IS PERCEPTION OF VAR OUTCOME BIOMECHANICALLY ACCURATE?

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The purpose of this study was to understand if offside judgments, using different video assistant referee (VAR) technologies (video replay vs. guiding lines), are biomechanically accurate. Ten college students viewed video clips of a football player, receiving the ball from his teammate, and from different camera angles. Participants were asked to determine the ball-kick moment and to judge whether the ball receiver was in offside. Participants' responses were verified with the kinematic parameters of the ball and the players. Participants' judgements were on average 132 ms later than the actual offside moment. While camera angles did not affect their judgements, participants had higher correct judgments at 0 and 90° viewing angles and when VAR guiding lines were present.

KEYWORDS: kinematics, offside, soccer.

INTRODUCTION: Technical officials play integral roles in football and their decisions change the outcome of the match. Considering various sources of information and distraction, football referees need to make quick and accurate decisions (Kubayi, Larkin, and Toriola, 2021). Technological tools are incorporated in different sports to help officials in decision making and to make their judgements more accurate (Leveaux, 2010). In association football, the law of the game 2018-2019 introduced the video assistant referee (VAR) to help referees reviewing decisions of head referees for goals, red cards, penalty, and mistaken identity. After replaying and checking the footages, VAR officials offer their opinions to the head officials about the incidents.

While some argue that VAR hampers the flow of the game (Ryall, 2021), others have found that since the introduction, the number of fouls, offsides, and yellow cards have been decreased (Lago-Peñas et al., 2019). In a situation where intervention is possible, VAR may also be able to eliminate referees' biases (Holder, Ehrmann, and König, 2021). On the other hand, VAR increases total playing time and reduces effective playing time (Errekagorri et al., 2020). Due to dynamic nature of the game, line of vision could still be obscured (Lex, Pizzera, Kurtes, and Schack, 2015). Being too close or too far from the match event, could also increase the risk of missing important visual information when needed. The final VAR outcome is also determined by the operator which might be prone to human error.

Optical motion capture systems record 3D positions of subjects between two or more cameras calibrated to provide overlapping projections. These systems can be used to accurately validate the outcomes of 2D video systems. Such validations are important as it remains unclear if existing video replay technologies are accurate enough in identifying the exact moment and locations of the ball and players, particularly in more disputable and debatable situations like offsides. Therefore, the purpose of this study was to compare the offside judgements, using two VAR technologies (video replay vs. guiding lines), with 3D motion capture.

METHODS: For creating offside events, one player passed the ball to his teammate who was standing next to a member of the opponent team. Spherical reflective markers were placed on the players' bodies, their shoes, and the ball (Figure 1). The 3D position of each marker was recorded at 180 Hz using 22-camera motion capture system and acquisition software (Qualisys Track Manager 2021.2, Qualisys AB, Gothenburg, Sweden). Ball-kick moment was determined using the changes in ball velocity. Offside was determined by comparing the x-coordinates of body markers of the players (Figure 1).

Three broadcast video cameras (PXW-FS7, Sony, Japan), with 35mm full frame lens (SEL-28135G, Sony, Japan), operating at 59.94 Hz were placed at 0° (parallel to the players), 45°

(corner view), and 90° (behind the players; Figure 1). The video cameras and the motion capture system were synchronized using a timecode generator (Timecode Buddy, Mini TRX, Timecode Systems, UK). A calibration cage of 100 x 100 x 100 cm was placed in the middle of the room. On each plane, gridlines of 10 x 10 squares were created using a video editing software (Premiere Pro, Adobe Inc., USA; Figure 1). Crosshairs were also positioned for both attacker and defender's body parts that can be used to score goals.

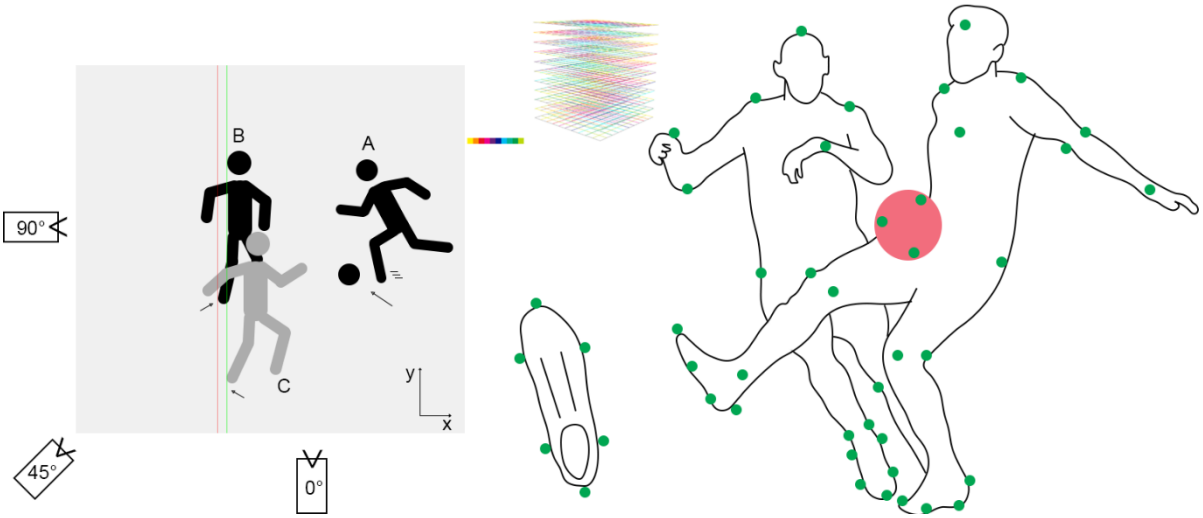

Figure 1. Experimental and marker setup. Participants had to determine the moment player A kicks the ball toward player B, and whether player B was in offside (smaller -x coordinate compared to player C) at this moment.

Four female and six male college students (mean±SD 19.3±1.5 vs. 19.5±1.0 years of age) watched four pre-recorded events from three camera angles randomly. In each scenario, the mean±SD distance between the attacker and the defender, as measured by -x coordinate, was 11.8±7.9 cm. First, they were asked to determine the ball-kick moment. Second, they were asked to judge whether the teammate was in offside when the ball was kicked, once in video replay mode and once when the guiding lines were present.
Mean video frame differences (delay) with the actual ball-kick moment, were compared between camera viewing angles using one-way analysis of variance (ANOVA). To understand whether there is any association between VAR type and judgment, while weighing for camera angle, Chi-Square test was used. Level of statistical significance was set to 0.05.

RESULTS: While not statistically significantly different ($p > 0.05$; $\eta_p^2 = 0.009$), participants across three viewing angles, determined the ball-kick moment later than the actual moment (average 8 frames) which corresponds to 132 ms delay (Table 1).

Table 1: Mean video frame differences of the participants' judgements with the actual ball-kick moment as verified by 3D motion capture.

	0°	45°	90°	Total
Video frame difference	8.4±3.2	7.8±3.9	7.5±4.8	7.9±3.9
Delay (ms)	140.3±53.5	130.26±66.2	125.2±79.6	131.9±65.2

There was also no statistically significant association between VAR type and offside judgements ($\chi(1) = 2.22$, $p = 0.14$, Phi and Cramer's V = 0.33; $\chi(1) = 1.82$, $p = 0.18$, Phi and Cramer's V = 0.30; $\chi(1) = 2.40$, $p = 0.12$, Phi and Cramer's V = 0.35, for 0°, 45°, and 90°, respectively). However, participants had higher correct judgements when viewing from 0 and 90°, and when guiding lines were present. When viewing at 45°, participants had more correct judgements when guiding lines were not present (Figure 2).

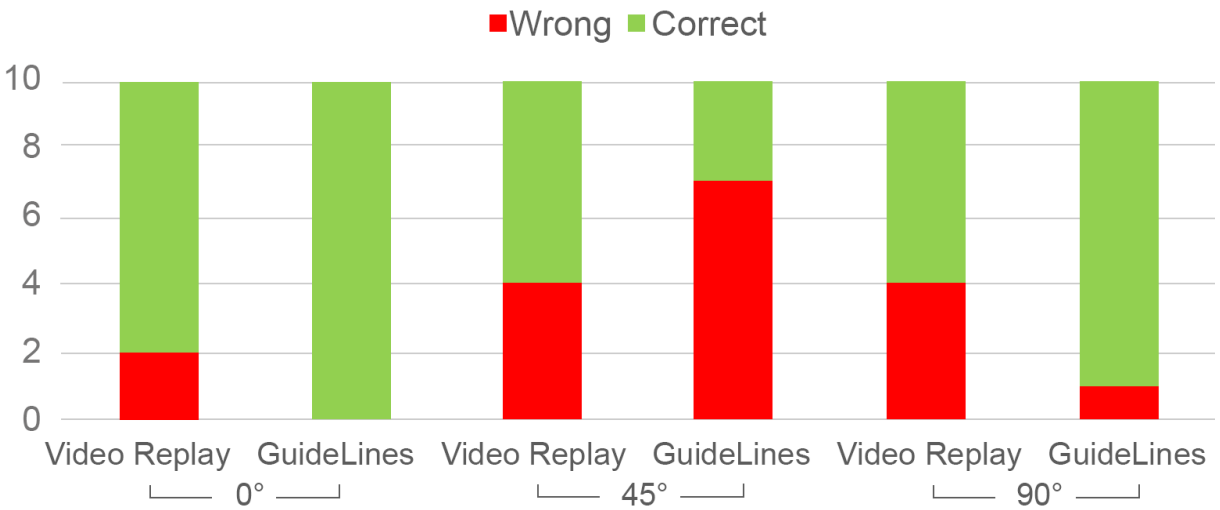

Figure 2: Number of correct and wrong offside judgements with two VAR technologies and across different camera angles.

DISCUSSION: By using 3D motion capture, it was possible to determine the exact temporal and spatial parameters of the ball and the players' body parts. The present study showed that participants' judgements of offside moment, are on average 132 ms later than the actual ball-kick moment. Such delay may not seem a lot but in fast-paced games like soccer, it could be fast enough to put players in another location and therefore, change the outcomes of offside completely. For example, assuming that a player is moving at ~8 m/s, a delay of 0.13 s could correspond to ~1 m.

When viewing from 0 and 90°, participants had higher correct judgements compared to 45° viewing angle. It is possible that in these two viewing angles, participants had better view of the players' lateral side and could easily determine who is in offside. In 45° viewing angle and when the image of the attacker is to left side of the defender, sometimes the attacker appeared to be closer to the goal line, resulting in wrong offside judgement. Similarly, when the attacker was on the right side of the defender, even when he was in offside, sometimes he appeared to be next to the defender. It seems that these wrong decisions are the results of relative optical projections of the two players at this camera viewing angle (Oudejans et al., 2000).

As there is still a human element in VAR operations, it seems impossible to remove all potential errors and biases, and achieve 100% accuracy (Royce, 2012). Several solutions could be implemented to reduce these biases further. First, higher frame-rate cameras could be used to determine ball contact and offside moment in slower motion. Second, later judgements could also lead to changes in different positions of the limbs in space. As a result, for marginal offside decisions, adjustments should be made to VAR and rather than the one-pixel line, thicker lines could be applied to represent the uncertainty zone. Where the lines overlap, those situations could be deemed as inside. Finally, in case parallel or perpendicular view of the event is not possible, the VAR outcome should be checked with other camera angles.

CONCLUSION: VAR is definitely an improvement but controversies may still arise because the outcome is still heavily dependent on human interpretation. Therefore, the objective of the instrument should not be on minimizing errors but to tackle obvious mistakes. In this study, I showed that human judgement could still change the offside outcome. My results suggest that 0 and 90° camera viewing angles offer better offside judgements. Participants' judgements were also more accurate when the guiding lines were present.

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