READ-THE-GAME SKILL EVALUATION BY ANALYZING HEAD ORIENTATION IN IMMERSIVE VR

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ABSTRACT

This paper proposes a Virtual Reality (VR) system that allows both players and coaches to measure *Active Visual Exploratory Activity* patterns (AVEA). The main purpose of the system is to analyze the ability to "read the game" of soccer players under pressure. By making use of Head Mounted Display (HMD) technology and its head tracking capabilities, the users experience an in-game situation. They are set in the place of a defender with ball possession before making a passing decision while being pressured by a rival player. Therefore, being forced to make quick decisions based on visual information. By extracting the motion tracking data of the HMD, the gazing direction of the user is saved and divided in three zones of interest. A trial test was carried (N=10) to evaluate the system and the IPQ questionnaire was applied post session for analyzing AVEA performance and presence relationship.

Index Terms — Read the game, Virtual reality, Soccer, Football, Presence, Perceptual training, Visual exploratory activity, Active looking behavior, Training.

1. INTRODUCTION

For soccer players, the ability to find the best passing option is critical for good game outcomes. There is broad agreement that skilled perception is important for good performance in sports [1]. This is the case in team-based sports where athletes must make quick decisions in constrained situations under high pressure. The decisions are based on knowledge of the position of other players and how those players will change their position on the pitch, or as it is also known, the ability to "read the game".

In this paper, we propose a new immersive VR system that can log and analyze in the visual cognitive processes of the users by obtaining the head tracking information from the HMD. Therefore, it is possible to keep tracking of the head orientation of the user, while he searches for the best passing option under pressure from a rival player. Our final goal is to improve open play decision-making based on visual information.

The information related to the active visual exploratory activity (AVEA) patterns of the player (i.e., moving their bodies and/or heads for obtaining visual information) is obtained by making use of the HMD head tracking data. With this, it is possible to observe the radial range of visual search performed by the subject. The performance of the AVEA is assessed by dividing the Field of Regard (FOR) of the HMD into three (3) referential zones. The corresponding number of frames spend looking in direction to each zone during the VR session is logged. By calculating the percentage of total frames corresponding to each zone, the amount of wide AVEA per session is successfully obtained.

For the design of the simulation, elements of realism such as auditory and spatial fidelity were carefully considered and implemented to reinforce the sense of immersion inside the Virtual Environment (VE).

As an example of the type of studies that are made possible by our system, the subjects were asked to answer the Igroup Presence Questionnaire (IPQ) after using the simulation. This allows the comparison of objective visual performance data with subjective presence evaluation tools, exploring possible elements of presence that may affect the ability to "read the game" of athletes.

Main Contribution: Our work is the first to propose a technical solution for the study, training and development of the AVEA of soccer players. In comparison, other proposals that focus on eye-tracking while omitting the postural and head rotation approach proved to be insufficient for understanding the full visual exploratory activity in team ball sports [2].

Also, since the hardware employed for the system is commercially available and relatively portable, the proposed solution is easily applied in a variety of situations. For example, in the locker room to mentally warm up before a match, or even at home, which is a big advantage considering the time required to develop and optimize the individual behavioral skills. This cannot be done so easily with other type of solutions like CAVE or projector based systems.

The system also facilitates the future application of sport psychology studies to perceptual training, as is shown at the end of this paper with the IPQ questionnaire. Despite being a questionnaire applicable to any VR solution, it led to the subsequent discovery of a possible relationship between sense of involvement and performance of the AVEA inside the VE. This may help in future studies to further refine the simulator to assess, and effectively develop the ability to Read-The-Game in soccer players.

2. RELATED WORK

2.1 Read-The-Game: Perceptual Training in Soccer

Both mental and motor skills are of the utmost importance for soccer players. In the present work, we focus in the visual exploratory elements required to "Read the game." In soccer, the capacity of a player to correctly discriminate the actions unfolding around him, and to anticipate the moves of rivals and teammates in relationship to himself is known as the ability to "Read the Game"

Previous work [3] reported that the lack of this ability was related to problems of vision and intelligence in relation to the game. Experienced players could read and react quickly (i.e., passing the ball to a teammate with one touch) while inexperienced players were suggested to not be able to perceive the positional information from the other players with the same efficacy. Therefore, we focused on finding innovative ways to measure and analyze the AVEA patterns of players searching for passing options while under pressure from rivals. The proposed scenario

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requires the ability to quickly anticipate and react to the position of the players, and how they change their position on the pitch. In other words, to Read-The-Game.

Regarding the perceptual training in soccer, an extensive variety of studies have been made to elucidate how the information which is perceived by the human visual system is used to support decisions and actions in sports. A good resume of related research may be found on the book of Williams et. al (1999) [4].

Most of the experiments related to perception in sports make use of video images presented to the players, whom in turn are asked to follow certain instructions and respond accordingly to a given situation. Several of these studies are focused on the eye movement of the player, departing from the assumption that the eye fixation tells the object of interest. However, in the present work we focus on the body and head movements of players when making passing decisions. The reason for this approach is that it has been suggested that more extensive movements of body, head and eyes are required to be present to improve the visual search performance [2]. In response to this, we developed a training system focused on the measure and development of the AVEA behavior of the player.

Another aspect to consider about the approach of the studies described above, is that they lack the necessary immersive elements, and rely highly in the mental abstraction of the player, which leads to inconsistencies and sub-optimal results.

2.2 Virtual Reality Training in Sports

There is an increasing adoption of VR technologies for training several abilities. Related researches, focused on the skill transfer capabilities of VR to real world task oriented activities, have shown satisfactory results. There is research that suggests that VR can be effective for training motor skills in sports. Tai-Chi practitioners that employed both common video and VR technology to learn, practice and assess their performance throughout the exercises. In the mentioned research, the performance of those subjects that employed VR was approximately 25 percent more effective than learning from conventional video [5]. Another research measured the ability of expert and novice soccer players to make judgments about the ball's future arrival position [6]. As well, other research employed VR to teach successfully the disguise and deceit strategies employed by rugby attacking players to fool a defender VR [7].

Thanks to the high adaptability of the VR technologies, it allows the researchers to conceive cognitive, and to a certain extent, physical training experiences. These limitations are inherited from the constraints and characteristics of the VR platform of choice. For the present research, the field of regard (FOR) of 360 degrees of the Oculus Rift, which is the chosen HMD, offers the perfect environment to study and train the AVEA patterns of the players.

3. EXPERIMENT

3.1 Virtual Reality Simulation

For the simulation, the system was required to be able to have 360 degrees of FOR to allow the user to engage in full range active exploratory activity. Since we are focused on body and head movement patterns, there was no need to apply eye tracking. Considering this, and the fact that one long term objective of this project is to give the chance to the players to train with technologies available to the mass market, the retail version of the Oculus Rift CV1 was a fitting choice.

A soccer in-game situation is recreated in Virtual Reality (VR) using 3D Computer Graphics (CG) with Unity 3D as the development platform. The reason for choosing CG and not real life video from a design perspective, is that it makes possible to

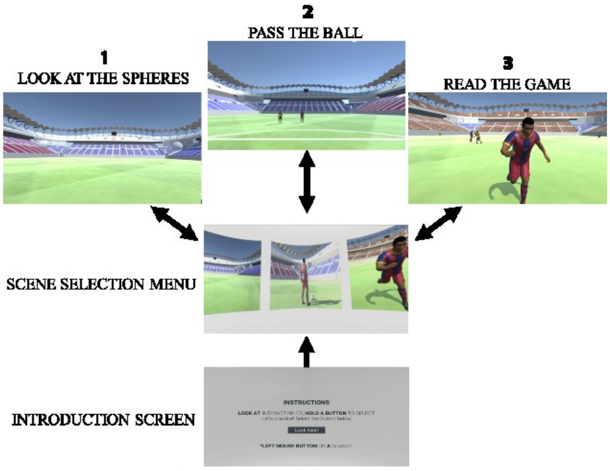

Figure 1. Simulation Workflow

recreate various situations at will in contraposition to real video, that require the collaboration of athletes and other elements that were required for the simulator. The test subject from a first-person perspective is put in a situation where he/she is in possession of the ball, and experiences the pressure from an opponent player prior to making a pass to another team member. Before the main test scene, the user experiences an introduction and two short tutorial scenes to get used to the simulator mechanics and structure. The users (N=10), composed of self-assessed Beginner level soccer players, would experience the simulation by means of a Head Mounted Display, while the data from their gazing behavior is obtained for further analysis.

The main goal is the assessment of the proposed system for Read-The-Game skill training in soccer, and measuring the sense of presence experienced in the proposed virtual environment (VE). In figure 1, the simulation workflow can be appreciated.

After explaining to the user both the conditions and rules of the experiment, he proceeds to put on the HMD while holding a Microsoft Xbox One PC controller in his hands. When the simulation starts, the user first encounters an introduction screen that explains the gaze based input mechanics. One pink crosshair with round shape on the center eye of the screen serves as the pointing reference. When the user looks in the direction of an interactive item, by the push of one button of the controller the interaction occurs. After two (2) successive messages that asks the user to look and interact with virtual buttons, the user accesses the scene selection menu. This menu displays the three scenes to be engaged in numerical order, from left to right and is asked to access them in order, from scene one (1) to three (3).

In scene one (1) *Look at the spheres*, the main purpose is to allow the user to get used to the VR gaze pointer mechanics. By asking him to search and gaze four (4) spheres positioned around him/her in an empty soccer stadium pitch, which would be the main background for the whole simulation, the user engages in visual search of the four objects. Whenever the user looks directly to one sphere it changes of color and a sound is played, after successfully finding the four spheres, the scene returns automatically to the scene selection menu, and the user proceeds to select the next scene.

In scene two (2) *Pass the ball*, the user now find himself in the same position at the pitch, but now faces three (3) teammates in yellow, and three (3) rivals in red, positioned in pairs (one teammate beside one rival) in three (3) distinct locations around him. The objective of this scene is getting him used to the player models used in the upcoming scene. In this occasion, the user is required to make a successful pass to the teammates by looking in their direction and pressing the action button of the controller. If the pass fails and the ball don't reach the teammate, the user is required to do it again until he succeeds with each of the 3 teammates.

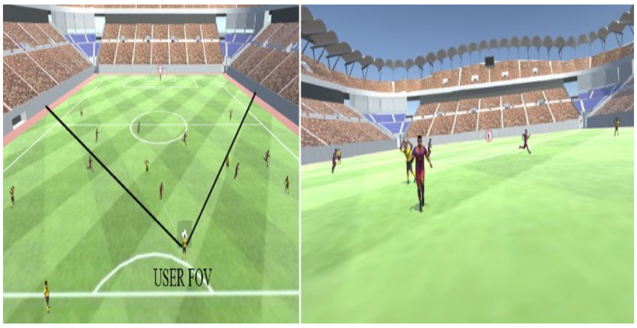

Figure 2. (Left) Unity editor snapshot from the scene view, depicting the FOV of the user and the spatial relation of the scene. (Right) What the user sees in the HMD.

Audio is present, and the user can hear both an empty stadium ambient sound and ball kick every time he makes a pass, all with purpose of creating a better sense of immersion. After the task is completed successfully the scene returns to the scene selection menu, before accessing the main test.

For scene three (3) *Read the game*, which is the main test scene, before advancing to it the user is warned to be quick in his decision making. He is also told that the teammates are waiting for him to pass the ball, and he will receive pressure from a rival that will come towards him to try to tackle and make him loose ball possession. The head tracking information is logged and saved during the whole scene. In Figure 2, we see on the left the editor view of a user experiencing the simulation with the corresponding FOV, and what the user HMD sees on the right. The spatial relationship was carefully recreated inside Unity by applying the real measures as stated by FIFA [8]. The measures were translated from meters into Unity units, to preserve fidelity between the VE and reality.

In real games, the objective of the pressing player is "to prevent the ball from approaching the defended goal or to prevent an opponent player from sending or receiving a pass. Let us call the direction from the pressure target towards the goal or a teammate "*threat direction*". The movement in this direction can most effectively be prevented or obstructed by the presser when he is positioned on the movement vector in front of the target." [9]. Based on this principle, the test scene was designed in a way that the rival pressing player comes towards the user while obstructing the effective passing area. Other rival players are running towards some of the teammates to further reduce the passing options of the user, with only two (2) teammate players without rival marking, and in advantageous position for receiving the pass.

This creates a situation where the passing player is forced to look, analyze, anticipate and make decisions based in a considerable amount of visual information. All in a short timespan (less than seven seconds), just like real players do in a real match. The two players without rival marking are located to the left of the user at θ =90°and 100° respectively, where θ = 0 is the initial position of the user head looking forward towards the rival goal. This means that for the user to see them and perform a pass, he/she is required to rotate his head >=90° to the side, engaging in both long and 180° exploratory activity. The justification for choosing this specific wide area of interest is that this type of wide visual exploratory activity has been linked to more experienced players in past studies. They tended to spend less time fixed on the ball and more time exploring wider areas of the field in comparison to less experienced players [10].

In this scene, elements such as presence of the crowd and strong, real ambient sound recorded of a sold-out game adds to the elements of pressure and immersion of the simulation. Also, the height and physical properties of the players and ball were taken into consideration for the conception of the scene.

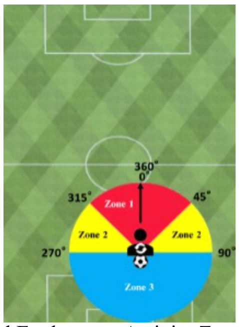

Figure 3. Visual Exploratory Activity Zone Division

3.2 Head Orientation and Active Visual Exploratory Activity Performance

In the Oculus Rift CV1, rotation is registered as a unit quaternion, but can also be reported in yaw-pitch-roll form, this last form is the one we used to easily understand where the user is looking each frame. As stated in Oculus official documentation: "Positive rotation is counter-clockwise when looking in the negative direction of each axis, and the component rotations are: Pitch is rotation around X, positive when pitching up. Yaw is rotation around Y, positive when turning left. Roll is rotation around Z, positive when tilting to the left in the XY plane." [11]. From that info, the head movement direction and ergo the exploration frequency of the player can be studied. The degree of rotation of the HMD of the user makes possible to know how much he/she is rotating his head in search of good passing options.

For making the analysis of the data easier, criteria for punctuating the high AVEA was defined by dividing the 360° (FOR) area into zones. Zone 1 pertains to the area in front of the user between 45° and -45° (315°). This is the area that requires less rotation of the head and body to search. Zone 2 pertains to the area between 45° and 90° to the right, and -45 (315°) and -90 (270°) to the left of the user. This area requires a wider active looking activity. Zone 3 is the area located at >90° and <270° clockwise, covering the full area behind the user. This zone requires the widest active looking activity of 180°. A comprehensive diagram of the zonal division and its respective angles for measuring the Visual Exploratory Activity can be observed in Figure 3.

The gazing direction of the center eye of the HMD is logged frame by frame during scene three (3), *Read the game*. Then based on the number of frames spend in each Zone during the test, the respective percentage value per Zone is obtained. For the present experiment, long and 180° exploratory activity as defined by Fagereng (2010) [12], was calculated based in the visual explorations between zones 2 and 3, and on the total percentage of the frames spend between both zones during the test session. The cumulative percentage would be considered as the resulting score, which relates to high active visual exploratory activity performance engaged during the session.

3.3 Presence Questionnaire

After experiencing the simulation, a presence questionnaire was answered by the test subjects. The reason for choosing the Igroup Presence Questionnaire (IPQ) is that its psychometric values consistency was put to the test and validated with multiple samples. The authors states that the sense presence is a variable of a user's experience. Reason why they rely on self-reports for measuring presence employing a seven (7) point Likert Scale [13]. A strong point of the IPQ is that it allows to make distinction between three factors of presence: spatial presence (five questions), involvement (four questions), and sense of realism (four questions); an extra question measures the general presence,

AVEA Performance Correlations	IPQ	PRES	REAL	INV	SP
Pearson Correlation	-.481	-.106	-.434	-.668*	-.137
Sig. (2-tailed)	.159	.771	.210	.035	.706
N	10	10	10	10	10

Table 1. Active Visual Exploratory Activity Performance and elements of Presence Correlations. IPQ: total score of the IPQ questionnaire, PRES: General presence, REAL: Sense of realism, INV: Involvement, SP: Spatial presence. **Correlation is significant at the 0.05 level (2-tailed)*

to make the total of fourteen (14) question items. Each factor can be measured individually or the total value obtained across all items can be used to compose a global Presence valuation [13].

4. ACTIVE VISUAL EXPLORATORY ACTIVITY PERFORMANCE AND PRESENCE RELATION

Correlation tests were carried to explore if there is some relationship between AVEA performance and elements of Presence, the results may be observed in Table 1. Both, the long and 180° exploratory activity performance values obtained at the test and questionnaire total computed values were found to be normally distributed by Shapiro-Wilk test (total sample, Test p = 0.069 and Presence p = 0.137). Normality was also confirmed for the independent correlation tests regarding the Factors of presence. By performing correlations tests between Performance and Presence values, no statistically significant relation was found between presence and performance. Neither between performance and three of the four factors that compose presence. Interestingly, a strong negative significant correlation r= -0.668 was found between the factor of Involvement and AVEA performance. The criteria employed to stablish the degree of relation is the one stablished by Cohen (1988) [14].

This inverse relationship between Involvement, which translates in the degree of attention devoted to the VE, and performance may stem from the fact that the higher involvement is translated in a higher exposure to the stress-inducing elements of the simulation. For example, the crowd, visual stimuli and overall competitive feeling, may induce higher tension and mental stress, which has been demonstrated to impair decision speed [15]. From these findings, is possible to infer that increasing the sense of *Involvement* is a key element to add real mental stress to the user, which impairs his capacity of actively look and think for passing options and overall in-game decision making. We expect to see this trend in further studies. These results encourage further analysis, that could help identify the key presence related elements to be considered, to maximize the accuracy of VR based sport training systems for visual exploratory activity training.

5. CONCLUSIONS AND FUTURE WORK

In this paper, a novel system for measuring *Active Visual Exploratory Activity* performance of soccer players was proposed. Through the experiment, the capacity of the system to measure the active visual exploratory activity patterns was confirmed. The system allowed us to give a value to wide exploration activity through the HMD head tracking capabilities, while players make passing decisions under pressured by a rival player. In other words, it was possible to measure the “Read the Game” skill of soccer players. Also, elements of presence were measured with the IPQ. Statistical analysis was done with the objective of searching possible relations between presence and active visual exploration activity performance. As a result, a negative strong correlation between involvement and visual exploratory activity performance was found. In future work, more tests and questionnaires with larger number of samples, and players with different amount of experience in soccer should be implemented to further improve the system. This may change or rather corroborate the obtained results during our test, but we expect to see a similar tendency in future tests. As well, coaches could evaluate not only the visual exploratory activity but also the passing decision criteria under various circumstances recreated with the simulator. Finally, comparison of the effect of using different media on the players should be conducted (e.g., psychophysiological response to CG stimuli in comparison to “real” video stimuli).

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