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Original Scientific Article

Evaluation of Factors Influencing Assistant Referee Decisions in Determining "Offside" in Football

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Abstract

Background and Study Aim. The human factor and referee errors are an inherent part of football. The number of mistakes can be significantly reduced, but it cannot be completely eliminated. At the same time, we must understand the nature of the error, what exactly influences the occurrence of the mistake, which part of the error is a subjective factor, and which part is an objective factor that is less susceptible to correction and does not depend on the referee's practice, experience, and training. This study is based on the procedure and factors that influence decision-making in the context of Law 11 (Offside). Decisions regarding the "offside" position are made by assistant referees and are among the most complex and discussed topics among experts and fans. The goal of the study is to determine the factors influencing the assistant referee's decisions when determining "offside" in football.

Material and methods. The study involved 33 football assistant referees of different qualifications, including assistant referees from the Youth Football League of Ukraine, the Professional Football League of Ukraine, and the Ukrainian Premier League. The following research methods were used during the study: non-interventional observation, where regular observation was conducted from the side to study the decision-making process on the football field; video content analysis, where the technical aspects of referees' behavior were assessed; statistical methods to process the quantitative data obtained during experiments and observations; and the modeling method, which involved creating 3D computer models to analyze the impact of assistant referees' positions on the assessment of situations related to the interpretation of Law 11.

Results. The conducted research allowed for the identification factors that influence the decision-making process regarding the determination of the "offside" position.

Conclusions. Factors influencing the decision-making process regarding the determination of the "offside" position have been identified: AR's position relative to the offside line, focus shift to the player making the pass, level of concentration, movement of attacking and defending players, attacking players in offside position and possible movement of defenders, number of attacking and defending players, type of AR movement along the sideline, head, torso, and body movements, distance between attacking and defending players, fatigue, color of stands and advertising boards, style of the football field's grass cutting.

Key words: assistant referee, offside position, influencing factors, decision making.

Анотація

Оцінка факторів впливу на рішення асистента арбітра при визначенні положення «поза грою» у футболі

Анатолій Абдула, Станіслав Марулін

Передумови та мета дослідження. Людський фактор та помилки арбітрів є невід'ємною складовою футболу, кількість помилок можна значно зменшити, але не можна прибрати на 100%. Але в той же час ми повинні розуміти природу помилки, що саме впливає на факт виникнення помилки, яка частина помилки

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це суб'єктивний чинник, а яка об'єктивний чинник, який мало піддається корегуванню і не залежить від практики, досвіду та навченості арбітрів. В цьому дослідженні взято за основу процедура та фактори, що впливають на прийняття рішення в контексті правила №11 Offside. Рішення стосовно положення "поза грою" приймаються асистентами арбітра і є найбільш складними та обговорюваними серед фахівців та вболівальників. Метою даного дослідження є визначення факторів, що впливають на рішення асистента арбітра при визначенні положення «поза грою» у футболі.

Матеріал і методи. У дослідженнях приймали участь 33 асистентів арбітрів з футболу різної кваліфікації, включаючи асистентів арбітра дитячо-юнацької футбольної ліги України, професійної футбольної ліги та Української прем'єр ліги. Під час дослідження були задіяні такі методи дослідження як неінтервенційне спостереження, коли відбувалось звичайне спостереження зі сторони за процесом прийняття рішень на футбольному полі; метод аналізу відео-контенту де відбувалась оцінка технічних аспектів поведінки арбітрів; метод математичної статистики для обробки кількісних даних, отриманих під час експериментів і спостережень; метод моделювання, який включав створення комп'ютерних 3D моделей для аналізу впливу позиції асистентів арбітрів на оцінку ситуацій пов'язаних з трактовкою правила №11.

Результати. Проведені дослідження дозволили визначити фактори, що впливають на прийняття рішення стосовно визначення положення "поза грою".

Висновки. Визначено 12 факторів, що значно впливають на прийняття рішення стосовно визначення положення "поза грою": позиція AR відносно лінії поза грою, перенесення фокуса на гравця, який робить передачу м'яча, рівень концентрації, рух гравців, що атакують і захищаються, атакуючі гравці в положенні «поза грою» та можливі переміщення захисників, кількість гравців, що атакують і захищаються, тип руху AR вздовж бокової лінії, рухи голови, тулуба та тіла, відстань між гравцями, що атакують, і гравцями, що захищаються, втома, колір стендів і рекламних щитів, стиль стрижки трави на футбольному полі.

Ключові слова: асистент арбітра, положення "поза грою", фактори впливу, прийняття рішення.

Introduction

Football is not only a game but also a powerful socio-political phenomenon that influences people's lives, culture, and politics. Football often serves as a symbol of national or regional identity and national unity.

Particular attention is given to the game even during times of war, and it is not by chance, as it helps to perform several important functions, even in the context of conflict. Unity and support, distraction from reality, humanitarian aid, infrastructure restoration, political statements, and international support are just a few examples of the impact the game has on millions during difficult times for a country.

In this context, the role of the referee and assistant referees (AR) increases as official figures in a match, ensuring the integrity and fairness of the game outcome, which is crucial for the trust of players and fans. Their work requires a high level of professionalism, concentration, and the ability to make quick decisions.

At the same time, the cost of referees' mistakes grows, as they can influence various aspects of the game and society, such as:

1. **Financial Impact.** Mistakes can lead to unfair results in matches, affecting the clubs' revenues from ticket sales, TV rights, and sponsorships. Controversial decisions may alter a team's chances of qualifying for tournaments with large financial rewards. 2. **Reputation and Trust.** Repeated mistakes can undermine trust in referees and the system of officiating. Fans, players, and clubs may lose faith in the fairness of the game, leading to calls for changes in refereeing standards or the introduction of new technologies.

3. **Social Media Reaction.** In the modern digital age, mistakes are often amplified on social media. The response can be intense, leading to public outrage and criticism of referees, further affecting the perception of the game's fairness.

4. **Impact on Fans.** A referee's mistake can have a significant impact on fans, leading to disappointment, anger, or even violence in extreme cases. Emotional attachment to teams makes these mistakes particularly significant.

Thus, the consequences of referees' mistakes in football go beyond the field, affecting finances, reputation, morale, and fan engagement.

Sports organizations such as FIFA, UEFA, and regional associations invest considerable physical, moral, and financial effort to improve the professional level of refereeing. In recent years, many innovative computer technologies and artificial intelligence have been introduced to assist in making accurate and fair decisions, such as:

- Goal Line Technology (GLT).
- Video Assistant Referee (VAR).
- Semi-automated Offside Technology (SAOT).

Indeed, these technologies significantly improve objectivity and assist in making correct



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decisions, but is it possible to eliminate mistakes entirely, and could referees be replaced by artificial intelligence? How would this affect the game as a whole?

Currently, the complete replacement of referees with artificial intelligence in football seems unlikely because football is not just a sport but a culture where human interaction is important. Referees act as intermediaries who can understand the emotions of players and the context of situations. Some game moments are very complex and require intuitive understanding, which is difficult to program.

The absence of the human factor could raise ethical questions and erode trust in the system. Players and fans might be less inclined to accept decisions made by machines.

Therefore, the human factor and referees' mistakes are an inherent part of football. The number of mistakes can be significantly reduced, but it is almost impossible to completely eliminate them 100%. However, we must understand the nature of mistakes, what influences their occurrence, what part of the mistake is subjective, and what part is an objective factor that is little affected by practice, experience, and training of referees.

This study focuses on the procedure and factors influencing decision-making in the context of Law 11 - Offside. Decisions about "offside" are made by AR and are among the most complex and debated by experts and fans. Currently, semi-automated offside technology (SAOT) is being actively implemented. SAOT uses a combination of optical tracking and artificial intelligence to monitor players' movements and the ball's position in real time. The system relies on three main aspects: cameras, artificial intelligence, and data processing, as well as instant feedback systems.

SAOT can also generate 3D animation that visually represents the offside decision. This animation can be shown to spectators in the stadium and viewers at home, ensuring transparency and a clear understanding of why the decision was made.

However, this technology has a significant drawback, as it undermines the human element of refereeing, leading to a more sterile interpretation of the game, where "fine" offsides that might have gone unnoticed in real-time are flagged.

In any case, this technology is a tool to assist and support the referee's decision, but mistakes can still happen, and it is essential to understand how to perceive these mistakes, even after they have been corrected by artificial intelligence.

In football, being in an offside position is not considered an offense, but a player is in an offside position in two cases [1]:

• when any part or the whole of the head,

• when any part or the whole of the head, body, or foot is closer to the opponent's goal line than the ball and the second-to-last player of the defending team.

It should be noted that a player in an offside position only violates the rule when, at the moment the teammate plays/touches the ball, the attacking player in the offside position is actively involved in the play.

The assistant referee interprets all the criteria established by the laws of the game, Law 11, for the correct assessment of the position and actions of the player in the offside position, determining whether the player should be penalized for that position.

The process of correctly interpreting and determining Law 11 may be complicated by objective and subjective factors, as well as the training, practical experience, and knowledge of the assistant referee.

Purpose and objectives of the research

The goal of the study is to determine the factors influencing the assistant referee's decisions when determining "offside" in football

To achieve the goal of this study, the following tasks need to be addressed:

determine the factors that affect the accuracy of decisions made by assistant referees in identifying violations of "offside";

• develop a 3D graphic modeling that explains the nature of erroneous decisions regarding the position of the assistant referee to the penultimate defender during the game; determine the distance between the defensive player and the player in the "offside" position, which arises as a result of the action of objective factors that affect the actions of the AR during the game.

Materials and Methods

Participants

The study involved 33 assistant referees from football of various qualifications, including assistant referees from the Ukrainian Youth Football League, the Professional Football League, and the Ukrainian Premier League.

Procedure

The following research methods were used during the study:

• Non-intervention observation in the form of naturalistic observation of the decision-making mechanics of assistant referees on the football field during matches of the Ukrainian Youth League and competitions among amateur teams. The observation covered assistant referees of

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both amateur and professional competitions.

 Video content analysis method, which involved systematically studying video materials to identify certain behavioral patterns during decision-making. A total of 250 games from the Ukrainian Youth League, second and first professional leagues, the Ukrainian Premier League, the Champions League, the Conference League, the Europa League, as well as the World Cup and European Championship were analyzed. Typical aspects influencing the quality of decision-making were identified. Additionally, 25 special video fragments simulating situations [2] on the football field, created by trained athletes, were analyzed. This resulted in quantitative data for further statistical analysis. Under each video, a delay time was provided, characterizing the position of the attacking player relative to the second-last defender. The "-" sign represented the time remaining before the player entered an offside position, while the "+" sign indicated the time the attacker had already been in an offside position.

• Mathematical statistics methods (mean and mode) for processing the quantitative data obtained from the experiments and observations of the previous points.

• Modeling method, which included the creation of computer 3D models to analyze the influence of assistant referees' positioning on the assessment of situations related to the interpretation of Law 11.

Interim results

33 assistant referees of different categories reviewed 25 specialized clips. The following results were obtained:

- Clip with no mistakes made by any referee/ assistant: #3

- Clip with the highest number of mistakes: #5

- Overall, 7 clips (40%) did not cause any issues (0-1-2-3 mistakes), meaning that almost all referees/assistants correctly decided whether to raise the flag or keep it down.

- 9 clips (36%) had the highest number of mistakes (12-10-9-7).

- For the 9 clips with the highest number of mistakes, the average time before the "offside" position was 0.048 seconds. This indicates that assistants raised the flag, but there was no "offside"!

- The average number of mistakes for "more" experienced referees was 32%, while for "less" experienced referees, it was 36%.

The figure 1 illustrates the total number of correct and incorrect responses for each clip.

literature review

The possible nature of AR errors and the relationship between the geometric position of the AR

The work [3, 4, 5] describes the potential impact of errors depending on the position of the assistant referee and the location where the offside position occurs on different areas of the field.

Figure 2 illustrates the areas where the assistant referee may make incorrect decisions, such as raising the flag incorrectly or failing to raise it at the right moment, due to the assistant referee's position ahead of the offside line (the "Ahead" position) (a geometric effect).

On Figure 3, the areas are shown where the assistant referee could potentially mistakenly raise the flag or fail to raise it, not only due to an "Offside" position but also because of the flash-lag effect. It should be noted that flag-raising errors and flag-not-raising errors are not topographically

NUMBER OF CORRECT AND INCORRECT ANSWERS PER CLIP 25 CLIPS, 33 RESPONDENTS



Figure 1. Total number of correct and incorrect answers for each clip

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Figure 2. Areas where incorrect decisions may be made (errors in raising the flag/failing to raise the flag) due to the assistant referee's position



Figure 3. Areas of the field where flag-raising errors or failure to raise the flag may occur due to the position of the assistant referee and the flash-lag effect

symmetrical, unlike in Figure 2. The area of flagraising errors has expanded under the influence of the flash-lag effect, while the area of flag-notraising errors has decreased.

In the work by [6], the following cases are described:

 Changes in the number of incorrect decisions during the match;

• How the topographical position of the attacking player relative to the offside line influences the making of correct or incorrect decisions;

How the topographical position of the assis-

tant referee relative to the offside line affects the making of correct or incorrect decisions.

It is concluded that increasing the distance between the attacking player's position and the offside line encourages a higher number of correct decisions compared to incorrect ones. In 88.6% of cases when attacking players were ahead of the offside line, correct decisions were made. In 88% of cases when incorrect decisions were made, the players were in an offside position.

Regarding the distance at which the assistant referee is positioned ahead of the offside line,

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there were no significant differences between correct decisions (0.81 meters) and incorrect decisions (0.77 meters). 80.8% of correct decisions and 88.6% of incorrect decisions were made when the assistant referee was ahead of the offside line.

Over the course of the match, the number of offside errors did not increase, with the highest percentage of errors occurring in the first 15 minutes of the match (38.5%). This indicates that the assistant referee requires some time to adapt to the typical movements of defending and attacking players around the offside line.

Visual factors caused by incorrect positioning of the assistant referee slightly contribute to the flash-lag effect, increasing the flag-raising error rate to 86.6% compared to the rate of not raising the flag (13.4%).

In the work by [3], the displacement distance due to the flash-lag effect is calculated as the product of the attacker's speed and the delay magnitude (from 0.02 to 0.64 meters) (D in Figure 3) when the attacker's speed is 2-8 meters per second and the flash delay is 10-80 milliseconds [3, 7, 8].

The perceptual error due to the flash-lag effect aligns with the distance of the attacking player from the offside line. The effect of the flash-lag is stronger when the second-to-last defender and the attacking player are running in opposite directions.

Experiments with professional ARs

In the work by [9], the influence of the flashlag effect on offside violations was studied. The research involved professional referees who made offside decisions on the field using computer animation and recordings of real matches. The findings confirmed the impact of the flash-lag effect on decision-making.

It is important to note that experienced assistant referees have the necessary skills to consider the current situation on the football field and the appropriate context of the situation when making decisions, unlike less experienced assistant referees.

The researcher [8], in order to assess the skills of offside detection, used the following test data:

Standard on-field situations;

Computer simulations;

 Determining offside positions based on video recordings of real matches.

The on-field offside review for FIFA category ARs demonstrated that the probability of errors (either raising the flag incorrectly or failing to raise it) was 20% in situations where the attacker was in a static position relative to the defender. The highest number of correct decisions (81%)

occurred when the assistant referee lagged behind the second-last defender's line.

In cases involving dynamic defensive actions, the probability of errors (either raising the flag incorrectly or failing to raise it) was 24%. Similarly, the highest number of correct decisions (74%) was observed when the assistant referee lagged behind the second-last defender's line.

In addition, we noticed an interesting dependence between the distance between the attacking and defending players and the number of errors made, both with raising the flag and failing to raise it:

 distance < 25 cm: 20% errors from not rais- ing the flag – 50% errors from raising the flag;

distance 25 cm – 50 cm: 22% errors from not raising the flag - 35% errors from raising the flag;

• distance 50 cm - 75 cm: 15% errors from not raising the flag – 25% errors from raising the flag;

• distance 75 cm - 100 cm: 1% errors from not raising the flag - 20% errors from raising the flag;

• distance > 100 cm: 1% errors from not raising the flag – 7% errors from raising the flag.

The results of offside review for FIFA ARs using computer animation at a frame rate of 6/8 fps showed a high average rate of correct decisions (73.7%, 3207 decisions) based on the position of the attacker relative to the offside line (-20, -10, 0, 10 pixels) and the static or dynamic nature of the episode.

Conducted experiments and 3D modeling

On Figure 4, a situation on the football field is modeled in a 3D projection, where the assistant referee is positioned in line with the second-tolast defender (D) and is able to correctly determine the position of the attacking player (A1) at the moment the ball is passed by the teammate (A2), thus making the correct decision. There is no offside. The situation takes place at the far end of the field, away from the assistant referee.

Figure 5 depicts a game episode identical to the previous one, but the assistant referee is ahead of the line with the penultimate defender (D), which undermines the ability to accurately assess the attacking player's (A1) position at the moment the ball is passed by a teammate (A2). No offside position exists. There is an increased likelihood of incorrect assessment of the episode due to the different viewing angle.

Figure 6 depicts a game episode where the assistant referee is aligned with the penultimate defender (D) and has the ability to accurately assess the position of the attacking player (A1) at the moment the ball is passed by a teammate (A2). Offside is present. The situation occurs on



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Figure 4. Position of the assistant referee on the line of the penultimate defender. The situation occurs on the far side of the field from the assistant referee. No offside is present.



Figure 5. The assistant referee is ahead of the offside line. The situation occurs on the far side of the field from the assistant referee. No offside is present.



Figure 6. The assistant referee is on the same line as the penultimate defender. The situation occurs on the far side of the field from the assistant referee. Offside is present.

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Figure 7. The assistant referee is behind the offside line. The situation occurs on the far side of the field from the assistant referee. Offside is present.



Figure 8. The assistant referee is on the same line as the penultimate defender. The situation occurs on the closer side of the field to the assistant referee. No offside is present.

the far side of the field from the assistant referee.

Figure 7 depicts a game episode where the assistant referee lags behind the penultimate defender (D) and cannot accurately assess the attacking player's (A1) position at the moment the ball is passed by a teammate (A2). Offside is present. There is an increased likelihood of incorrect assessment of the episode due to a different viewing angle.

Figure 8 depicts a game episode where the assistant referee is on the same line as the penultimate defender (D), but unlike the previous episode, the players (D and A1) are located on the closer side of the field relative to the assistant referee. No offside is present.

Figure 9 depicts a game situation identical to Figure 5, but in this situation, the assistant referee is ahead of the line with the penultimate defender (D) and cannot accurately assess the position of the attacking player (A1) at the moment the ball is passed by a teammate (A2). The pair of players (D and A1) are on the closer side of the field to the assistant referee. No offside position exists. There is an increased likelihood of incorrect assessment of the episode due to the different viewing angle.

Figure 10 depicts a game situation where the assistant referee lags behind the line with the penultimate defender (D) and cannot accurately assess the attacking player's (A1) position at the moment the ball is passed by a teammate (A2). The players (D and A1) are on the closer side of the field to the assistant referee. No offside is present. There is an increased likelihood of incorrect assessment of the episode due to a different viewing angle.

3D modeling tools and the depiction of the assistant referee's viewing angle provide a clear representation of the impact of the assistant referee's position – position ahead of the offside line, position behind the offside line, and position aligned with the offside line – on the accuracy of



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Figure 9. The assistant referee is ahead of the offside line. The situation occurs on the closer side of the field to the assistant referee. No offside is present.



Figure 10. The assistant referee is behind the offside line. The situation occurs on the closer side of the field to the assistant referee. No offside is present.



Figure 11. Situation determining the offside position with two attacking players and two defending players moving in opposite directions

decision-making. The position of the attacking and defending players relative to the assistant referee (on the near side, far side, or middle of the field) also has a significant impact on decision-making accuracy.

In the work [4], the optical effect of incorrect viewing angles on correct/incorrect decisions regarding the offside rule is discussed.

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The following factors that both negatively and positively affect the assistant referee's decisionmaking are presented:

1. Attention shifting factor. Assistant referees often focus their attention on the player making the pass to a teammate in a potential offside position [10].

2. Movement method along the sideline. The assistant referee's movement method sprinting, walking, jogging, or being stationary – significantly impacts the accuracy of decisions [4].

3. Fatigue. Maintaining a high and constant pace of play on the part of the assistant referee leads to fatigue, which increases the likelihood of errors [11].

4. Number and direction of movements of attacking and defending players. The number and direction of movement of attacking and defending players (Figure 11) can also affect the decision-making process of the assistant referee.

In this situation, the attacking player (A1) is moving to the left of the assistant referee, while another attacking player (A2) is moving to the right of the assistant referee and positioned ahead of player A1. The defending player D2 is moving to the right of the assistant referee, and player D1 is moving to the left of the assistant referee.

Based on the research of the mentioned authors and the personal experience of the assistant referee, the following factors influencing the accuracy of decisions regarding the offside rule can be identified:

1. Position of the assistant referee relative to the offside line. The assistant referee's position relative to the offside line is key to making the correct decision.

2. Focus shift to the player making the pass. Shifting the assistant referee's attention to the player who is making the pass changes the ability to correctly assess the subsequent situation on the field.

3. Concentration of attention. The assistant referee's concentration on the events on the field significantly influences accurate decision-making.

4. Movement of attacking and defending players. The direction of movement of the attacking and defending players may complicate the assessment, especially if they are moving in opposite directions.

5. Attacking players in an offside posi-tion and possible movements of defenders. The positioning of attacking players relative to the offside line and potential movements of defenders affect the assistant referee's decision.

6. Number of attacking and defending **players.** The number of players involved may influence the assistant referee's ability to make a

clear assessment.

7. Movement style of the assistant referee along the sideline. Whether the assistant referee is walking, jogging, running at speed, or stationary may influence their ability to accurately assess the game.

8. Head, torso, and body movements. The assistant referee's head and body movements can affect their field of view and perception.

9. Distance between attacking and defending players. The spatial relationship between players, both in terms of depth and length of the field, is important for an accurate offside assessment.

10. Fatigue.

11. Color of stands and advertising **boards**. The color and contrast of surrounding elements can affect the assistant referee's visual perception and focus.

12. Grass cutting style and pattern on the football field. The clarity and direction of grass stripes on the field can affect visual judgment and perception.

These factors, in varying proportions, may influence the accuracy of decision-making, and this impact can be reduced through prior preparation and training for such situations.

Discussion

The brain of a baseball player, when catching a fast-moving ball, makes predictions by extrapolating the position of the object along its perceived trajectory [12]. In the same way, the assistant referee tries to understand the positioning of attacking players with respect to the offside rule. Predicting where the baseball will be at a certain moment is a good example of this process, whereas for the assistant referee, such predictions can potentially lead to mistakes in determining an offside position.

Several scientific studies identify factors that influence the speed of visual perception. Let's consider possible identical situations on the football field that may affect the assistant referee's decision-making:

• Compromise between speed and accuracy [13]. The first glance at a situation on the football field may be perceived quickly but not very accurately.

• The speed of visual categorization does not improve with training [14]. Certain time for initial processing may be needed to perceive a situation on the football field, regardless of whether the assistant referee has seen a similar situation before. The unchanging speed of visual categorization suggests that there is a constant delay in perception, which affects the accuracy of decisions regarding the offside rule.

• "Sweet spot" of brain activity [15]. Factors



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such as fatigue, headaches, surrounding problems, and external pressure can also impact the correctness of the final decision.

• Expectations accelerate perception [16]. Preparation and forecasting of future situations on the football field can, first, reduce the processing time of emerging situations and, second, increase the likelihood of making the correct decision.

• Brightness issues [17]. The choice of team uniform color can affect the clarity and speed of perception. Additionally, the lighting and background of stands or advertising projections can positively or negatively influence the assistant referee's final decision.

Considering the points that influence the correctness of the decision-making and which were defined above in the text, as well as the objective factors of speed and quality of visual perception, the contribution of all these mentioned indicators to the integral indicator that determines the minimum permissible distance that may remain unnoticed when determining the offside position by the AR is open to discussion.

Perceptual illusions are an important subjective factor that influences decision-making in sports.

These illusions arise due to the peculiarities of the functioning of the human brain, which tries to predict the movements of objects and adapt to fast-paced situations. This can lead to errors in arbitration.

Perceptual illusions are cognitive effects where a referee misinterprets visual information due to the way their brain functions. In sports, where time to make decisions is limited, perceptual illusions can lead to significant errors that affect the course of a game or competition.

Cognitive skills – the functions our brain uses to think, focus, process information, and remember things, constantly aiding thought processes and memory retention. Some of these functions include sustained attention, auditory processing, and short-term memory. They can be used simultaneously by the brain to increase its overall performance.

Cognitive or psychophysiological influence is a very delicate topic, which is connected with the secrets of brain functioning and psychologically reverse human reaction to certain influences from the outside. Our work considers the topic of the influence of various factors of influence on decision-making by assistant referees in football, both objective (incorrect position on the field, speed of players, etc.) and subjective (speed of processing electrical signals by the brain). But a similar topic of various factors of influence in other sports, in particular when evaluating other game episodes, both by athletes and referees, has been considered by the following authors and requires discussion:

The article [18] explores the impact of cognitive biases on refereeing in sports:

• binding effect (anchoring bias). Referees may unconsciously base their decisions on prior information or initial assessment of a situation. For example, an early whistle or a prior opinion about a particular player may influence subsequent decisions.

• false hindsight effect (hindsight bias). After analyzing events (for example, watching videos or discussing with colleagues), referees tend to believe that their decision was obvious and correct, even in difficult situations. This can limit their ability to objectively evaluate their own mistakes.

The authors conducted experiments with referees, analyzing their reactions in various situations, including using simulations and video replays. After which the following conclusions were drawn:

• judicial decisions depend to a large extent on cognitive biases, especially in complex or ambiguous situations;

• training programs for referees should include practices that help minimize the impact of such biases;

• the use of technologies such as VAR helps compensate for the human factor and improve the objectivity of decisions.

The authors [19] analyze the influence of factors such as prejudice, stereotypes, and perceptual features on the accuracy of judicial decisions:

• mechanisms of cognitive biases are considered, in particular the anchoring bias and the hindsight bias;

• the use of technologies (VAR, Hawk-Eye) to minimize errors caused by the human factor is discussed;

• emphasis is placed on the importance of training referees and considering cognitive limitations during arbitration.

This article [20] analyzes refereeing decisions through the lens of social cognitive psychology. It examines how external factors, such as the context of the game, player behavior, and audience interaction, influence refereeing perceptions and decisions:

• considered how stereotypes can influence player evaluations (e.g., expecting better results from experienced players or teams);

• mechanisms that help avoid such errors are discussed, including increasing referees awareness of cognitive processes.

Publication [21] investigates how level of expertise affects visual search strategies in racket sports (tennis or badminton):

• visual search for professionals and beginners. Experts demonstrate more effective visual

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search strategies compared to novices. They are able to detect key cues (e.g., opponent position or ball trajectory) more quickly;

• beginners usually have a scattered view and are less focused on important details, which leads to slow downs reactions and errors.

• experienced athletes can predict an opponent's actions based on previous experience, which allows them to react more quickly to changing situations;

• training helps athletes make better use of peripheral vision, reducing dependence on central vision for analysis and decision-making.

Article [22] examines how actions and goals affect the perception of object speed. The authors focus on how a person judges the speed of an object, for example in sports, and how this perception may change depending on what the person plans to do with the object (e.g., catch a ball or dodge it).

The influence of goals on the perception of speed:

• the authors found that the intensity and type of action a person plans to perform (for example, attempting to hit a ball in tennis or dodge it in badminton) can alter their perception of the speed of that object;

• when a person has a specific goal regarding an object, such as catching a ball, their speed estimate may be underestimated because they are focusing more on what needs to be done with the object rather than its actual speed;

• the role of actions in sports. This research has important implications for sports training and refereeing because it helps to understand how an athlete may perceive the speed of a ball or other objects during play depending on their goals (e.g., when attempting to hit the ball or handle it on a reception). Identifying these changes in perception may be important for training practices to help athletes accurately assess and respond to the speed of objects in high-speed games.

The influence of cognitive factors and perceptual illusions is an integral part of sport, affecting the actions of athletes and referees. The use of modern technologies, training methods and cognitive development can significantly reduce the impact of these illusions, increasing the accuracy of decisions and the effectiveness of sports actions.

Article [23] examines the term "implicit biases" as a factor of error in decision-making in basketball, which occurs automatically and unintentionally and is especially present when decisions have to be made in a split second.

The term "implicit bias" is used to describe when we display prejudiced attitudes toward people or associate stereotypes with them without our conscious knowledge. An interesting factor that has been studied in relation to NBA referees and requires separate research in football refereeing is implicit bias such as: home-versus-away bias, bias towards individual players or teams, and racial bias.

The NBA results show that there is a bias towards home team refereeing, there is reliable statistical evidence that specific players benefit more from referee decisions, but no evidence of racial bias has been found.

Article [24] investigates the impact of artificial intelligence systems (Hawk-Eye) on tennis referee decisions. The authors found that after the implementation of Hawk-Eye, referees reduced the total number of errors, but the impact on the psyche regarding the possibility of a decision being reviewed led to the correction of errors from one type to another.

This topic is extremely interesting and requires in-depth and separate research into the impact of VAR technology on the psychology of decision-making by match officials and whether other types of errors may increase when this technology is implemented.

Paper [25] explores the role of artificial intelligence (AI) in improving officiating in sports. The paper examines the benefits, challenges, and ethical implications of using AI to assist referees in sports competitions.

Along with the advantages of implementing AI in arbitration, such as accuracy of decisions, uniform application of rules, speed of decisions, there are also challenges. Significant challenges include: difficulties in combining with human refereeing, as technology should complement, not replace, referees; technical problems; resistance to innovation; lack of experience or fear of change; ethical implications; data privacy; the possibility of interfering with the source code of technologies; clarity for players, coaches and fans.

This publication highlights the importance of balancing the use of technology with the preservation of the human element in refereeing, and also emphasizes the need for careful monitoring of the ethical aspects of technology in sport.

That is, as separate topics for further discussion and development, we can include topics related to the influence of cognitive factors, perceptual illusions and technologies on decision-making by arbitrators. Particular attention should be paid to such topics as:

1. Cognitive biases and perceptual illusions.

2. Expertise in decision-making.

3. Impact of technology (VAR, SAOT) on refereeing.

4. Psychology of decision-making.

5. Ethical and social aspects of technology implementation.

A correct and accurate assessment of a game



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situation in the context of offside violations is an integral measure and a nonlinear function, which includes many objective and physiological factors that should be further studied in specific contexts.

Conclusions

According to the stated goal, factors affecting the accuracy of decisions made by assistant referees have been identified. The position of the assistant referee on the football field relative to the offside line is the main factor. The "lagging" or "leading" position of the assistant referee distorts the correct viewing angle and increases the likelihood of incorrect decisions being made.

Several influencing factors have been identified that should be researched separately:

• The shifting of the assistant referee's attention to the player making the pass;

• Focus and concentration on events happening on the field;

• The movement trajectories of attacking players and defenders;

• The number of attacking and defending players;

• The assistant referee's movement style;

• Forced and unforced head and torso rotations;

• The distance between attacking and defending players, considering both the depth and length of the field;

• Fatigue;

• The color of objects surrounding the core of the football field;

• The style of lawn mowing and maintenance. Using 3D modeling tools, the impact of the

assistant referee's geographical position on the football field and the resulting change in the viewing angle for the offside situation have been visually demonstrated. This change increases the percentage of errors related to both flag-raising and errors where the flag is not raised.

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