematically manipulated the environmental constraints. However, we deem it an important endeavour for future studies to systematically examine the impact of various wind intensities and expertise levels to prevent multicollinearity between covariates and to further improve our understanding of the relationship between sailors’ focus of attention, environmental constraints such as wind, and performance.
In conclusion, our results revealed that in constantly changing environments, attentional focus does not predict better upwind sailing performances. This result may be explained by relatively large interindivdual differences. It seems that different attentional focus strategies can lead to similar performance outcomes in sailing. In this respect, coaches and athletes are advised to train upwind speed trials under as many as possible different circumstances (e.g., many different locations) to enforce athletes to actively explore the manifold situational constraints, such as wind direction, currents and opponents’ actions (for a similar example during the start in sailing, see Araújo et al., 2015). A second main result of our study is that we have shown that action sport cameras are a valid method to quantify visual focus of attention in sport settings. Researchers, coaches and athletes can therefore use action sport cameras in the practical field to measure visual focus of attention in various situations, including open skills in unpredictable environments.