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Does Sport-Specific Experience Affect Reaction Times in the Premotor Phase?

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Abstract

Objective: When reacting in a sport-specific situation, athletes use body movements as cues. For example, soccer players use lower body movements as cues, while volleyball players use upper body movements as cues. Despite differences in these focal points, both groups of players use specific cues to recognize sport-specific situations, based on sports-specific experience. This paper aims to investigate how sports-specific knowledge and experience affect reaction times associated with anticipation and prediction by comparing responses during simple and complex tasks performed by athletes with different backgrounds (soccer and volleyball).

Methods: Twenty-six collegiate male soccer players (20.0 ± 0.77 years) and twenty-one collegiate male volleyball players (19.8 ± 0.98 years) completed video-based single direction (SDRT) and multiple direction (MDRT) reactive agility test trials. Participants reacted to a soccer pass that was executed by the model in the video. Both groups completed a questionnaire about the reaction cue used. A two-factor mixed analysis of variance, with the within-factor as "Tasks" (i.e., SDRT, MDRT) and the between-factor as "Sports" (i.e., Soccer, Volleyball), analyzed the main effects and interactions. The generalized η2 was used to compare the within- and between-factors, and Cohen's *d* was used to compare the effect size between groups. For the questionnaire, a chi-square test of independence was used.

Results: The time from presentation of the stimulus to the time when the participant started to move was shorter in the simple task condition (i.e., SDRT; $p<0.01$), and for more experienced soccer players ($p<0.01$). The generalized η2 was larger in the between-factor "Sports" than the within-factor "Tasks." The Cohen's *d* between tasks was greater in the volleyball group than the soccer group. No significant differences in the questionnaire responses were found between sports groups.

Conclusion: These results suggest that sport-specific experience affects reaction times in the premotor phase.

Keywords

Single direction reaction time (SDRT); Multiple direction reaction time (MDRT); Premotor phase; Sports-specific experience; Sports; Anticipation; Prediction

Introduction

In soccer, agility and reactive agility are often important to win a game or accomplish a task. Intercepting an opponent's pass is a high priority for defense players as it facilitates the commencement of a counterattack. Counterattacks and other plays in transition phases are essential to increase the probability of scoring [1]. Therefore, agility and reactive agility in soccer are crucial for superior play.

Sheppard and Young [2] proposed the definition of agility as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" and described the importance of cognitive components, such as anticipation, as part of the decision-making process. Soccer players can initiate movement when a decision is made, even before the opponent's action is completed. This response is particularly important when reacting to an opponent's actions, such as intercepting a pass or tackling a dribble. The cognitive components of decision-making are essential factors to consider. Information processing in agility skills is described as comprising "stimulus perception, response selection, and movement execution" [3]. During this ordered process, the time taken in the stimulus perception and response selection phases relies on cognitive functions, which are not categorized as physical abilities. These are also described as the premotor phase times. Botwinick and Thompson [4] reported that the premotor phase time has a strong correlation with reaction times that was defined as time from the stimulus onset to reactive movement ends such as finger lift response in his study. The time taken for response selection phase is extended when the difficulty analyzing the task increases [5]. In sports, this would be readily apparent since the ability to analyze movements or situations is associated with sports-specific knowledge and experiences. Williams et al. [6] suggested that sports experts can better predict what movement the opponent is executing by rapidly detecting the cue that directly, or indirectly, precedes the movement. Furthermore, these authors argue that sports experts can better anticipate future movements by effectively recognizing situations based on stored memories. The predictive ability helps the player detect cues based on the opponent's movements. The player needs to remain alert, anticipate, and make decisions quickly and efficiently so as to be able to make accurately calculated moves within shorter time spans. Likewise, the ability to anticipate will reduce the time elapsed for completion of the response selection phase since it reduces the number of choices of movements from which the player must decide. Therefore, it is reasonable that the reaction time may be increased when players receive less information, such as in situations requiring reactions to brief, momentary movements, which don't allow players to anticipate actions. Shortening the time of the response selection phase can be achieved by reducing the time taken to analyze the situation, which is also based on specific, relevant experiences [7-9]. There are various strategies which allow players to recognize a situation in each specific sport. According to Savelsbergh et al. [10], expert goalkeepers tended to focus on the kicking leg, the non-kicking leg, and the ball over a long period. These areas of the lower extremities could be used as cues to recognize a kick motion in soccer. In contrast, volleyball players tend to focus on upper body movements of the opponent setter, such as the body leaning back or the angle of wrists, and the ball in order to anticipate where to make a pass and predict when to make a pass [11]. In spite of differences in the focus points of the body, these players use a specific cue to recognize the situation effectively, which is based on the sports-specific knowledge and experience. The duration of the reaction process can

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be shortened by using anticipation, prediction, and situation analysis as cognitive functions. However, many studies in reaction time do not include anticipation and prediction processes, and these studies focus only on the time taken to analyze situations [5,7,12-14]. Only a few studies have focused on anticipation or prediction during the reaction process [15]. Prediction and anticipation abilities are only used when responding to a cue that moves continuously, or changes over time.

This paper aims to investigate whether sports-specific experience is related to differences in the reaction times on simple and complex tasks by comparing responses to different tasks, simple and complex, and between athletes with different backgrounds, namely, soccer and volleyball. We hypothesized that the time associated with anticipation and prediction in an athlete's reaction time would be longer in the complex task, and the delay between the times on the tasks would be bigger in the volleyball group due to prior sport-specific experience.

Methods

Experimental approach to the problem

This study aimed to investigate simple and complex reaction times in sport-specific situations. This study explored how subjects recognized different situations and how they performed on different reaction time tasks. Video-based reactive agility tests incorporating single-direction and multi-direction trials were completed by two groups (i.e., a group of soccer players and a group of volleyball players). Both groups completed a questionnaire which was used to identify which cues the subject used when responding to the videos. First, the Single Direction Reactive Test (SDRT) was completed, in which subjects were instructed to move in a designated direction described beforehand by the experimenter. Next, subjects completed the Multiple Direction Reactive Test (MDRT), in which the subject was instructed to move in the direction in which a ball was passed in a soccer scenario. Lastly, subjects were asked to complete the questionnaire identifying the cues they used, such as focusing on specific body parts to anticipate movements about to be executed. The group results were then compared.

Participants

Twenty-six collegiate male soccer players (mean ± SD age=20.0 ± 0.77 years) and twenty-one collegiate male volleyball players (mean ± SD age=19.8 ± 0.98 years) were recruited to participate in this study. All the subjects were first-string team members. As mentioned in the introduction section, the subjects in this experiment used the ability to anticipate, or predict movements, in their sport on a daily basis. This ability allowed them to be aware of how to initiate better reactions in response to others' movements. The differences between the groups primarily were related to the familiarity with body areas that served as cues while anticipating a situation and predicting a movement. In accordance with the literature, this familiarity was due to sports-specific experience. This study was approved by the Ethics Review Committee on Research with Human Subjects of Waseda University and written informed consent was obtained from each subject or legal guardian.

Construction of video clips as test stimuli

A coach of the soccer team from which players were recruited served as a model for the video clip but did not participate in any other aspects of this study. Video clips were created using a digital camera (KissX7i; Canon Inc, Tokyo, Japan) with a frame speed of 30 fps. Video clips were recorded on an outdoor field with artificial turf. The model wore training clothing typical to soccer practice sessions. The camera was positioned 15 m in front of the model at the height of 110 cm. The model was instructed to do a short dribble and then execute a pass within 5 m of the start position in his own time toward a point 7 m from the digital camera's position. The model was asked to execute each of the following types of passes 10 times:

1. Inside kick-Right (IR): Execute a pass to the right from the viewer, using an inside kick with the right leg.

2. Inside kick-Left (IL): Execute a pass to the left from the viewer, using an inside kick with the left leg.

3. Outside kick-Right (OR): Execute a pass to the right from the viewer, using an outside kick with the left leg.

4. Outside kick-Left (OL): Execute a pass to the left form the viewer, using an outside kick with the right leg.

In each video, a red circle was placed in the corner of the frame, indicating that the foot had made contact with the ball. This processing was conducted using video editing software (Adobe Premiere Elements 2018; Adobe Systems Incorporated, Tokyo, Japan).

The test clip for the SDRT comprised five randomly-selected clips each from only the IR and OR conditions. The test clip for the MDRT was composed of two randomly-selected clips from each of the four conditions. Therefore, ten trials were performed for the SDRT, and eight trials were performed for the MDRT.

Questionnaire items

The questionnaire consisted of three sections: SDRT, MDRT, and relative difficulty performing in each of the situations. In both the SDRT and MDRT sections, questions were asked regarding what cues were used to anticipate the actions and how the subject saw the cue. The cues used to anticipate the actions were defined by the question "What was the biggest cue that you reacted to?" The options were: 1) Whole-body movement (not a specific body area, but the entire body as a comprehensive situation), 2) Face (orientation of the face, eye movements), 3) Arms and shoulders (arm swing, lateral bending, or rotation of upper body), 4) Feet and legs (appearance of contact with the surface of the foot, leg swing, the change of direction of the supporting foot's toe or stride), and 5) Ball (position of the ball, the ball physically being kicked). How the subject saw the cue was defined in the question "How did you see the visual cues when you reacted?" The choices were: 1) You recognized the motion as a pass when you reacted; 2) You recognized a change in body position, rather than a pass action, when you reacted, and 3) Other. In the difficulty per situation section, participants were asked to compare the level of difficulty for different tasks. Difficulty was defined in the question "Was reacting in the MDRT condition more difficult than in the SDRT condition?" Options were as follows: 1) Yes, 2) No, and 3) Unsure. Those who answered "Yes" to this question were asked the additional question: "Was it because you had to identify the direction carefully?" Options were as follows: 1) Yes, 2) No, and 3) Unsure. Subjects were instructed to choose only one answer for each question.

Procedure

The experiments took place on a tiled floor in an indoor classroom. No soccer or volleyball practice sessions, or strength training, were conducted before the experiments commenced. Owing to the team's schedule, the experiments for each group were completed within a two-day period. The average illumination level in the experiment room was 227.5 lux for soccer players and 224.5 lux for volleyball players. The average level of sound in the room was 44.8 db for soccer players and 43.8 db for volleyball players. Subjects completed the agility tests wearing indoor training shoes and clothing of their choice. For familiarization purposes, immediately prior to the SDRT test, subjects were given one practice trial using each IR and OR video clip, different from those used in the actual trial.

For the agility tests, subjects were instructed to move in the direction that the ball was kicked in the video clip as if intercepting the pass that the model executed, which was done by the subject sprinting to break the goal gate's timing system, which has been reported by the manufacturer as accurately and reliably reporting players' reaction time. Since the timing system was set as "Start on Motion," it started to measure when detecting movement by the subject. The start sensor to detect the subject's movement was placed behind the subject. Subjects could anticipate the condition and start moving before the execution of the pass motion in the video clip; however, they were also instructed not to make a mistake by moving in the wrong direction and not make a random guess, as if they were playing in a real game. Data was collected using a video camera (EX-ZR1000, CASIO COMPUTER CO., LTD., Tokyo, Japan) with the frame rate of 120 fps and infrared timing gates (TC Timing System; Brower Timing Systems, Utah, USA). The screen on which the video clips were played and the red circle appeared, and the timing system display, where MT appeared, were all recorded within the same frame of the video camera. This was done for synchronization of key measures.

After an explanation of the experimental procedure and completion of the practice trials, subjects completed the experimental conditions in the following order: SDRT, MDRT, and then they completed the questionnaire. The recorded video was analyzed using the following key measures. All measurements were reported in seconds.

1. Motor Time (MT)-The time taken to perform the movement as measured by the timing system.

2. Displaying Time (DT)-The time lag between the subject breaking the timing system gate and the time when the MT measurement appeared on the timing system display. This was not measurable in the study setting; however, the timing system manufacturer confirmed the consistency of this time period.

3. Estimated Simple Reaction Time (ESRT)-The time between the frame with the red circle appearing and the MT being displayed. The time was measured by counting the number of frames between the two incidents at an accuracy of 0.008 seconds.

4. Premotor Time (PMT)-The time between stimulus presentation and the start of the MT. This was calculated by subtracting the MT and DT from the ESRT.

5. ESRT-MT-A finer calculation of the subtraction between the ESRT and MT, indicating a shorter PMT given that DT remains consistent.

Statistical Analyses

A two-factor mixed analysis of variance, with the within factor as "Tasks" (SDRT, MDRT) and the between factor as "Sports" (Soccer, Volleyball), was used to determine whether main effects and an interaction were present. Before calculation of the subject's ESRT-MT, the following data were excluded: fastest and slowest of each IR and OR for the SDRT; the fastest and slowest inside kicks among IR and IL; and the fastest and slowest outside kicks among OR and OL for the MDRT, which reduced the impact of outliers. Therefore, the average of the remaining six trials in SDRT and four trials in MDRT were used to calculate ESRT-MT per subject. A chi-squared test of independence was used for comparison of the results of all three sections of the questionnaire. All statistical analyses were performed using SPSS software (version 25; IBM Japan, Chuo-Ku, Tokyo, Japan). To compare the effect between the within factor and between factor, the generalized η2 was calculated and the comparison was based on the guideline (≥ 0.02 is a small effect, ≥ 0.13 is a medium effect, and ≥ 0.26 is a large effect) [16]. In addition, the effect of the differences between the tasks, SDRT and MDRT, was compared between groups using the Cohen's *d,* which followed the guideline >0.20 is a small, >0.50 is a medium, and >0.80 is a large effect [17]. An alpha level of $p<0.05$ indicated statistical significance.

Results

Table 1 shows the descriptive data for the ESRT-MT measurements. There was no interaction between Tasks and Sports, $F(1, 45)=1.45$, partial $\eta^2=0.03$, $p=0.235$. However, there was a significant main effect of the factor Tasks on ESRT-MT, $F(1, 45)=18.77$, partial $\eta^2=0.29$, generalized η2=0.08, $p<0.001$. ESRT-MT values were significantly smaller in the SDRT condition (M=0.71, SE=0.02, 95% CI [0.66, 0.76]) than in the MDRT condition (M=0.79, SE=0.02, 95% CI [0.76, 0.82]). Similarly, there was a significant main effect of the factor Sports on the ESRT-MT, $F(1, 45)=8.35$, partial $\eta^2=0.16$, generalized η2=0.12, $p=0.006$. ESRT-MT was significantly smaller for the soccer group (M=0.70, SE=0.02, 95% CI [0.65, 0.75]) than the volleyball group (M=0.80, SE=0.03, 95% CI [0.75, 0.85]). The Cohen's *d* for the soccer group was 0.47 (a small effect) and the Cohen's *d* of the volleyball group was 0.72 (a medium effect).

For the questionnaire responses, Tables 2 and 3 show the descriptive data for the cues used to anticipate actions. A chi-square test of independence was performed and no significant relationship between the response selections was found for SDRT (χ^2[4, N=47]=4.94, Cramer's V=0.32, $p=0.293$) or for MDRT (χ^2[4, N=47]=5.93, Cramer's V=0.36, $p=0.204$). Tables 4 and 5 shows the descriptive data illustrating how the subjects attended to the cues. None of the subjects chose "other," so this item was excluded from the analysis. A chi-square test of independence showed that there was no significant relationship for the SDRT (χ^2[1, N=47]=0.74, Cramer's V=0.13, $p=0.391$), or MDRT (χ^2[1, N=47]=3.31, Cramer's V=0.27, $p=0.069$). In addition, no significant relationship was found between sports for the difficulty between situations (χ^2[2, N=47]=3.91, Cramer's V=0.29, $p=0.141$). In this question, 22 subjects in the soccer group answered "Yes," and all of them answered "Yes" to the additional question. On the other hand, 18 subjects in the volleyball players answered "Yes," and one subject each answered "No" and "Unsure" while the remainder answered "Yes" to the additional question (Tables 1-5).

Table 1: Single Direction Reactive Test and Multiple Directions Reactive Test for ESRT-MT between Sports.

	SDRT		MDRT			
	Mean	S.D	Mean	S.D.	d	p
Soccer†	0.67	0.15	0.73	0.10	0.47	0.00*
Volleyball	0.75	0.17	0.85	0.10	0.72	0.00*

*Significantly smaller than MDRT (p<0.01); †significantly smaller than Volleyball (p<0.01)

Table 2: Questionnaire results for cues used to anticipate (Single Direction Reactive Test).

SDRT		Visual Cues chosen							
		Whole-Body Movement	Face	Arm/Shoulder	Foot/Leg	Ball	Total	X^2 (df=4)	p
Sports	Soccer	11	0	2	11	2	26	4.941	0.293
	Volleyball	5	1	0	13	2	21		

Note. N=47

Table 3: Questionnaire results for cues used to anticipate (Multiple Direction Reactive Test).

MDRT		Visual Cues chosen							
		Whole-Body Movement	Face	Arm/Shoulder	Foot/Leg	Ball	Total	X^2 (df=4)	p
Sports	Soccer	14	0	2	8	2	26	5.932	0.204
	Volleyball	5	1	1	12	2	21		

Note. N=47

Table 4: Questionnaire results for subjects observing the cue (Single Direction Reactive Test).

SDRT		How you saw the visual cue				
		Recognize "a pass"	Recognize "a change"	Total	X^2 (df=1)	p
Sports	Soccer	8	18	26	0.735	0.391
	Volleyball	9	12	21		

Note. N=47

Table 5: Questionnaire results for subjects observing the cue (Multiple Direction Reactive Test).

MDRT		How you saw the visual cue				
		Recognize "a pass"	Recognize "a change"	Total	X^2 (df=1)	p
Sports	Soccer	8	18	26	3.305	0.069
	Volleyball	12	9	21		

Note. N=47

Discussion

This study examined the differences in the PMT, the time from when the stimulus presented to when the subject started to move, among soccer and volleyball players when reacting in a soccer-specific situation. This study compared both the effects of the Tasks factor (i.e., SDRT, MDRT) and the Sports factor (i.e., Soccer, Volleyball). The PMT was shorter in the simpler task, SDRT, and in the groups with soccer-specific experience congruent with the video clips in the trials (Soccer group).

The differences in the PMT between Tasks indicated that the subjects started to move earlier in the simpler condition, which supported our hypothesis and the results of previous work [5]. Since the subjects in the SDRT condition already knew which direction to move in, they were only required to determine when to move. At this point, subjects needed to detect the initiation of movements that were definitely different from dribble actions and may not even need to recognize the model's action as pass execution. On the other hand, subjects in the MDRT situation had to perform two tasks: 1) Determining when to move; and 2) Determining in which direction to move. Then the subjects needed to recognize not only a change in the model's movements but also the direction that the ball was being kicked by detecting kinematic cues from the model's body movements. To perform these tasks efficiently, subjects were required to make a broad estimate to predict the likely movements for the direction of the pass based on the two choices, and they were required to estimate the kick technique based on the two choices, which required subjects to perform a sport-specific analysis for the situation. The MDRT task is more complex in terms of both numbers of choice and sports specificity for prediction, and thus it extended PMT.

The athlete's ability to estimate can be described as a component of anticipation. According to Williams et al. [6], the ability to anticipate in sports is the ability to reduce choices between possible movements, and this can be based on the assembling of information from different cues dotted within the field of vision, or on sport-specific memories. This ability to anticipate may sharpen the detection of the cue, which brings the initiation of the decision-making process forward and shortens the response selection phase time. Likewise, Serpell et al. [18] proposed that identifying key sport-specific kinematic cues in opponents is important to react more quickly. Additionally, skilled players are better at identifying these cues. Individuals with a better ability to anticipate and predict are able to initiate movement responses before the key movement triggering the reaction [19]. Thus, the results suggest that the ability to predict and anticipate sport-specific movements affects PMT, and players with more experience in a specific sport are better able to predict and anticipate. In our hypothesis, the difference in the PMT between the tasks would be larger in the volleyball group compared to the soccer group because the content of the unfamiliar soccer-specific information that they needed to process would be increased in the MDRT situation. The generalized η2 in the between-factor differences was larger than in the within-factor differences; moreover, the Cohen's *d* for the volleyball group was larger than the soccer group. These differences indicate that the differences in sports background between the athletes affected their performance.

The results shown in Table 1 demonstrate the influence of sport-specific experience on PMT in the two conditions and show that soccer players exhibited a smaller ESRT-MT than the volleyball players when reacting to a soccer-specific situation. Afonso et al. [20] classified two kinds of informational processing: top-down processing and bottom-up processing. They proposed that top-down processing is associated with an individual's previous experience in specific situations and bottom-up processing is associated with the recognition and detection of unexpected events or cues. Thus, in this experiment, the soccer players may have had faster top-down informational processing than the volleyball players due to the soccer-specific situation, which affected the results. In this regard, it is interesting to note that research has indicated that the ability to detect key kinematic cues tends to be superior in individuals who perform the related movements, such as athletes, as opposed to those who only watch the related movements, such as journalists [21]. This reasonably supports the results of this study, even when considering that the subjects in the volleyball group may have had a good understanding of human biomechanics and was aware of how to react appropriately to movements. This discrepancy may be related to the volleyball players' lack of experience in soccer-specific situations.

In addition, the results of the questionnaire provided some suggestions and potential explanations. More than 80% of all subjects chose either "whole-body movement" or "feet and legs" as cues to focus on the movement, although subjects in the volleyball group tended to choose "feet and legs" more often than "whole-body movement." However, as noted in the result section, the difference between groups was not significant, indicating that the subjects were aware of the cues providing the most information to recognize potential movements in a soccer-specific situation reported by Savelsbergh et al. [10]. The results of their study demonstrated that expert goalkeepers focused on the head area in the early phases of the visual search and that both the expert and novice goalkeepers focused on broad areas of the opponent's lower legs and the ball and not on a specific area when reacting to a penalty kick. They suggested that focusing on the position and actions of the kicker's head may have been used to recognize facial characteristics and that fixation on the broad area of the lower legs and ball was likely used to identify relevant information in the peripheral vision. As mentioned, anticipation, which leads to the ability to make a broad estimation, can be achieved by collecting and assembling information relating to the movements and situations to which they are reacting. In our study, soccer players tended to observe the whole-body movement to collect information as much as they can, suggesting that soccer players had the capacity pay attention to large areas of the body in addition to critical areas such as the lower extremity, whereas volleyball players tended to focus on the small areas such as the feet and legs.

Aside from the differences in the technique used to recognize soccer-specific movements, the differences in the identified cue could be due to the amount of information processing space that is used when performing a task. This is based on the concept of a capacity model of selective attention whereby unlearned tasks will consume a large amount of information processing space, resulting in a shortage of capacity for other tasks. This would then lead to a reduction in performance [22]. Attending to the soccer-specific movements in the lower extremities to recognize a future movement may have consumed a large amount of information processing space for the volleyball players since they are unfamiliar with the soccer-specific movements, resulting in limiting the capacity for other processing tasks and performing comprehensive decision-making by assembling the available relevant information.

The findings in this study indicate that cognitive functions are important factors when reacting in sport-specific situations. The efficiency of a player's anticipation and prediction in a sport-specific situation can be improved by specific, relevant experience. Training in sports-specific situations might be one key to improving performance, particularly in terms of prediction and anticipation of opposing players' movements. According to Young and Farrow [23], non-sport-stimuli, such as preplanned cutting drills may improve reaction times in terms of improving tolerance on time stress, but these drills should progress to tailored drills based on sport-specific situations as a way to maximize an athlete's performance and improve cognitive functions. Reviewing plays focusing on the components of reactive agility, including both cognitive and physical functions, may be important for players to improve sport-specific physical skills [24].

Conclusion

In summary, our results suggest that sports-specific experience affects the PMT. However, since the measurement in this study focused on when the motor phase process starts, rather than when the premotor phase starts, which ability among cognitive functions, such as anticipation, prediction, and response selection, subjects in the more experienced group used while reacting in the sport-specific situation is unclear. The questionnaire responses provided some suggestions regarding the techniques used to react in soccer-specific situations, but further studies comparing performance levels and ages in subjects playing the same sport are required, as are studies incorporating the complexities of different situations, including multiple players in the field of vision. Such future studies may help identify how different experiences affect cognitive function related to reaction time, such as the anticipation phase, prediction phase, or response selection phase.

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