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VISUAL SEARCH STRATEGIES OF EXPERIENCED AND NON-EXPERIENCED
SWIMMING COACHES

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Summary –The aim of this study consists of the application of an experimental protocol that allows us to obtain information about the visual search strategies elaborated by swimming coaches. Sixteen swimming coaches participated in this study. The Experienced group ($n = 8$) had 16.1 (SD = 8.2) years of coaching experience and, at least, five years of experience in underwater vision. The Nonexperienced group in underwater vision ($n = 8$) had 4.2 (SD = 4.0) years of coaching experience. Participants were tested in a laboratory environment using a video-projected sample of the crawl stroke of an elite swimmer. This work discusses the main areas of the swimmer's body used by coaches to analyse and determine errors in technique from overhead and underwater perspectives. In Front-underwater videos, body roll and mid-water were the locations of the display with higher percentages of fixation time. In the Side-underwater slow videos, the upper body was the location with higher percentages of visual fixation time, and it could be used to detect the *low elbow* fault. Side-overhead takes could not be the best perspectives to pick up information directly about performance of the arms, and coaches located their attention on the head as a reference for their visual search. The observation and technical analysis of the hands and arms is facilitated by an underwater perspective, locating visual fixations on the elbow as a reference to identify errors in the upper body. The side underwater perspective may be an adequate way to identify correct knee angles in leg kicking, also the alignment of swimmer's body and leg actions.

Several authors suggest that visual perception is the most efficient channel to obtain information about the environment in which our actions appear (e.g. Williams, Davids, & Williams, 1999), and an effective performance requires that the observer focus their attention only on the most relevant or crucial sources of information. In recent years there has been growing acceptance that skill in sport is not merely a by-product of physical prowess (Williams, Ward, & Smeeton, 2004), where expert athletes are typically characterized by superior perceptual and cognitive skills compared to their novice counterparts (Williams, *et al.*, 1999). Expert athletes possess more specific knowledge of the task and a greater ability to select, process, codify, organise, and recover the information in a more efficient way (Nougier, Ripoll, & Stein, 1989; Helsen & Pauwels, 1992). Conclusions obtained from studies of athletes could be used in other examples, such as referees or coaches, in this case. To sum up, the quality of the observation, together with precise knowledge of the sport, allows some coaches to perceive some stimuli that the majority of spectators miss (Piasenta, 2000; Chollet, 2003), which facilitate visual search of the environment and ability to extract useful information from the visual display (Hodges & Franks, 2004).

The relevance of the feedback that coaches pass on to the athletes is directly related to what they have observed. When a coach does not perceive details of the performance, his feedback will be reduced, and may not include information that is useful for the learning process. Therefore, those coaches that pick up verbal cues from their observations that facilitate and promote the learning of sport skills could be considered expert coaches. Effective verbal cues should be directed to relevant task stimuli (e.g. Magill, 2001) and help to convey finer aspects of the performance (McCullagh, Stielh, & Weiss, 1990). The detection of errors in performance for feedback was chosen here as outcome variable.

Visual fixations, which establish the target area on the fovea, provide detailed information of the visualised area (Ávila & Moreno, 2003). Certain inferences can be drawn

from the location and duration of the perceiver's visual fixations. The location of the visual fixations usually regarded as an index of the relative importance of a given cue within a stimulus display, while the number and duration of fixations recorded (denominated "search rate") are believed to reflect the information-processing demands placed on the perceiver. The visual search strategy employed by the observer highlights the way in which the eyes move around the display to extract task-relevant information (Williams, *et al.*, 2004). The development of the perceptive process, which improves coaches' teaching methods, involves previous knowledge of the critical stimulus of the action (Chollet, 2003; Ávila & Moreno, 2003), besides which are the best tools or procedures to extract information from these areas. During the observation of a crawl stroke, a difficulty is added because the water covers part of the swimmer's performance. Some studies about observation in swimming have studied the process of the detection of mistakes through digital images (Persyn & Colman, 1999) or through systematic observation (Campaniço & Anguera, 2000), and the observation from different perspectives is important in order to detect the more mistakes in a swimmer's performance (Hannula, 1995).

The search behaviour employed is determined by a range of factors in addition to the performer's skill or experience level, such as the nature of the task and the physical or emotional stress created by the competitive environment (Williams, *et al.*, 2004). It has been assumed that visual search strategies are determined by task-specific knowledge (see Williams, *et al.*, 1999), developed through years of coaching experience. These knowledge structures direct the observer's visual search strategy towards more important areas of the display based on past experience and contextual information. Many researches have examined visual behaviour using film simulations of sport situations, and there is some consensus in that experts focus their gaze on more informative areas of the display compared to novices (see, Williams, *et al.*, 1999). Therefore, the aim of this study is to analyze which cues of crawl

stroke are used by experienced coaches to identify mistakes in the swimmer's performance. The experience may pursue the visual search strategy of those coaches during the error detection process in comparison novice coaches. The search behaviour employed is determined by a range of factors in addition to the experience level, such as the nature of the task (Williams, *et al.*, 2004). Furthermore, different visual fixations on the swimmer's body were expected for the observation viewpoints (underwater and overhead viewpoints, front and side views), because different information is offered to the observer. That information about the visual search of expert coaches may be beneficial for novices in order to identify the cues that they must attend.

Method

Participants

Sixteen swimming coaches took part in this study. All participants were measured during their participation in two national swimming meetings. Two groups were formed, taking into account their experience in underwater vision (through observation windows) for an error detection process. The Experienced group ($n = 8$) had at least five years of experience in underwater viewing, an average of 16.1 (SD = 8.2) years coaching experience and the mean age was 41.8 years (SD = 6.4). The Nonexperienced group in underwater viewing ($n = 8$), had a mean of 4.2 (SD = 4.0) years of coaching experience and their mean age was 27.5 years (SD = 4.8).

Apparatus

The ASL SE5000 (headband) eye tracking system (Applied Sciences Laboratories™) was used to detect and record viewing points of the eye movements in the visual field. This video-based monocular system measured the eye-line-of-gaze with respect to a helmet-mounted scene-camera by computing the relative positions of the pupil and corneal reflection

in relation to the optics. Gaze position data were then recorded by a small camera positioned above the eye which was connected to and processed by an external microcomputer. Data were superimposed as a cursor on the scene camera image, highlighting the participant's point of gaze.

A video-recorder S-VHS (Panasonic NV-HS1000ECP) and a LCD video-projector (Hitachi CP-520W) were used to project the displays on a screen. The images obtained by the eye tracking system were videotaped and analysed by the same S-VHS video-recorder with a data sampling rate of 50 frames/s.

Procedure

Two dependent variables were considered in this study: (a) number and duration of the visual fixations per trial, taking into account the type of display presented to the subject, and (b) number and duration of the visual fixations on the spatial locations. We have considered here a visual fixation as a spatial location that is kept in focal vision for more than 60 msec (Moreno, Luis, Salgado, García, & Reina, 2005). The body of the swimmer and spatial areas were subdivided into several locations, taking into account the following variables: front or side view, and overhead or underwater viewpoint. Twenty-seven locations were considered in the front-overhead view, 26 in the side-overhead views, 28 in the front-underwater views, and 33 in the side-underwater views. Therefore, each display has a different number of locations due to the different spatial areas (locations) that can be viewed from them. These locations were grouped into and finally designated as other contained locations (see Figures 1 to 4).

*****Figure 1 near here*****

The independent variables manipulated in this study were the following ones: (i) the display's viewpoints (front-overhead, side-overhead, front-underwater and side-underwater displays); (ii) the display's speed or projection's speed (normal and slow speed, where the slower display was projected at 33% of the normal speed); and (iii) the coaching experience

in underwater viewpoint (Experienced and Nonexperienced coaches). For instance, the design of this study is a with-in-group design for the angle of vision and the display speed, and a between-group design for the experience variable.

Participants were tested in a laboratory setting using a projected video recording crawl stroke, and visual behaviour of the swimming coaches was measured in a single session. The crawl performance of an elite swimmer was recorded by a video-camera (Sony DCR-TRV20E), as much in overhead and underwater viewpoints as frontal and side views. The film was edited using an S-VHS video-recorder (Panasonic NV-HS1000ECP), also used for the video-projection through a multimedia projector (Hitachi CP-S833). All participants view the same video sequences.

The participants were seated 5 meters away from a 2 x 3 m screen. The subjects were instructed to view the performance of the swimmer in order to detect as many errors as possible. Later on, they had to indicate if these errors were of the upper body, the lower body or in the coordination of the motion. This feedback was required because high attention levels increase visual acuity (Secadas, 1992), besides a poor attention could modify the visual behaviour (Sonneschein, 1993). Also, verbal reports procedures requires subjects to verbalise the area of the display which they consider particularly informative and, consequently, a more direct measure of attentional allocation and information extraction is provided (Ericsson & Simon, 1993).

All of the coaches viewed the same sequence of performances: 11 s for the normal motions and 18 s for the slower ones. Before the sequence of motions, there is a “neutral” image of the swimming pool take for 5 s without the swimmer. The same image was inserted between motions (4 s) and when the motion was interrupted (2 s). The motion projected was the three cycles of the crawl stroke, performed at 1.80 m/s. The motion at normal speed was always presented first, followed by the same motion at a slower speed. For instance, each

subject viewed eight displays: Front-overhead Normal speed, Front-overhead Slow, Side-overhead Normal, Side-overhead Slow, Front-underwater Normal, Front-underwater Slow, Side-underwater Normal and Side-underwater Slow.

An analysis related to the search rate of the visual fixations on the swimmer body locations will be presented. Furthermore, a 3-way ANOVA (2 within-subject variables, video speed and viewpoint, and 1 between-group factor, experience) was carried out for the eight conditions in which the two groups of coaches observed the crawl motion.

Results

The results obtained from the two groups of coaches appear first for each one of the eight videos. Each figure contains the results for both normal and slow speed. The table of the front-overhead videos shows that the coaches attended to body roll location as indicated by the number of fixations and visual fixation time (Figure 1). The second location emphasized was mid-water for both groups. On the other hand, the figure referring to the side-overhead videos again showed few differences between the total fixations for these videos in both groups (Figure 2). At normal speed, the body roll was the location where more fixation time was dedicated, but the Experienced group showed slightly higher values of number of visual fixations on the torso. At slow speed, the Nonexperienced group showed larger number of visual fixations on all the locations, emphasised the body roll location, while the Experienced group fixated more time on the upper body.

*****Figures 1 and 2 near here*****

In the front-underwater videos (Figure 3), at normal speed, both groups dedicated more time to the mid-water fixation location. This location clearly stands out over the rest in the Experienced group, whereas the Nonexperienced group also had high number and fixation durations for the body roll location. At slow speed, both groups dedicated more time to fixate

as well mid-water as body roll location. For the side-underwater videos (Figure 4), upper body was the location where both groups dedicated the most time to at normal speed, but the Experienced group distributed their visual fixations between the different locations. In the slow speed videos, the upper body was the location with greater visual fixation time for both groups.

*****Figures 3 and 4 near here*****

A between-groups analysis of variance about the visual fixations was made. In the Side-overhead Slow video, the Nonexperienced group fixated longer (720 msec) on the area located in front of the hands than the Experienced group (80 msec) ($F_{1,14} = 4.946$; $p < .05$). On the other hand, in the Front-underwater Normal video, there were differences in fixation duration below the swimmer, where Experienced group fixated longer (1050 msec) than the Nonexperienced one (107.6 msec) ($F_{1,14} = 9.038$; $p < .01$). Differences were also found in this location for the Side-underwater Slow video, where the Nonexperienced group did not fixate, as opposed to 517.4 msec average fixation duration for the Experienced group ($F_{1,14} = 6.023$; $p < .05$). Statistically significant differences were found for the left elbow location in the Side-underwater Normal video, with longer visual fixation of the Nonexperienced group (400 msec) than the Experienced group (100 msec) ($F_{1,14} = 5.713$; $p < .05$).

A repeated measures analysis of variance was carried out between the overhead and underwater videos for the locations common to the views. Between the Front-overhead and Front-underwater Normal videos, significant differences were found for the head, body roll and right-side upper body locations (Table 1). For the head and body roll locations, longer visual fixation were obtained in overhead videos than underwater ones, while higher mean durations on the right-side upper body were obtained in the underwater videos. In the Frontal Slow videos, there were group differences in the visual fixation time between both videos for the elbow location, where the average time was longer for the underwater videos.

*****Table 1 near here*****

In the Normal Side videos, differences were found in the number and duration of the visual fixations. In overhead video there were average of 10.25 fixations compared to 15.06 in the underwater video ($F_{1,14} = 8.734; p < .05$). The average duration of visual fixations was found to be 614.8 msec in the overhead video, compared to 432.4 msec in the underwater video ($F_{1,14} = 6.736; p < .05$). There were significant differences with respect to the time of visual fixation on the head and the body roll locations, where greater fixation time was found in the overhead videos. Significant differences were also obtained for the right elbow, the left elbow and the upper body, with longer visual fixation in underwater videos. Differences were found between groups for the variation in the visual fixation time between both types of videos. In the Nonexperienced group, an average variation of 20 msec was found for the left elbow location in the overhead videos compared to 405 msec in the underwater videos ($F_{1,14} = 5.181; p < .05$), which represented an increase statistically different compared to that made by the Experienced group which fixated 25 msec in overhead videos and 100 msec in the underwater ones.

For the Slow Side videos, significant differences in the time of visual fixation on the head, knees, body roll, and upper body was observed. Longer visual fixation were obtained on the head and body roll in the overhead videos, while the knees and the upper body received longer fixation time in the underwater videos. On the other hand, in these videos, there were also between-group differences for the differences between both videos. The Nonexperienced group increased its time dedicated to the left hand from 512.4 to 590 msec, while the Experienced group showed a reduction in the average from 499.4 to 339.4 msec of visual fixation in this location ($F_{1,14} = 16.441; p < .01$).

Finally, for the side views, the 3-way ANOVA analysis did not show significant differences in the interactions among the viewpoint (overhead and underwater) and level of

experience variables; significance levels were unchanged by Greenhouse-Geisser correction. However, there was an interaction effect among the speed of the videos and the experience, concretely for the time of visual fixation on the lower body ($F_{1,14} = 5.34$; $p < .05$) and the body roll ($F_{1,14} = 6.81$; $p < .05$). This way, the Nonexperienced group increased the time of visual fixation on the lower body in the videos with slow speed ($M = 116.06$ msec), so the motion length is longer than the normal videos ($M = 24.75$ msec). However, the Experienced group maintain the duration of their visual fixations on the lower body, although they have an extra time due to the speed of the motion (M normal = 40.56 msec; M slow = 44.75 msec). Also, the Experienced coaches significantly increased the visual fixations on the body roll in the slow videos (M normal = 96.69 msec; M slow = 197.94 msec), while the Nonexperienced group lightly increased their visual fixation time on that location (M normal = 82.38 msec; M slow = 107.63 msec).

Discussion

Discussion will be made based on the results of the visual fixations performed by the coaches in each one of the videos that they viewed. In the front-overhead videos, it highlights the visual fixation time on the body roll, showing about 62% of overall fixation time in normal videos and 40% in slower ones. These data agreed with other studies in which the body-roll was analysed and the swimmer was filmed with cameras placed out of the water and in front of him (Liu, Hay, & Andrews, 1993; Castro, Minghelli, Loss, & Guimaraes, 2003).

When coaches were faced with front-underwater videos, body roll and mid-water were the locations of the display with higher percentages of fixation time. These locations, next to the sagittal axis of the swimmer, are presented by different authors as references for technical analysis and error recognition of the swimmer (Colwin, 1992; Monteil, Rouard, Duford,

Cappaert, & Troup, 1996; Arellano, López, & Sánchez, 2003; Ito & Okuno, 2003; Maglischo, 2003).

In the side-underwater videos, there was no any particular area of the swimmer clearly focused on by all coaches. However, the Nonexperienced group tended to focus on the upper body. This difference may be due to the relevance that experienced coaches gave to the adequate alignment of swimmer's body and leg actions. To focus on that alignment, fixations were needed over shoulders and hips to see the angle between this imaginary line and the surface as proposed by previous studies (Costill, Maglischo, & Richardson, 1992; Hay, 1993; Maglischo, 2003). In slowed videos, the upper body was the location with higher percentages of visual fixation time, and several authors have noted that this is the best way to recognise one of the most important faults performed by swimmers, the *low elbow* (Cappaert, Pease, & Troup, 1996; Arellano, *et al.*, 2003; Maglischo, 2003).

Research on visual search strategies have been characterised by the use of an expert-novice paradigm in most of the studies carried out about sport performance (e.g. Abernethy, Gill, Parks, & Packer, 2001). From the results presented above about slow side-overhead videos, it may be point out that Experienced group, unlike Nonexperienced one, preferred to focus on the position of the hands and areas located around where the hands would enter the water. It may be concluded that experienced coaches tried to pick up information about the position of the hands at the time of entry and they anticipated this location.

Comparing the strategies shown by coaches in the front-overhead and front-underwater videos, there were differences in visual fixation time on the head of the swimmer. In overhead videos, the head is the reference point used to organise movement visualization, whereas in underwater takes, the extension of the sagittal axis of the swimmer provides relevant information about technical performance, as already commented on in previous

studies (Colwin, 1992; Monteil, *et al.*, 1996; Arellano, *et al.*, 2003; Ito & Okuno, 2003; Maglischo, 2003).

When analysing coaches' visual behaviour in front videos, results about right arm are noted, where visual fixation time increased in underwater videos compared to overhead ones. This could be due to the fact that coaches have noted important errors in the left arm. Instructions were directed to coaches to find as many errors as possible. Therefore, it could be concluded that, having found this error in the left arm, they located their visual attention on the other side of the upper body.

In the side-overhead videos, it could be noted that in normal speed videos, there were two locations where coaches focused their visual fixations, head and torso. However, when faced with side-underwater videos, coaches distributed their visual fixations on more locations, so they adapt to the specific viewpoints (Smeeton, Ward, & Williams, 2004). Another difference between overhead and underwater videos was the time dedicated to the elbows. The observation and technical analysis of the hands and arms is facilitated by an underwater perspective, locating visual fixations on the elbow as a reference to identify errors in the upper body. Moreover, as referred to above, the *low elbow* has been reported as one of the most typical errors in crawl stroke (Maglischo, 2003).

In the results presented of the side slow videos, differences between the locations with longer fixation time were emphasised. Side-overhead videos should be good viewpoints to pick up information about performance of the arms, because the coaches located their attention on the upper body and head as reference for their observation. On the other hand, in underwater videos, the upper body had the longest visual fixation time possibly due to the importance of the path of the arms and hands. In these underwater videos, differences were also found in the fixation time on the knees. Fixation time on the knees was shorter in

overhead videos because this location is partially hidden under the water, but underwater viewpoints may be the most adequate way to identify correct knee angles in leg kicking.

No differences were found in the interaction between the coaches' experience level and the viewpoints. The variables for which the Experienced group showed differences in visual fixation compared to the Nonexperienced group were specific locations seen from each viewpoint. No differences were found between Experienced and Nonexperienced coaches' visual fixation time on the common locations of the overhead and underwater viewpoints.

Regarding the interaction between the coaches' experience level and the video speed, in the slow videos, the experienced coaches has similar visual fixation time on the lower body in spite of the increased available time, and they paid attention to other locations like the body roll. The Nonexperienced group did not show that visual behaviour. They observed the lower body as much as the body roll, with a slightly more time spent on the latter area. It could be concluded that the Experienced group considered the body roll as an important visual location to analyze the crawl technique, in the underwater as well as the overhead viewpoints.

Finally, the results suggest the main areas of the swimmer's body used by coaches to analyse and determine errors in crawl stroke from overhead and underwater viewpoints. It is probable that any differences in the visual search strategies used by Experienced and Nonexperienced coaches are related to their experience in underwater vision and knowledge about the specific locations from each of the viewpoints. More research is needed to determine if these differences are found in other swimming strokes and how to improve novice coaching performance.

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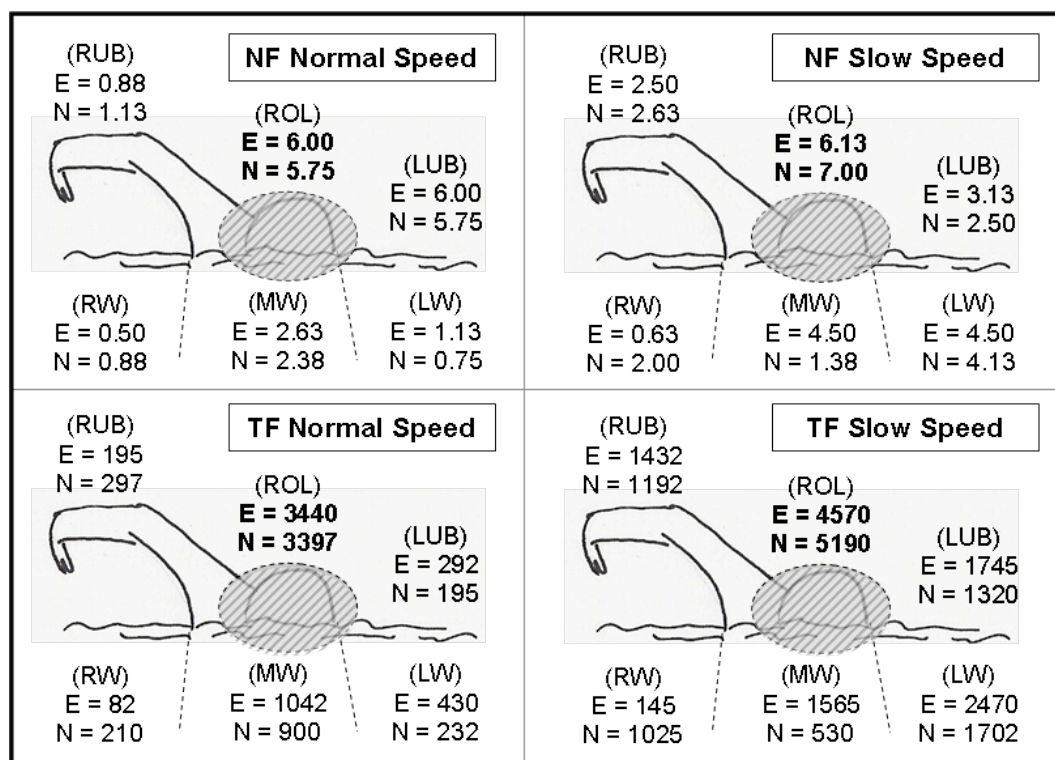


Figure 1.

Number (NF) and duration of the fixations (TF) for the Front-overhead videos (LUB = left-side upper body; RUB = right-side upper body; ROL = body roll; LW = left-water; MW = mid-water; RW = right-water).

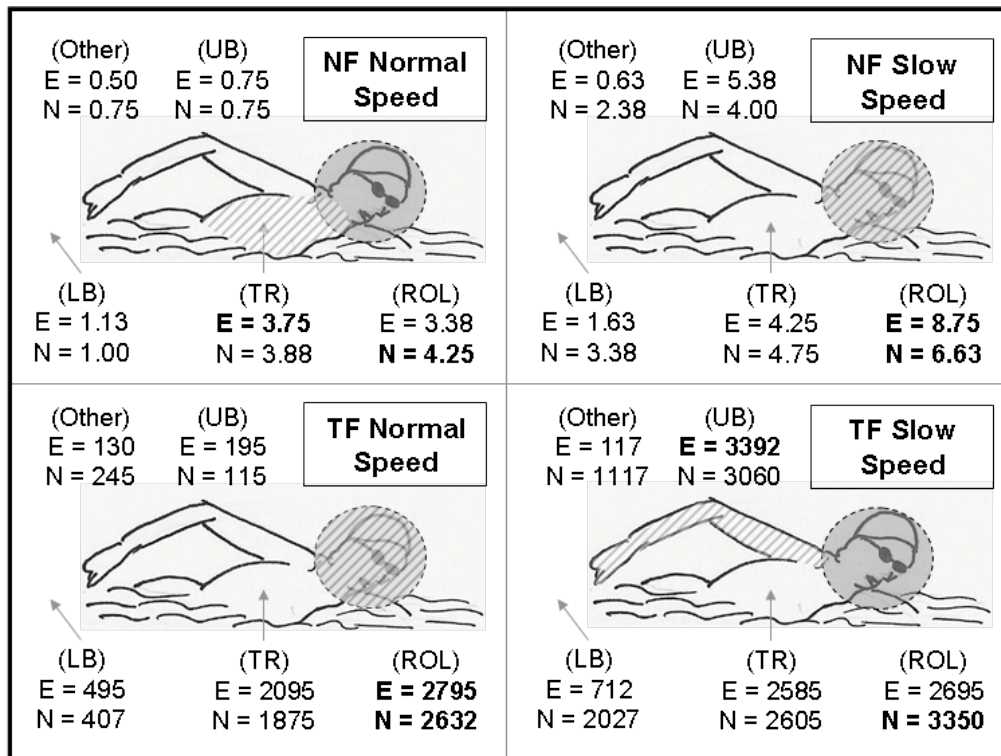


Figure 2.

Number and duration of the fixations for the Side-overhead videos (LB = lower body; TR = torso; ROL = body roll; UB = upper body; Other = other locations).

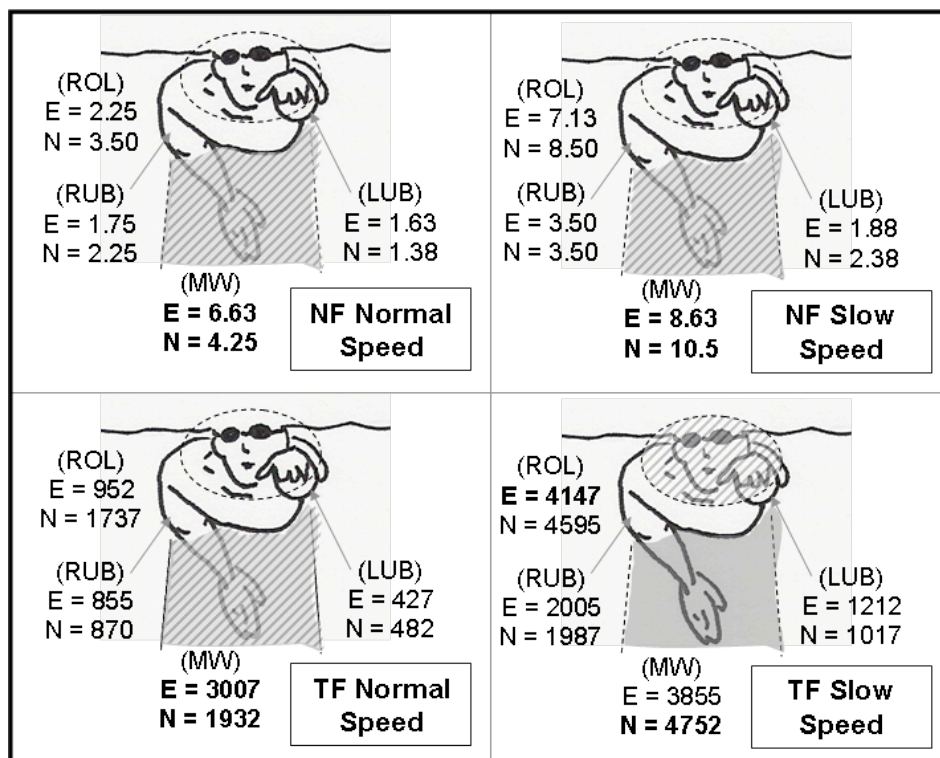


Figure 3.

Number and duration of the fixations for the Front-underwater videos (LUB = left-side upper body; RUB = right-side upper body; ROL = body roll; LW = left-water; MW = mid-water; RW = right-water).

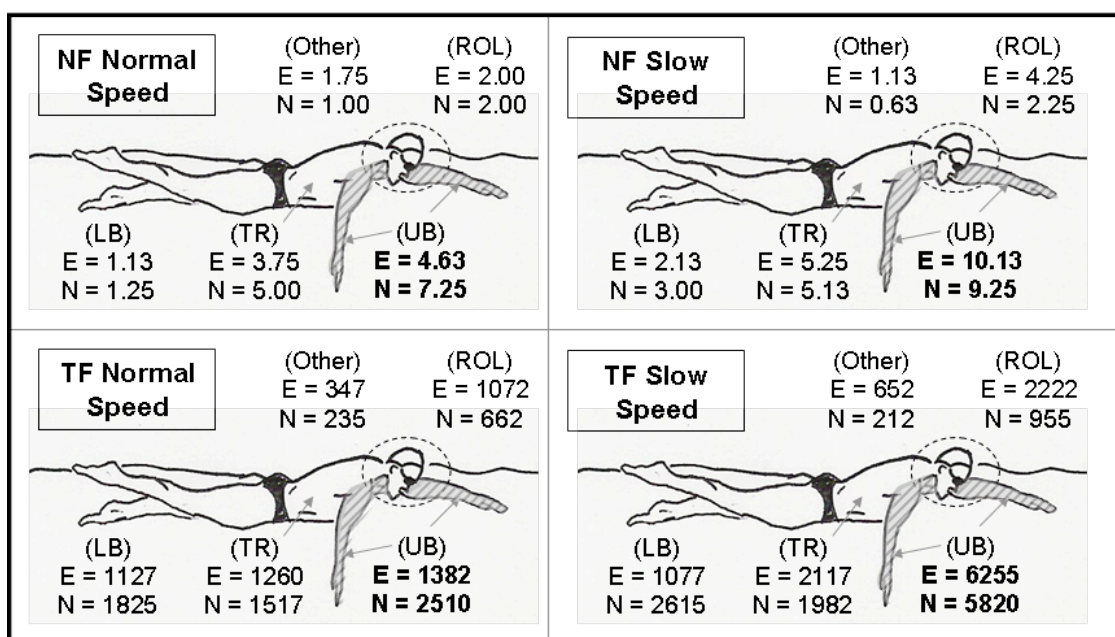


Figure 4.

Number and duration of the fixations for the Side-underwater videos (LB = lower body; TR = torso; ROL = body roll; UB = upper body; Other = other locations).

Table 1. Main locations with significant differences of the repeated measures ANOVA for the viewpoint variable (values in msec)

Location	View	Speed	Viewpoint				$F_{(1,14)}$	p
			Overhead		Underwater			
			M	± SD	M	± SD		
Head	Front	Normal	2681.2	± 1760.4	666.2	± 904.6	20.211	.01
Body Roll	Front	Normal	3418.6	± 1538.6	1345.0	± 1018.6	30.537	.01
Right UB	Front	Normal	246.2	± 371.6	862.4	± 880.6	6.859	.05
Elbow	Front	Slow	335.0	± 452	872.0	± 138.2	5.328	.05
Head	Side	Normal	2450.0	± 1309.4	862.4	± 802.4	17.733	.01
Body Roll	Side	Normal	2713.6	± 1347.8	867.4	± 766	19.393	.01
Left Elbow	Side	Normal	22.4	± 52	252.4	± 292.4	8.921	.01
Right Elbow	Side	Normal	41.2	± 112.6	291.2	± 390.4	5.887	.05
Upper Body	Side	Normal	155.0	± 226.2	1946.2	± 1485.2	22.139	.01
Head	Side	Slow	3716.2	± 2490.2	1333.6	± 1675.4	8.925	.01
Knees	Side	Slow	131.2	± 270.6	771.2	± 743.2	10.636	.01
Body Rol	Side	Slow	4522.4	± 2448	1588.6	± 1731	13.510	.01
Upper Body	Side	Slow	3226.2	± 1487.6	6037.4	± 2340.8	17.609	.01