

RELATIONSHIP BETWEEN AMOUNT OF VARIABILITY IN EYE MOTION AND PERFORMANCE IN SIMULATED SAILING

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ABSTRACT

The start regatta is a key moment in the race. The aim of this research was to know the relationship between variability of eye motion and the performance achieved in simulated regatta start. Thirty young sailors were distributed among three performance groups: Optimum Performance Group – OPG– (N=11), Middle Performance Group –MPG– (N=13) and Low Performance Group–LPG–(N=7), considering the distance above or below the start line. A system of measurement, which integrates the VSail-Trainer® simulator and the Eye Tracking System™, was used. The vertical and horizontal positions of boat at start, the velocity of boat, and the mean velocity on start regatta were measured. The standard deviations of displacement and velocity of eyes were registered. From the results it is emphasized that OPG got a closer position to the start line than MPG and LPG ($p = .001$; $d = 1.29 / p = .001$; $d = 3.90$). Best located sailors at the start line show a negative correlation between boat mean velocity and the variability on eye velocity ($r = -.718$; $p = .013$). In conclusion a greater amount of variability in eye motion is related to a worse performance at the start regatta.

Key Words: variability, eye motion, simulated regatta, performance

RELACIÓN ENTRE LA CANTIDAD DE VARIABILIDAD EN LOS MOVIMIENTOS OCULARES Y EL RENDIMIENTO EN NAVEGACIÓN SIMULADA

RESUMEN

La salida en una regata de vela es un momento clave de la competición. El objetivo de esta investigación fue identificar la relación entre la variabilidad de los movimientos oculares y el rendimiento logrado en una salida de regata simulada. Treinta regatistas jóvenes fueron distribuidos en tres grupos: Grupo de Rendimiento Óptimo –OPG– (N=11), Grupo de Rendimiento Medio –MPG– (N=13) y Grupo de Rendimiento Bajo –LPG– (N=7), considerando la distancia por encima o por debajo de la línea de salida. Se utilizó un sistema de medida integrado por un simulador de navegación VSail-Trainer® y el Sistema de seguimiento de la mirada Eye Tracking System™. Se registró la posición horizontal y vertical del barco en la salida, su velocidad y la velocidad media alcanzada en la salida. Se calcularon las desviaciones estándar de los desplazamientos y velocidades de los ojos. En los resultados se destaca que el OPG logró una posición más cercana a la línea de salida que el MPG y el LPG ($p = .001$; $d = 1.29 / p = .001$; $d = 3.90$). Los regatistas mejor situados en la línea de salida muestran una correlación negativa entre la velocidad media de la embarcación y la variabilidad en la velocidad de los ojos ($r = -.718$; $p = .013$). En conclusión, una mayor cantidad de variabilidad en el movimiento de los ojos se relaciona con un peor rendimiento en la salida de regata.

Palabras clave: variabilidad, movimientos oculares, regata simulada, rendimiento

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INTRODUCTION

Athletes' visual behaviour and its relationship with sport performance has been a recurrent topic of study in the area of learning and motor control. Several researches have been carried out in different sports with the aim of determining how the visual strategy used by athletes can be a success determinant factor. In those actions involving the execution of a motor behaviour in a short period of time and/or, the need to respond to an opponent, the efficient use of visual sense is a prime objective in order to get optimum anticipation time.

Researches carried out using record and analysis of corneal reflection with head mounted glasses, have proved that the amount of visual fixations and time devoted to them on the locations available on the scene are the variables to take into account to understand whether an athlete has an efficient visual strategy. There are some studies which also consider saccades movements and micro saccades as factors to be taken into account in the study of visual search strategy (Martinez-Conde & Macknik, 2008; Martinez-Conde, Macknik, Troncoso & Hubel, 2009).

In that sense, it seems the distinction between expert and novel visual behaviour is not clear yet. Results of eye-tracking measures demonstrated that experts made fewer fixations and had longer fixation durations than non-experts during sport-specific tasks (Ruiz, Peñaloza, Navia & Rioja, 2013; Piras, Lobietti & Squatrio, 2010; Davids, Savelsbergh, Bennett & Van der Kamp, 2002). However, authors as Afonso, Garganta, McRobert, Williams & Mesquita (2012), or Roca, Ford, McRobert & Williams (2011), state that more experienced athletes carry out more visual fixations of shorter duration.

According to this approach, visual behaviour analysis, in a sport like sailing, raises an emerging interest in view of the latest researches carried out, both in real and simulated sailing conditions. Pluijms, Cañal-Bruland, Kats & Savelsbergh (2013) and Pluijms, Cañal-Bruland, Hoozemans & Savelbergh (2015), performed an analysis of visual behaviour in a real sailing situation. They found out that a sailor achieved better performance when fixing his or her gaze on the tangent point of the mark, while rounding the windward mark. Similarly, the authors claim that skilled sailors look for relevant information outside the boat and on the sea (wind direction, waves and currents) when the situation occurs without an opponent. If performed with an opponent, the behaviour is the opposite, with a higher number of fixations inside the boat and a more focused visual behaviour.

Santos, Dias, Araújo & Mendes (2014), acknowledging the importance of the start regatta as a key moment for being successful in the race, studied the effect of verbal instructions and video visualization during start regatta, finding

out that the visualization had a greater influence over the performance achieved.

Walker (2015), compared sailors visual behaviour in simulated races with radio-controlled boats, concluding that top ranking sailors performed fewer numbers of fixations on the boat but, of longer duration.

Manzanares, Menayo, Segado, Salmerón & Cano (2015), moved forward in the research of sailors' visual behaviour on simulated regatta, using an analysis of recurrences with the aim of determining visual behaviour pattern as an additional variable to the number and duration of fixations. These authors suggest, from the results of the study, that top raking sailors perform a more active perceptive-visual strategy than bottom raking sailors.

From the last investigation, and within the area of investigating about eye movement patterns, this study aims to solve this research problem: is there any relationship between eye movement and eye velocity and the performance achieved in simulated regatta? Up to now, researches have not included analysis on those variables, which can be registered with eye tracking system. More precisely, we wonder whether the following situation would be possible: an increase in the amount of variability of movements and velocity of eye movement could be linked to the level of performance achieved in a simulated start regatta.

This relationship has been studied in relation to human movement kinematics and kinetics in different motor skills, suggesting that an increase in the amount of variability relates to a decrease in motor performance in short-term with loss of accuracy, coordination and effectiveness (Van Emmerik & Van Wegen, 2000). However, evidences on researches about the amount of variability of eye movement and a possible relationship with sport performance have not been found. That is why the following hypothesis is established: a greater amount of variability on eye movements will be linked to a lower performance level, since this variability is associated to a strategy based on the perception of stimuli present on the environment on the part of sailors, which would lead to a worse boat handling.

METHOD

Participants

Thirty sailors ($N = 30$) were selected as participants from the Optimist sailing class, aged 11.9 ± 1.9 years old and sailing experience of 3.3 ± 1.9 years. All participants gave their consent to participate in the research as well as their parents or legal guardians did. The research was approved by the Ethics Committee of the Catholic University of Murcia.

As an establishment group criterion, the boat position at the moment of start signal in the vertical axis was taken as a grouping value. It is considered

that a greater adjust to value zero in this axis is understood as a closer position to the start line.

For group distribution, it was considered that length Optimist boat (2,3 m.), located on the start line, should be inclusion or exclusion criterion for each group, considering " ≤ 1 ", "1-3" y " ≥ 3 " length above or below start line, obtaining three performance groups: Optimum Performance Group (OPG $N=11$), Middle Performance Group (MPG $N=13$), and Lowest Performance Group (LPG $N=7$). Although any distance exceeding this line is considered as void start, that means ineffective. We have considered that adjusting the boat to the above mentioned line is a better performance variable than effectiveness, to value performance level of the sailors in the start.

Experimental procedure and data collection

Participants performed a protocol in order to familiarize with sailing simulator VSail-Trainer®. It is a virtual simulator with a partially immersive hull boat, in which the sailor can act similarly as would be done in a real sailing situation. The main difference is that the race is screened in front of the simulator (2D) using a software (Figure 1).

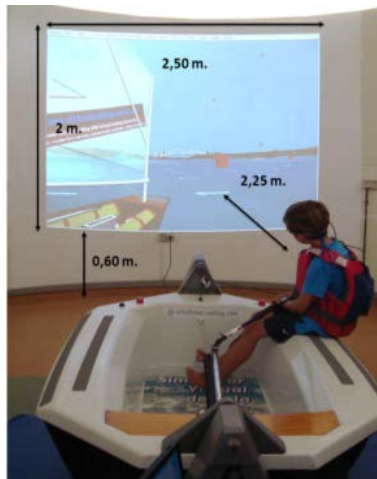


FIGURE 1: Sailor handling the boat during data collection.

The familiarization process was performed in two different phases of three minutes each: firstly a free navigation and secondly, a guided navigation through an audio file which indicated the sailor the manoeuver to be executed every time. Next, a start regatta with 5 minutes protocol was carried out, when all the measurements were taken. Participants' position in this start regatta should be as close as possible to the start line, delimited by two buoys, as it happens in a real situation. The race was shaped with 12 knots stable wind and

5 opponents, who had previously been planned and classified according to their proximity to the start line at the moment of start signal. Connecting the hull and the computer through simulator software, the vertical and horizontal position at start, the velocity of boat at start, and the mean velocity in race were registered, with a frequency of data collection of 30Hz.

Simultaneously, eye tracker (MobileEye™) registered sailors' pupil movement on pixels in vertical and horizontal axis in the sailing scene screened in front of the boat. Gaze behaviour data were collected at 30 frames per second (30 Hz) and analysed frame by frame.

Statistical analysis

Kolgomorov-Smirnov test showed the lack of normality in data distribution, therefore Kruskal Wallis test was used to identify whether position at the moment of start signal, which has served to establish three groups, affected the rest of performance variables. A significance value of $p \leq .001$ was determined. Rho Spearman correlation was used in order to analyse relationship between amount of variability on eye movement and performance achieved during the start regatta. Cohen's d was applied to calculate effect size, taking values of $d = .20$ as small, $d = .50$ as moderate and from $d = .80$ as big (Cohen, 1988).

RESULTS

Participants' positions at the moment of start signal determine performance achieved during this part of the regatta. Figure 2 shows boat positions at the start moment, which were used to distribute sailors in three different groups-OPG, MPG and LPG-.

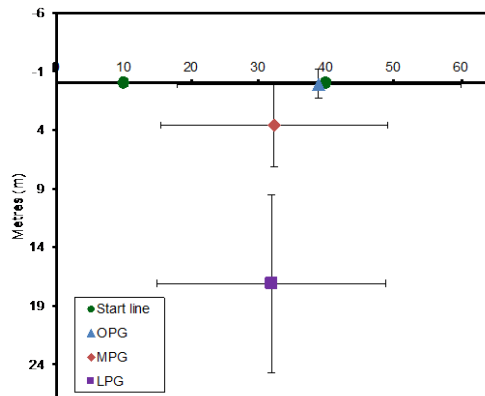


FIGURE 2: Boat positions at the moment of start signal, horizontal and vertical axis.

From the registered variables, the only one showing significant differences among the groups is boat position in the start moment (Table 1), where OPG

got a closer position to the start line than MPG and LPG ($p = .001$; $d = 1.29$ / $p = .001$; $d = 3.90$). MPG also got a closer position to the line than LPG ($p = .001$; $d = 2.96$). Horizontal position results of the boat show that all the participants were able to locate within 30 meters delimited in the horizontal axis by start buoys (Table 1). Neither velocity of the boat reached in the start by the participants of the three groups, nor the average velocity registered during the start protocol highlight significant differences (Table 1). However, the latter does show a tendency to increase among the groups which were further from the start line (MPG and LPG) regarding the group with the best location (OPG).

With respect to variability in eye movements and eye velocity, expressed through standard deviation of temporal series captured during 5 minutes of sailing, it would be worth pointing out that, although differences have not been found out, there is an evident tendency which shows a greater amount of variability as participants move away from start line in that precise moment of the regatta (Table 1).

TABLE 1

Results obtained in simulated start regatta in relation to the position got in the start.

	OPG	MPG	LPG
	Boat data		
	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>
Vertical position at start (<i>m</i>)	0.1 ± 1.26*	3.58 ± 3.60*	17.07 ± 7.59*
Horizontal position at start (<i>m</i>)	38.85 ± 21.08	32.26 ± 16.78	31.82 ± 16.87
Velocity at start (<i>km/h</i>)	2.82 ± 1.00	2.59 ± 1.03	2.81 ± 0.84
Mean velocity in regatta (<i>km/h</i>)	2.72 ± 0.43	2.76 ± 0.54	2.79 ± 0.63
	Eye motion variability (pixels)		
Horizontal eye displacement (<i>SD</i>)	97.66	93.25	89.04
Vertical eye displacement (<i>SD</i>)	89.39	85.85	79.08
Horizontal eye velocity (<i>SD</i>)	24.86	24.5	23.94
Vertical eye velocity (<i>SD</i>)	26.53	23.91	22.51

* $p \leq .001$

Regarding eye movements, Figure 3 shows an example from one participant, who was chosen randomly.

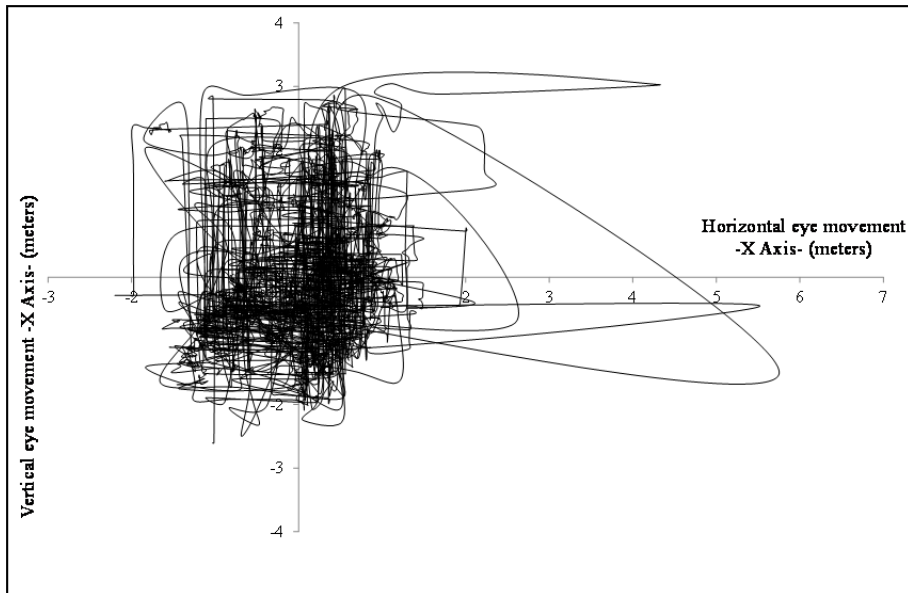


FIGURE 3: Eye movement done on the screen during the five minutes of the start.

In order to investigate the relation between the amount of variability of eye displacements and velocity and the performance achieved in the start regatta an intra-group correlation analysis was carried out, taking into account variables of boat behaviour and that eye behaviour. The group which was best located at the start line (OPG) shows a negative correlation between average mean velocity reached during the race and the amount of variability registered in eye velocity ($r = -.718$; $p = .013$).

The intermediate group (MPG) shows positive correlations between horizontal eye displacement (SD) and velocity at start ($r = .588$; $p = .035$), with horizontal position at start ($r = .753$; $p = .003$) and with mean velocity in race ($r = .626$; $p = .022$). Within the same group (MPG), there is a positive correlation with horizontal eye velocity (SD), velocity at start ($r = .599$; $p = .031$) and horizontal position at start ($r = .687$; $p = .010$). Finally, this group shows positive correlations of vertical eye velocity (SD) with horizontal position at start ($r = .577$; $p = .039$) and with mean velocity in race ($r = .676$; $p = .011$).

Lowest level group (LPG) shows significant negative correlation between horizontal eye velocity (SD) and horizontal position at start ($r = -.893$; $p = .007$) and also between vertical eye velocity (SD) and vertical position at start ($r = .929$; $p = .003$).

DISCUSSION

The main objective of this research has been identifying the relationship existing between visual behaviour, evaluating variability in ocular motility and performance achieved during the simulated regatta. Although performance during the simulated regatta has been previously analysed (Manzanares, Segado & Menayo, 2016; Santos, et al., 2014), this is the first time where visual behaviour has been analysed using measure of pupil movement and velocity and its relationship with the success achieved when performing this particular action.

As it can be observed in the results, there are differences regarding boat position in the start moment in vertical axis in the three different groups. OPG sailors are the group closer to the start line and, therefore, they obtain a greater performance. These results strengthen group classifying criterion, considering Optimist boat length an appropriate distance to classify groups of performance for this boat class regatta. Being closer to the start line at the start moment, when is no favoured by wind direction, offers a greater advantage to sail with clean sweet wind and preference in order to choose the tactic to be followed. As stated by Santos (2013), performing a good start may favour a good result in the regatta.

Considering present correlations, data show that more variable pupil velocity in OPG on horizontal axis will relate to lower average velocity of the boat during start protocol. In relation to the latter result, it is worth pointing out that most of relevant events in simulated regatta situation occur over horizontal axis not over vertical axis (moreover, projection is done in 2D). In this regard and in view of the correlation, it could be suggested that variable eye velocity showed by OPG could be a characteristic behaviour within this group based on constant changes of pupil velocity, which will be related to loss of boat velocity. Jafarzadehpur, Aazami & Bolouri (2007), in their research with female volleyball players, observed that expert players had a greater capability to perform saccadic movements than a non-player group. However, the result observed in OPG would not match visual behaviour described in that research, since in our particular case, a higher variations of eye velocity is related to loss of boat velocity, affecting therefore negatively to start performance. It is possible that sailors emphasize on perceiving all the information present on the environment than on controlling and boat handling, therefore decreasing boat velocity while sailing. It is highlight that sailing at a higher velocity during start protocol may not guarantee the performance of a better start, since the main objective during the protocol is to position the boat in the most advisable place, even stopping the boat completely to start in the last second.

Regarding MPG, variability in eye displacement over horizontal axis and velocity over both axis –horizontal and vertical- relate positively to velocity at

the start signal moment and mean velocity during all the protocol. An explanation to this eye movement variability could be based on sailors' need to search for more visual information and increase boat velocity since they are further from the start. MPG sailors need to perform a visual behaviour based on saccadic and micro saccadic movements variability, which aim is to use a more active scanning strategy of the environment (Martínez-Conde et al., 2014), trying to get closer to the start line.

The same relationship can be obtained with the position in the horizontal axis in that moment, which means that a greater amount of variability in eye movements and velocity over horizontal and vertical axis by sailors who at the start moment have not reached a high level performance, will be related to sailing at a higher velocity in order to reach an optimum position at the start line. Likewise, that greater amount of variability of eye movement and velocity over both axis –horizontal and vertical– at the start position, will be interpreted as taking closer positions to the buoy located at 30 meters. From this information we can infer that sailors aim to handle the boat with more velocity during the last seconds, running to the start line and, therefore, they will reach the maximum velocity during the last second. Those results seem to show that any increase on the amount of eye displacement and velocity variability could let to a tendency of displacing the boat to the right in the start line. This result shows no relevance, since the start is not favoured towards any buoy. On the contrary, it would be interesting to take into account this information for races where the start is favoured by one of the two buoys in the horizontal axis, which means a more suitable position, because it could be interpreted as the need of reaching the first buoy of the race with wind on the starboard tack and, consequently, having an advantage over the rivals.

All those positive correlations between boat position in relation to eye displacement and velocity variability should be interpreted from position at the start moment of the MPG, since it seems to be no connection with the most important factor, achieving a good performance in the start regatta, which means to get a position in the vertical axis as close as possible to the start line. Therefore, this eye displacement variability, despite increasing velocity, is not related to a more successful result in accordance to the position reached by MPG in vertical axis.

The final position of LPG sailors over horizontal axis is related negatively with eye position variability over horizontal axis. A greater amount of variability in pupil displacement over horizontal axis is related to a boat closeness towards the buoy located at 0 meters. This result is the opposite to the one found in MPG, whose participants would get closer to the buoy located at 30 meters. In both cases, it should be reminded that this relationship

between eye displacement variability and position in horizontal axis is not relevant.

The latter could be produced due to the fact that visual behaviour of the subjects who achieve a lower performance is less active, and therefore, they are not able to get relevant information from which they can get a higher performance during the race. On the other hand, within this group it is remarked that a greater variability in eye displacement over vertical axis is related to a boat final position in the vertical axis which is further from the start line. The more variable the gaze upside down is; the worse performance sailors obtain. This action could be a consequence of gaze dispersion typical in athletes with a lower performance (McPherson & Vickers, 2004). In our case of study, the most relevant information is grouped towards horizontal axis, rivals and start line, instead of in the vertical axis, closely related to wind force and direction, which are irrelevant aspects in a simulated situation where wind conditions are stable.

CONCLUSIONS

This research aims at finding relationships between eye movement variability and performance achieved at start in simulated sailing regatta. The results clearly show three different behaviours according to performance achieved by the groups under consideration. However, as a general characteristic, it could be highlighted that a greater amount of variability in eye displacement and velocity, are either related to a worse performance at the start in relation to boat position at the start line or shows none remarkable effect.

To continue this investigation line, it would be appropriate applying non-linear measures in order to identify not only the amount of eye displacement and velocity found, but also its structure and relationship with capability to explore the environment using visual sense. In that analysis, it would be necessary to discriminate saccadic from microsaccadic and other different movements (for example from the head) when eye tracker systems are used for the registry of visual behaviour.

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