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Flag errors in soccer games: the flash-lag effect brought to real life

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Abstract. In soccer games, an attacking player is said to be in an offside position if he or she is closer to the opponents' goal line than both the ball and the second-to-last defender. It is an offence for the attacker to be in an offside position and in active play at the moment a fellow team member plays the ball. Assistant referees often make mistakes when judging an offside offence, probably because of optical errors arising from the viewing angle adopted by them (Oudejans, Verheijen, Bakker, Gerrits, Steinbrückner, Beek, 2000 *Nature* **404** 33). Looking more closely at Oudejans et al's data, we show evidence that the flash-lag effect may contribute significantly to these mistakes. Participation of the flash-lag effect in assistant referees' misjudgments would take this perceptual phenomenon from laboratory setups to a real-life situation for the first time.

1 Introduction

In Association Football (soccer), assistant referees (ARs) often make mistakes when judging offside offences. An attacking player should be penalized for being in an offside position if, at the moment the ball touches or is played by one of his or her team (usually, the instant the ball is passed to him or her), he or she is closer to the opponents' goal line than both the ball and the second-to-last defender (see figure 1a). ARs sometimes raise the flag to indicate an offside offence when the attacker was actually in an onside position at the time of the pass, a situation Oudejans et al (2000) called a *flag error* (FE), and sometimes they do not raise the flag when the attacker was in fact offside at the time of the pass (a *non-flag error*, or NFE).

An explanation for FEs might be that the errors arise from the time delay taken by the AR to shift gaze from attacking passer to attacking receiver. This delay could be long enough for the receiver to be perceived as offside when, at the time the ball was passed, he or she was actually onside. By equipping ARs with a head-mounted camera, Oudejans and colleagues (2000) disproved this simple hypothesis, showing that errors were not accompanied by shifts of gaze. Oudejans et al (2000) proposed that both FEs and NFEs are probably caused by a geometrical/optical effect, which inevitably leads to errors by ARs. This geometrical effect would arise from the viewing angle adopted by the ARs, who were observed to position themselves, on average, a little over 1 m ahead of the offside line (Oudejans et al 2000), as shown in figure 2.

In a much-debated phenomenon, the flash-lag effect (Nijhawan 1994; Baldo and Klein 1995; Purushothaman et al 1998; Whitney and Murakami 1998; Brenner and Smeets 2000; Eagleman and Sejnowski 2000; Krekelberg and Lappe 2001; Nijhawan 2001; Baldo et al 2002), a moving object is perceived as spatially leading its real position at an instant defined by a time marker (usually a briefly flashed stimulus). Here we propose that the flash-lag effect is a likely nominee for a supporting role in explaining the ARs' errors. Figure 2a shows how the geometrical/optical effect reported by Oudejans et al (2000) leads to a bias in favor of FEs when the attacker goes left (left trajectories), and to a bias in favor of NFEs when the attacker goes right (right trajectories). In many FE and NFE situations, the attacker that receives the ball is running towards the opposing goal at the time the ball is passed to him or her. In this case, the receiving attacker is

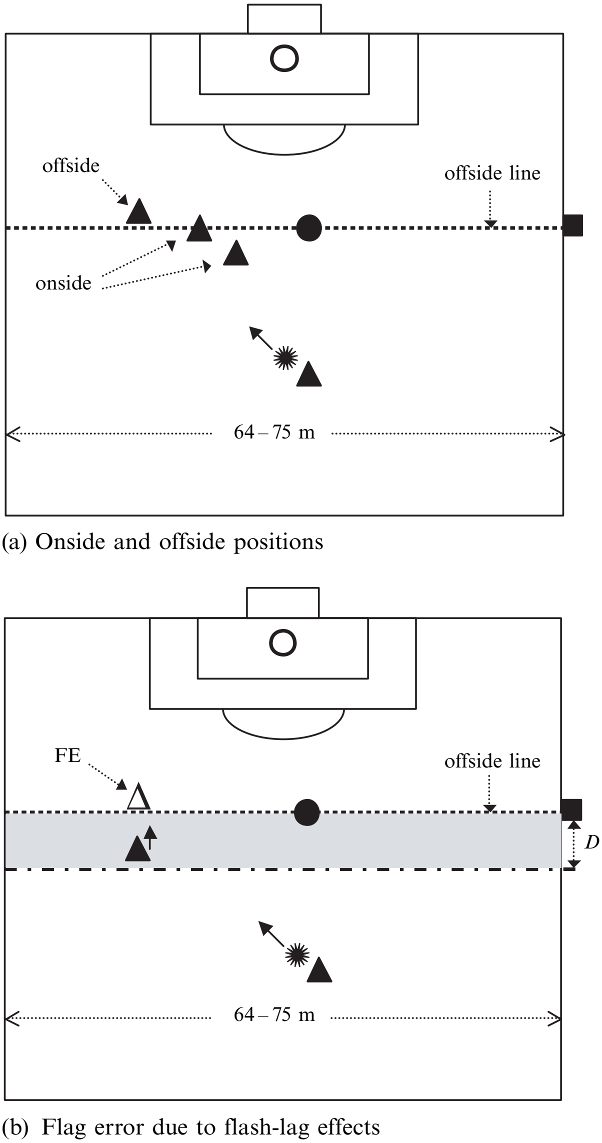
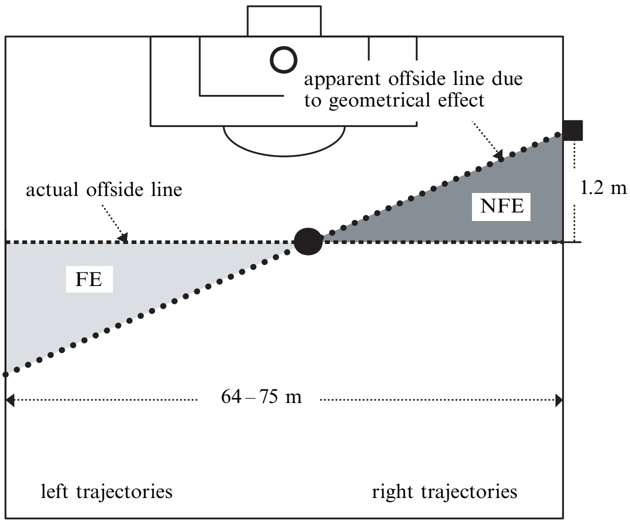
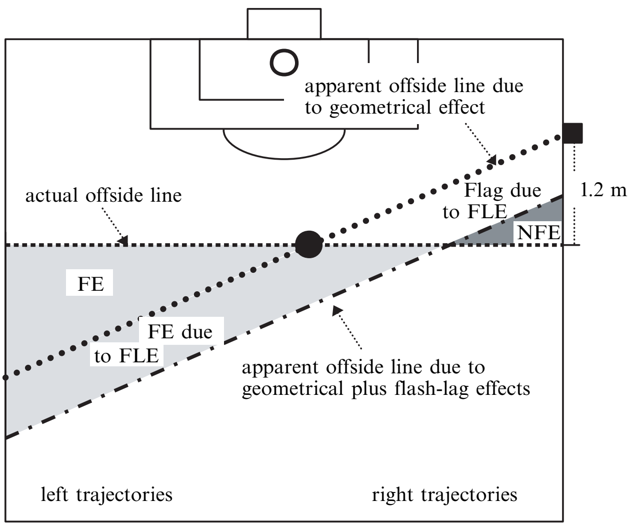


Figure 1. (a) The geometry of onside and offside positions. The moment of ball contact, often a pass by a fellow team member toward the player in a potential offside position, is the time marker defining the instant when the AR should judge whether the attacking receiver is beyond the second-to-last defender or not (offside and onside conditions, respectively). (b) The effect of the flash-lag phenomenon on ARs' judgments. The attacking receiver, often in forward motion, is perceived (white triangle) to be ahead of his or her actual position (black triangle), increasing the probability of FEs when the attacking receiver is in the shaded area. Symbols: ▲ = attacking player, ○ = goalkeeper, ● = second-to-last defender, ■ = assistant referee (AR), ✷ = moment of ball contact, △ = perceived position of the attacking player by the AR, D = perceptual advancement caused solely by the flash-lag contribution.

a moving stimulus. The pass made by the attacker doing the passing is an abrupt event, whereby the moment at which the pass is kicked works as the time marker that defines the instant in which the position of the receiving attacker must be judged by the AR (accordingly, the kicking of the pass would be equivalent to the flash in the classical flash-lag effect). Thus the flash-lag phenomenon may well add to the geometrical/ optical effect, leading us to expect an overall bias toward FEs in comparison with



(a) FE and NFE due to geometrical effect alone



(b) FE and NFE due to geometrical effect plus flash-lag effects

Figure 2. (a) According to the geometrical/optical hypothesis proposed by Oudejans et al (2000), ARs often position themselves beyond the second-to-last defender (1.2 m on average) and thus mistakenly perceive the offside line as a line not orthogonal to the touchline. Flag errors (FEs) are then likely when attackers, going on a left trajectory, are in the light-gray triangle. Non-flag errors (NFEs) are likely on a right trajectory when attackers are in the dark-gray triangle. This is a symmetric phenomenon, in which FE and NFE should occur with equal probability if left trajectories and right trajectories are equally likely. (b) In the presence of the flash-lag effect, the position of an attacker is perceived to be ahead of the actual position occupied by him or her at the time the ball is passed. Now, the regions in which FEs and NFEs are likely are no longer symmetrical. The region of likely FEs is increased, whereas the region of likely NFEs is reduced. 'FEs due to FLE' defines an additional area of likely FEs introduced by the flash-lag effect. Similarly, 'Flag due to FLE' defines an area where NFEs are no longer likely, again thanks to the flash-lag effect. Symbols: ○ = goalkeeper, ● = second-to-last defender, ■ = assistant referee (AR).

NFEs (figure 2b). This prediction is independent of the precise underlying mechanism that causes the flash-lag phenomenon, and we now turn to the interpretation of the FEs made by ARs in the light of the main conceptual models of the flash-lag effect.

2 Conceptual models of the flash-lag effect

2.1 *Extrapolation model*

According to Nijhawan's extrapolation hypothesis (Nijhawan 1994; Khurana et al 2000; Sheth et al 2000; Nijhawan 2001), the position of a moving object (the attacking receiver) would be perceptually extrapolated as a compensating mechanism to overcome transmission delays in sensory processing. However, an abrupt event (the pass made by the passing attacker), devoid of a prior trajectory long enough to allow a perceptual extrapolation, would be subject to the sensory delays intrinsic to visual processing. ARs, using the pass as a time marker, would thus judge the position of the attacking receiver, at the instant of the pass, as being ahead of his or her actual position, therefore increasing the probability of an FE.

2.2 *Differential-latency model*

According to the differential-latency model, different sensory latencies are assigned to moving and abrupt-onset stimuli (Purushothaman et al 1998; Whitney and Murakami 1998; Whitney et al 2000). Under similar conditions, an abrupt stimulus would be associated with a longer sensory latency in comparison with a moving stimulus. Therefore, if the receiving attacker (assumed to be in motion) happens to be aligned with the offside line (or even slightly behind it) at the moment of the pass (abrupt stimulus), the AR is likely to perceive the receiver as being ahead of the offside line, and so raises the flag, committing an FE.

2.3 *Attentional deployment*

According to the generalized latency model (Baldo and Klein 1995, 2001; Baldo et al 2000, 2002), the flash-lag effect arises from sensory and attentional delays. This model offers an explanation that is based on the modulation of differential sensory latencies by attentional allocation. Therefore, a nonuniform spatial distribution of visual attention during the AR's judgment would add to the overall perceptual latency, contributing to the perceptual error made by the AR. Moreover, an attempt to redistribute the attentional focus over the visual field might require a finite amount of time. In this case, the AR's judgment would indeed be made a split second after the pass occurred, not because of gaze shifts but rather because of a covert shift of visual attention, undetectable with the head-mounted camera of Oudejans et al (2000).

2.4 *Postdiction model*

A further alternative account for the flash-lag effect states that the percept attributed to the time of an event (the pass made by the passing attacker) is a function of what happens in a window of time (about 80 ms) following the event (Eagleman and Sejnowski 2000). According to this view, the visual system would integrate information after the attacker's pass, which would be the signal to reset motion integration. Therefore, the motion of the attacking receiver would be postdicted to the time of the pass, and the position of this player would be interpolated as a point within the integrated path, leading to the flash-lag effect and, consequently, to an FE.

3 Results and discussion

When we carried out a reanalysis of data reported by Oudejans et al (2000), we found that from a total of 564 errors recorded by them the proportion FE/NFE was 324/240; this departs significantly from a 1 : 1 ratio ($\chi^2 = 6.290$, $p = 0.0061$) in the direction predicted by the flash-lag hypothesis. On closer inspection, however, this bias might be attributed to the fact that those authors tallied more left trajectories (for which FEs are more likely) than right trajectories (for which NFEs are more likely). In order to determine if there really was an overall bias in favor of FEs, we looked for an asymmetry between the proportion of NFEs to FEs observed in left trajectories, in comparison to the proportion of FEs to NFEs observed in right trajectories. Such an asymmetry would not be expected from the pure geometrical/optical effect proposed by Oudejans et al (2000). However, taking into account that the flash-lag effect might be contributing to AR perception, we would predict an increase in number of FEs both in left trajectories (LT) and in right trajectories (RT), leading to unequal proportions (see figure 2b): $(\mathrm{NFE/FE})_{\mathrm{LT}} < (\mathrm{FE/NFE})_{\mathrm{RT}}$. As it turns out, we found that the proportion $(\mathrm{NFE/FE})_{\mathrm{LT}} = 65/266$ is indeed smaller than $(\mathrm{FE/NFE})_{\mathrm{RT}} = 58/175$ ($\chi^2 = 2.215$, $p = 0.0684$), in accordance with the flash-lag prediction.

The predicted perceptual advancement caused solely by the flash-lag contribution is the product of the attacker's velocity and the flash-lag magnitude. As an order of magnitude we estimate this to be between 0.02 and 0.64 m (*D* in figure 1b), considering typical attacker velocities of $2-8\ \mathrm{m\ s^{-1}}$ and laboratory-measured flash-lag magnitudes of $10-80$ ms (Nijhawan 1994; Baldo and Klein 1995; Purushothaman et al 1998; Eagleman and Sejnowski 2000; Whitney et al 2000; Krekelberg and Lappe 2001; Baldo et al 2002). Thus the order of magnitude of the perceptual error from the flash-lag effect is comparable to the size of the geometrical/optical effect proposed by Oudejans et al (2000).

We are aware, however, that other factors might be thought to introduce a response bias in favor of FEs. Overzealous ARs, for example, might tend towards FEs rather than NFEs, since their main responsibility in the game is to detect offside offences, and given the possible asymmetry of costs and benefits for FE and NFE. However, the law is clear: for an attacker to be offside he or she must be perceived to be *beyond* and not just *level* with the second-to-last defender (FIFA 2001). Furthermore, as part of a general move to encourage offensive play and increase the probability of scoring, FIFA recommends ARs do *not* call offside when in doubt. According to the *Advice to Referees on the Laws of the Game*, published by the United States Soccer Federation, when in doubt ARs, "... should decide in favor of the attacker; in other words, he should refrain from signaling offside" (Allen and Heldman 1998). Thus the possibility of overzealousness by ARs, which might lead to a response bias in favor of FEs, is counterbalanced by the strictness of the law and FIFA recommendations.

4 Conclusion

Looking closely at the data provided by Oudejans et al (2000), we propose that ARs misjudge offside not only because of geometrical/optical effects, but also because of perceptual errors associated with the flash-lag effect. Although our proposal is still speculative, the possible participation of the flash-lag effect in ARs' misjudgments may be subject to further empirical inspection. In contrast with the geometrical/optical contribution proposed by Oudejans et al (2000), the flash-lag contribution to the perceptual errors does not depend on the viewing angle adopted by the ARs. Therefore, a bias towards FEs should also be expected even when ARs are positioned in alignment with the offside line (figure 1b).

Despite the obvious coupling of many factors involved in AR perceptual judgments (optical and sensory constraints, response bias, and attentional deployment, among others) we are led to believe that the contribution of the flash-lag effect, if not established conclusively, is at least quite likely. In this sense, our aim with the present proposal is not to add any significant contribution to the current understanding of the flash-lag phenomenon itself, but rather to offer some suggestive evidence that its manifestation, so far confined to laboratory walls, may possibly lead to perceptual lapses in real-life scenarios.

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