Perception during Action Observation in Combat Sports

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ABSTRACT

Visual perception is of particular relevance for action anticipation within human social interactions. Competitive sports offer a great possibility to study visual perception, as it is necessary to anticipate action intentions of team members and/or opponents within a highly restricted timeframe. We conducted an eye tracking experiment and examined differences between athletes and novices during action observation in combat sports. Participants were instructed to respond to images of punches and kicks by pressing a left or right button. The images depicted different points-in-time during movement execution. Reaction times, error rates, fixation durations, and fixation rates were analyzed. Results showed that participants reacted faster, produced less errors, and used fewer fixations of longer duration at later points-in-time compared to earlier ones. A group effect regarding reaction times indicated expertise differences between combat-sports athletes and novices. However, no expertise-dependent differences in fixation duration and fixation rates were found.

Author Keywords

Action anticipation; visual perception; athletic expertise; gaze behavior; eye tracking

ACM Classification Keywords

• **General and reference~Empirical studies** • *Applied computing~Psychology*

INTRODUCTION

Interactive sports place high demands on visual perception, since visual stimuli are not only used for the control of own actions, but also for the anticipation of the actions of team members and opponents. Complex situations have to be perceived and actions have to be initiated within limited timeframes, which often last only milliseconds. Therefore, it is not surprising that there has been an increased interest in studying visual perception within various kinds of sports during the last years [14, 15]. The methodological approach most often taken is the expert-novice paradigm, in which the performance of expert athletes is compared to novices. In general, this kind of approach aims to understand what differentiates expert athletes from non-experts, in order to derive recommendations for training and competition, which are assumed to be helpful to develop expertise in a specific field of sports [18]. With regard to perception and anticipation, the following picture emerges from studies using the expert-novice paradigm: (1) Experienced athletes are able to precisely meet the spatio-temporal conditions of their sports. (2) In comparison to less experienced athletes, experts are better capable of encoding and retrieving sport-specific information, so that they can recognize action patterns more efficiently. (3) Experienced athletes compared to novices are able to detect relevant objects within their visual field faster and make better use of action-relevant (movement) cues prior to an event [30].

For studying visual perception, the eye-tracking paradigm is often used [32]. Different quantitative measures, like the number of fixation and fixation duration serve as an indicator for the amount of information an observer acquires. Furthermore, qualitative parameters, like the scan path and fixation location, can be used to analyze areas of interest.

Several eye-tracking studies have examined visual perception in the context of sports expertise. However, there are divergent results regarding differences between experts and novices. Some studies demonstrated that experts use a greater number of fixations of shorter duration, as compared to novices [26, 29], while others found the direct opposite, i.e. fewer fixations of longer duration for experts, as compared to novices [20, 21, 23], whereas other studies did not find any differences between both groups [1, 2, 31]. The reasons for these discrepancies seem to be diverse. They reach from typically small sample sizes in eye tracking studies [7], over the particular sport examined, to the complexity of the task and stimulus design [14, 21].

In many sports, experts' use of fewer fixations of longer duration seems to be plausible from a theoretical perspective. The psychological Information-Reduction-Theory (IRT) by Haider and Frensch [11, 12] is based on the assumption that not only information processing, but also information perception changes during skill acquisition. According to IRT, the distinction between relevant and irrelevant information is a crucial factor of learning and, as a consequence, expertise. This allows for a limitation of information processing to task-relevant information, so that the total amount of to-be-processed information is reduced. The restriction to task-relevant information is important, because only a small amount of available information on the retina can be processed at the time [5]. For skill acquisition in sports, it is assumed that learning leads to an improving or reorganization of mental action representations [6, 28]. This knowledge about movements should allow experts to better distinguish between relevant and irrelevant stimulus features and should therefore lead to fewer fixations of longer duration. This strategy would be accompanied by fewer saccades, i.e. eye movements between two fixations. Since it is assumed that information processing is suppressed during saccades [14], a gaze strategy involving fewer saccades seems to be reasonable.

In the present study, we examined gaze behavior in combat sports. A characteristic of all combat sports is the typical one-to-one situation, which requires a focused attention to a single opponent. In this way, combat sports are different from team and racket sports, which include perception of a larger sports field. To this day, however, only a few eye-tracking studies have investigated visual perception in combat sports [16, 17, 20, 21, 31]. These studies came to different results regarding expert-novice differences. For example, Ripoll and colleagues [21] asked participants of different level of expertise to react to filmed sequences of a French Boxer, who was performing different boxing techniques, by manipulating a joystick. Results showed expertise-differences in gaze behavior. Experts used fewer fixations compared to novices and intermediates. However, Williams and Eliott [31] conducted a study with expert karate athletes and novices. Participants were instructed to react to attacks by a karate athlete presented on a screen. In this study, no expertise differences regarding number of fixations and fixation durations were found. We therefore asked combat sports athletes and novices to respond to photo-realistic stimuli, depicting four different attacking techniques (composed of straight kicks and punches with either the left or the right leg or arm), by pressing one out of four different buttons. Every attacking technique was presented at one out of four different points-in-time during movement execution. That is, for the initialization of the movement, for two significant changes of the body posture during movement execution, and for the end point of the kick (leg completely stretched out) or punch (arm completely stretched out).

The assumptions made regarding the point-in-time of movement execution were based on earlier studies by Güldenpenning and colleagues, who conducted a subliminal priming experiment with combat sports athletes and novices [9]. The prime (picture) depicted a combat-sport athlete performing one of two different kicks (front kick vs. roundhouse kick) at one of six different points-in-time during movement execution. Participants were asked to react to a target (picture), which depicted the end position of the front kick or the roundhouse kick. Results showed an influence of the point-in-time of movement execution presented in the prime on reaction times of both, athletes and novices, even though the prime was not consciously perceivable. Furthermore, another study by Güldenpenning and colleagues revealed expertise-differences between athletes and novices in volleyball [10]. They conducted a priming experiment and asked their participants to respond to two beach-volleyball attack-hits. Results showed that beach-volleyball athletes were able to identify the technique at an earlier point-in-time during movement execution, as compared to novices. However, novices also showed a congruency effect for primes depicting later movement phases. That is, for pictures taken late during movement execution, novices also reacted faster for congruent prime and target pictures. Accordingly, we expected participants to be more familiar with later points-in-time during movement execution, as compared to earlier ones. Therefore, we expected them to react faster, to make fewer mistakes and to use fewer fixations of longer duration during observation of later compared to earlier points-in-time during movement execution. Furthermore, athletes were expected to react faster and to use fewer fixations of longer duration at every point-in-time of movement execution (i.e. general expertise effect).

METHOD

Participants

Thirty participants took voluntarily part in the experiment. They received neither course credit nor monetary payment. All participants were naïve to the purpose of the study, had normal or corrected-to-normal vision, and gave written consent in accordance with the 1964 declaration of Helsinki.

Eighteen participants were assigned to the group of novices (6 females, 2 left-handed, mean age 22.6, *SD* = 1.9) with no experience in combat sports. Another twelve participants (1 female, mean age 27.0, *SD* = 6.1) were athletes of different kinds of combat sports with an average of 12.7 years (*SD* = 6.3) of training experience. Importantly, only athletes, who were familiar with the presented attacking techniques, were assigned to the group of combat sports athletes.

Stimuli and Set-Up

The stimulus set consisted of sixteen static images (kicks and punches with the left and right leg/arm at four different points-in-time during the movement execution). The images were taken from videos of a combat sports athlete performing the two attacking techniques. These particular techniques were chosen on the basis of their popularity in different kinds of combat sports. Videos were filmed from a front perspective, so that the perspective matched the common perspective of an athlete viewing the opponent during sparring or competition. Besides the end point of movement execution, three different points-in-time during movement execution for each technique were used as targets, with t1 being the earliest point and t4 being the end point of the movement (see Figure 1). For the purpose of inducing an apparent motion [3], as well as directing participants' gaze

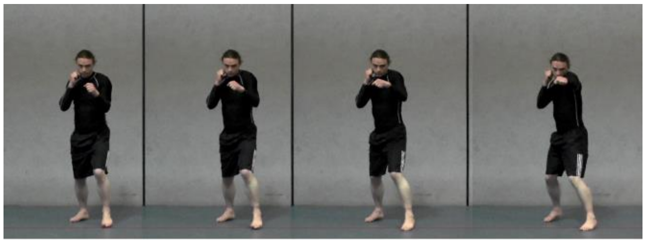

Figure 1. Depicted is a punch with the left arm from early to later points-in-time during movement execution.

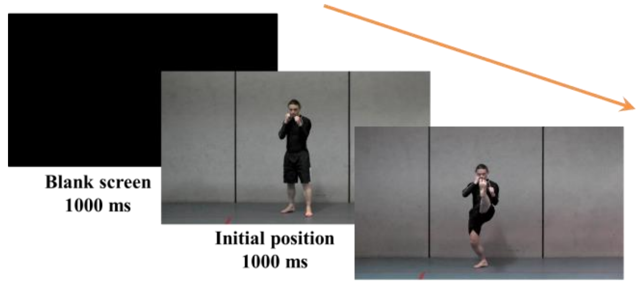

Figure 2. Sequence of a trial, exemplarily shown for the kick with the left leg.

to the middle of the screen, another image of the combat athlete standing in an initial position was presented prior to the target stimulus (see Figure 2). All stimuli were presented on a 24-inch monitor.

Eye-tracking data were recorded with a remote eye tracker (EyeFollower, Interactive Minds), which was located below the monitor. The EyeFollower possesses a sample rate up to 120 Hz and a gaze position accuracy smaller than 0.45°. Four different buttons on a keyboard ("<" = punch right arm/leg; "y" = punch left arm/leg; "n" = kick right leg/arm; "m" = punch left arm/leg) were used as response buttons. Button assignments to punches and kicks, respectively, were counterbalanced across participants.

Design and Procedure

A 4 x 2 mixed factorial design with the within-subjects factor "point-in-time" (t1, t2, t3, t4) and the between-subjects factor "expertise" (combat sport athletes vs. novices) was used in the present study.

Participants sat approximately 60 cm in front of a computer screen and were instructed to respond as soon and as accurately as possible to the presented kicks and punches by pressing one of four buttons. Each button was assigned to one of the four attacking techniques. A video of each technique was presented once to the participants prior to the experiment, so that participants were able to get familiar with these techniques. Afterwards, each participant completed a block of 32 randomized practice trials, before the 9-point calibration procedure for the eye tracking was conducted and the experiment started. The experiment was separated into two blocks with 120 trials each. Participants could take a rest between the blocks, if needed. Each trial consisted of a blank screen (1000 ms), a picture of the initial position (1000 ms), and the target picture, which remained on the screen until a response was given (see Figure 2). During the practice block, the subsequent trial only started if the participant had pressed the correct response button. During the experimental blocks, the subsequent trial also started after a wrong response and no error feedback was given.

RESULTS

Reaction times, fixation durations, and fixation rates were examined for correct responses, as well as error rates for incorrect responses. Each of the dependent variables was analyzed by mixed analyses of variance for the within-subjects factor "point-in-time" and the between-subjects factor "expertise". A violation of the sphericity-assumption resulted in a correction of the p-values and degrees of freedom according to Greenhouse-Geisser. All post-hoc t-tests were Bonferroni-corrected.

Reaction Times

The reaction times are displayed in Figure 3. A mixed ANOVA for the dependent variable reaction time showed a main effect for the factor point-in-time [$F(1.43, 40.02) = 38.75$, $p < .001$, $\varepsilon = .48$, $\eta_p^2 = .58$]. Reaction times decreased with shorter temporal distances to the end point: They were highest with 1365 ms at t1, were 1121 ms at t2, were 949 ms at t3, and were 757 ms at t4. Post-hoc t-tests showed significant differences between every point in time (all t's > 3.00, all p's ≤ .001). The main effect of expertise was also significant [$F(1,28) = 4.42$, $p = .045$, $\eta_p^2 = .14$]. There was a difference of 218 ms between athletes (917 ms) and novices (1135 ms). The interaction between point-in-time and expertise was not significant [($F(1.43, 28) = .91$, $p = .38$, $\varepsilon = .48$, $\eta_p^2 = .03$)].

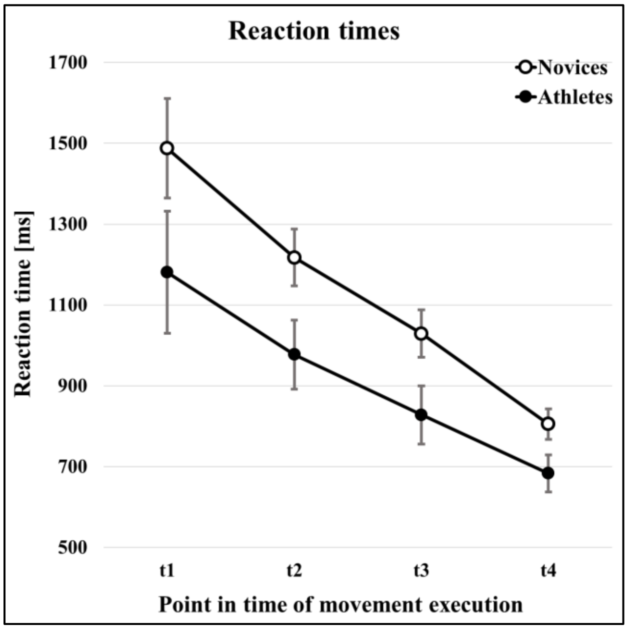

Figure 3. Reaction times (RT) in milliseconds (± SE) for combat sports athletes and novices at all points-in-time during movement execution.

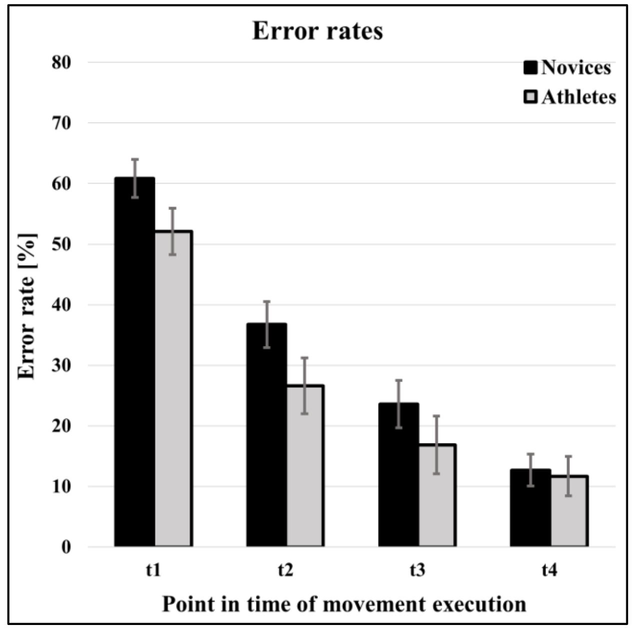

Figure 4. Error rates (ER) in percentage (± SE) for combat sports athletes and novices at all points-in-time during movement execution.

Error Rates

Error rates are presented in Figure 4. A mixed ANOVA for the dependent variable error rate showed a main effect for the factor point-in-time [F(3, 84) = 120.73, p < .001, η_p^2 = .81]. Error rates decreased with shorter temporal distances to the end point: They were highest with 57% at t1, were 32% at t2, were 20% at t3, and were 12% at t4. Post-hoc t-tests showed significant differences between every point-in-time (all t's > 3.00, all p's ≤ .001). The main effect of expertise [(F(1, 28) = 2.26, p = .14, η_p^2 = .08)] and the interaction between point-in-time and expertise [(F(3, 84) = 1.30, p = .28, η_p^2 = .04)] was not significant.

Fixation Durations

The fixation durations can be seen in Figure 5 A mixed ANOVA for the dependent variable fixation duration showed a main effect for the factor point-in-time [F(1.87, 52.37) = 22.02, p < .001, ε = .62, η_p^2 = .44], as the fixation duration especially increased for t4. The mean fixation duration was longer at t4 (529 ms) than at t3 (381 ms), t2 (367 ms), and t1 (354 ms). Post-hoc t-tests confirmed these differences between the three earlier points-in-time during movement execution and t4 to be significant (all t's < 5.00, all p's < .001). There was neither a significant main effect for expertise [(F(1, 28) = .36, p = .55, η_p^2 = .01)], nor a significant interaction between point-in-time and expertise [(F(1.87, 28) = .39, p = .67, ε = .62, η_p^2 = .01)].

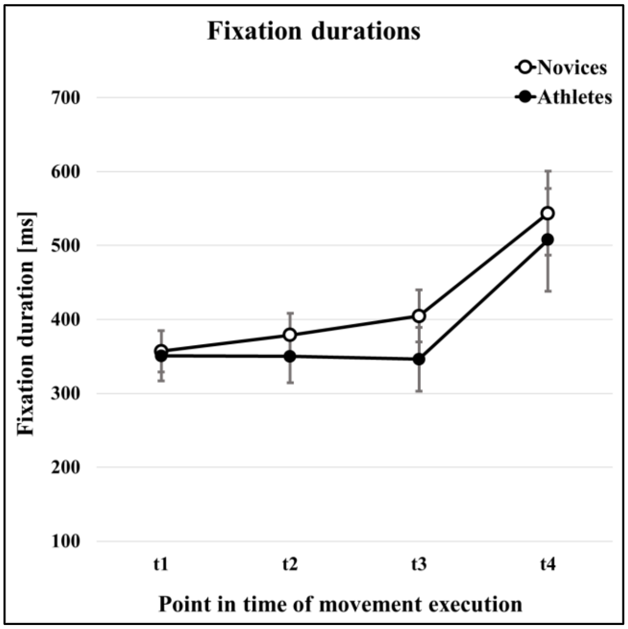

Figure 5. Fixation durations in milliseconds (± SE) for combat sports athletes and novices at all points-in-time during movement execution.

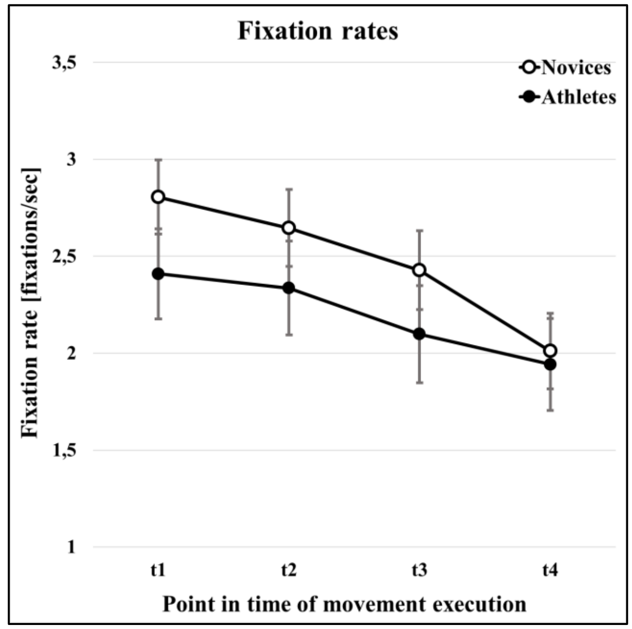

Figure 6. Fixation rates in fixations per second (± SE) for combat sports athletes and novices at all points-in-time during movement execution.

Fixation Rates

The fixation rates are presented in Figure 6. A mixed ANOVA for the dependent variable fixation rate showed a main effect for the factor point-in-time [($F(3, 84) = 34.45$, $p < .001$, $\eta_p^2 = .55$)], as fixation rates decreased from earlier to later points-in-time. The mean fixation rate was smaller at t4 (1.98 fixations/second) than at t3 (2.23 fixations/second), t2 (2.52 fixations/second), and t1 (2.65 fixations/second). Post-hoc t-tests confirmed significant differences between every point-in-time (all t's > 2.00, all p's < .001), except for the difference between t1 and t2 ($p = .05$). There was neither a significant main effect for expertise [($F(1, 28) = .85$, $p = .37$, $\eta_p^2 = .03$)], nor a significant interaction effect between point-in-time and expertise [($F(3, 84) = 2.27$, $p = .08$, $\eta_p^2 = .08$)].

DISCUSSION

In this study, we investigated differences in reaction times and gaze behavior between combat-sports athletes and novices, who responded to photo-realistic images of two attacking techniques commonly used in combat sports (straight kicks and punches). Importantly, the images displayed different points-in-time during movement execution. We examined if combat-sports athletes are better able to identify these techniques earlier during movement execution and if they use different perceptual processes (as revealed from eye-tracking measures) than novices.

In accordance with our hypothesis, effects of point-in-time were observed for reaction time, error rates, fixation durations, and fixation rates. Participants reacted slower, produced more errors, and used more fixations of shorter duration at early points-in-time compared to later ones. Higher error rates for early points-in-time of movement execution indicate participants' difficulties to identify the techniques during the early phase of movement execution. Furthermore, the pattern of response errors reassures us that the reaction time results are not due to a speed-accuracy tradeoff. The pattern for reaction times, as well as for gaze behavior, reflects higher effort of visual search for relevant cues during early phases of movement execution compared to later ones, when the action is still unfolding. Additionally, regarding the factor points-in-time during movement execution, the reaction time results are in line with findings from priming and temporal-occlusion studies. Priming studies demonstrated stronger congruency effects with primes from later compared to earlier movement phases [8, 10] and temporal-occlusion studies revealed an improvement of performance in later occlusion conditions compared to earlier ones [13, 22, 24].

The differences between combat-sports athletes and novices regarding reaction times were also significant, and numerically large, with the difference being 218 ms in favor of the combat sports athletes. In contrast to our expectations, there were no expertise differences regarding fixation durations and fixation rates. This is in contrast to some previous studies reporting differences in gaze behavior between expert athletes and novices [17, 21]. The absence of such differences in the present study might have several reasons: First of all, we only used an apparent motion paradigm with two static images, instead of using dynamic video stimuli. Differences between experts and novices have been reported for static images before, but fixation durations seem to be numerically smaller with static images compared to video presentations [14]. Considering the numerical results of the data for gaze behavior in our study, it becomes clear that there is not so much room for expertise differences. This is especially true for the fixation rates, which were about 2.3 fixations per second, with an average target duration of approximately one second. Second, the absence of expertise differences might relate to the size of the stimuli. Even though previous studies found expertise differences in gaze behavior with smaller stimulus sizes [4, 25], the majority of studies used large screens with life size images for the stimulus presentation [19, 26, 31]. In this study, stimuli were presented on a 24-inch screen with a visual angle of about 20°. The central field is regarded to have a size of about 10° [27]. This enabled our participants to pick-up a relatively large part of the picture with only one fixation. Furthermore, it is possible that participants used peripheral vision to gather additional information.

Thus, expertise differences regarding gaze behavior should be investigated in future studies with dynamic stimuli on a large screen. Nevertheless, this study provides further insight into the cognitive processing of attacking techniques in combat sports with regard to the information pick-up.

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