UNIVERSITY of CALIFORNIA PRESS | Collabra: Psychology

Wühr, P., Furley, P., Mertes, M., & Memmert, D. (2025). A Home Advantage in Offside Decisions in German Professional Football (Soccer). *Collabra: Psychology*, *11*(1). https://doi.org/10.1525/collabra.133671

Cognitive Psychology

A Home Advantage in Offside Decisions in German Professional Football (Soccer)

Peter Wühr[1][a], Philip Furley[2], Marc Mertes[3], Daniel Memmert[4]

[1] Psychology, TU Dortmund University, Dortmund, Germany, [2] Institute of Exercise Training and Sport Informatics, Sport Informatics and Sports Games Research, German Sport University, Cologne, Germany, [3] Federal University of Applied Administrative Sciences, Brühl, Germany, [4] Institute of Exercise Training and Sport Informatics, Sport Informatics and Sports Games Research, German Sport University, Cologne, Germany

Keywords: football, German Bundesliga, home advantage, offside judgments, soccer, VAR

https://doi.org/10.1525/collabra.133671

Collabra: Psychology

Vol. 11, Issue 1, 2025

Football teams perform more successfully when playing at home than when playing away. A possible cause for this home advantage is that spectators bias referee decisions in favor of the home team. This study is the first to investigate a possible home advantage in offside decisions in football. Therefore, we analyzed archival data from 1,836 matches from the German Bundesliga. We observed a home advantage in offside decisions when the effects of team dominance on the number of offside decisions were removed by calculating an offside score. The presence or absence of the video-assistant referee (VAR) did not affect the home advantage in offside decisions. Moreover, the home advantage in offside decisions occurred only in the presence of spectators and increased with their number. In summary, our study provides first evidence for a home advantage in offside decisions of professional referees, which might be related to spectator presence or behavior.

Introduction

It is difficult to name one other phenomenon in sports that is as well-established and extensively studied as the home advantage (HA; Gómez-Ruano et al., 2021). Most likely the HA is a multi-causal phenomenon that is explained by several factors and their interplay (Wunderlich, Furley, et al., 2021). The present research investigates one further factor that has been overlooked by previous research but can arguably contribute to the occurrence of the HA in football (soccer): offside decision making. Despite some contradictory results (Johnston, 2008), previous research has largely shown that biased decision making by officials contributes to the HA (Avugos & Bar-Eli, 2021). Hence, the central aim of our study is to test whether offside decision making is systematically affected by a range of contextual factors including game location in an archival football dataset and, hence, provide evidence for biased assistant referee decision making contributing to the HA.

The HA is based on a large body of research showing that athletes and teams perform better when they compete at home compared with away. This phenomenon has been shown to exist across various sports (Agnew & Carron, 1994; Goumas, 2014a; Moore & Brylinsky, 1993; Recht et al., 1995; Strauss, 2002), in team sports as well as individual sports (Jamieson, 2010; Jones, 2013; Pollard & Pollard, 2005), across different countries and continents (Pollard, 2006; Pollard & Gomez, 2014) and across different time periods (Pollard & Pollard, 2005). Although, the HA is not unequivocal and is more prevalent in some sports as compared to others (Jones, 2013), “there are no sports in which athletes or teams are more successful away from their home venue” (Allen & Jones, 2014, p. 48).

Several plausible mechanisms have been discussed as potential contributors to the HA (Allen & Jones, 2014; Courneya & Carron, 1992; Nevill & Holder, 1999; Pollard, 2008). The main factors contributing to the HA are assumed to be the support of the home audience (e.g., by cheering), and referee decisions favoring the home team (cf. Allen & Jones, 2014, for a review). Although, there is piecemeal empirical support for some other factors like travel fatigue of the away team (Goumas, 2014b; Recht et al., 1995), arguably, and pertinent to the present research, the most strongly supported factors leading to the HA are spectator presence and referee biases giving an advantage to the home team and a disadvantage to the away team (see, Gómez-Ruano et al., 2021, for a review).

a Correspondence concerning this article should be addressed to:
Peter Wühr, Technische Universität Dortmund, Institut für Psychologie, Emil-Figge-Straße 50, 44227 Dortmund
Phone: 0231-755-7928
Email: peter.wuehr@tu-dortmund.de

In support of audience effects, studies have demonstrated that physical aspects pertaining to spectators/fans (e.g., size, density, and propinquity) and crowd behavior (e.g., booing, fighting, and cheering) are correlated with the magnitude of the HA (e.g., Armatas & Pollard, 2014). Although the exact mechanisms of how supportive audiences might impact athletes (e.g., via a motivational boost for the home team or increased anxiety for the away team) remain unclear, there is solid evidence for audience effects on official's decision making (Downward & Jones, 2007; Goumas, 2014a; Unkelbach & Memmert, 2010). Several empirical studies indicate that unequal treatment of home and away teams is evident in match statistics in football. More specifically, it has been shown that referees award more extra time for home teams when trailing (by one goal), and less extra time when leading (Garicano et al., 2005; Scoppa, 2008). In addition, home teams have been shown to be favored in terms of disciplinary sanctions such as yellow cards, red cards, and penalties (Boyko et al., 2007; Goumas, 2014a; Lovell et al., 2014; Sutter & Kocher, 2004). Research shows that this referee home bias depends on the presence of spectators (Nevill et al., 1996; Pettersson-Lidbom & Priks, 2010) and largely disappears in matches played in the absence of a crowd (Bilalić et al., 2021; Lago-Peñas & Gómez-Ruano, 2021; Scoppa, 2021; Wunderlich, Weigelt, et al., 2021).

The outlined research shows that referees tend to favor the home team, which is commonly denoted as favoritism and assumed to be caused by social pressure (Garicano et al., 2005; Scoppa, 2008). Further experimental studies are in line with this reasoning as they demonstrate that referees are affected by crowd noise and tend to decide more favorably for the home team as opposed to the away team (Boyko et al., 2007; Nevill et al., 2002; Unkelbach & Memmert, 2010). Furthermore, recent studies conducted during the Covid-19 pandemic indicate that the referee bias was reduced when stadiums were empty (Bilalić et al., 2021; Lago-Peñas & Gómez-Ruano, 2021; Wolaver & Magee, 2022). This referee bias might be the result of various factors like motivation (i.e., referees are reluctant to displease the crowd) or that crowd noise serves as decision heuristic and thereby implicitly biases referees towards the opinion of the dominant crowd (Allen & Jones, 2014).

To date, research has almost exclusively focused on the main referee and has neglected that a variety of sports deploy a team of referees that might similarly be biased by audience effects and thereby contribute to the HA. One such instance regards offside decision making in football. As this rather difficult decision cannot be accomplished satisfactorily by the main referee in football, assistant referees are deployed to assist the main referee by alerting the main referee if a player is offside or not. According to FIFA's "laws of the game" (IFAB, 2022) a player is in an offside position if any of their body parts, except the hands and arms, are in the opponents' half of the pitch, and closer to the opponents' goal line than both the ball and the second-last opponent (IFAB, 2023). Given the solid empirical evidence on referee bias contributing to the HA it seems feasible that biased assistant referees' offside decision making might also contribute to the HA.

The Present Study

The main purpose of this study is to investigate a possible HA in offside decisions of (assistant) referees. An offside decision prevents the attacking team from scoring a goal, and therefore represents a disadvantage for that team. Hence, the HA in offside decisions would consist in less offside decisions against the home team as compared to the away team. For our study, we used data from 1,836 matches from six seasons played in the German Bundesliga, the highest level of professional football in Germany.

There are, at least, two possible sources for the HA in offside decisions of (assistant) referees. The first source is the already described referee bias that might be caused by the audience. A noisy support of the audience for the home team might prevent (assistant) referees from making an offside decision against the home team. Conversely, booing or whistling of the audience during offensive actions of the away team might increase the referees' propensity to make an offside decision against the away team. Moreover, operant-learning mechanisms might also contribute to the HA in offside decisions. Most football audiences will "punish" offside decisions against home teams, by booing or whistling, and "reinforce" no offside decisions against the home team. In addition, most football audiences will "reinforce" offside decisions against away teams, and punish no-offside decisions against away teams. Together, these consequences of referee decisions may decrease the likelihood of offside decisions against home teams, and increase the likelihood of offside decisions against away teams.

In addition to referee bias, perceptual sources for the HA in offside decisions are conceivable as well. Judging offside situations requires assistant referees to watch players that are close to an imaginary "offside line", and to judge if the second-last defender or a forward is closer to the goal of the defending team. Importantly, in a fully packed football stadium, many supporters are wearing the shirts or colors of the home team, reducing the figure-background contrast for home team players as compared to away team players. Numerous studies have shown that searching and perceiving low-contrast stimuli is more difficult than searching and perceiving high-contrast stimuli (e.g., De Vries et al., 2013; Harley et al., 2004). Results of a recent laboratory study suggest that differences in figure-background contrast may also affect offside decisions. Participants in that study missed offside positions of forwards more often, when forwards had lower figure-ground contrast than defenders as compared to when forwards had higher figure-ground contrast than defenders (Wühr et al., 2020).

Another purpose of the present study is to identify variables that influence the HA in offside decisions, and we investigate two such variables that were available to us. The first variable is the presence or absence of the video-assistant referee (VAR). The VAR is a supervisory referee that has the task of checking the decisions of the field referees by means of video recordings, and to inform the field referees about wrong decisions (e.g., Spitz et al., 2021). The VAR was introduced to the German Bundesliga in 2017. We chose our dataset to include three seasons before introduction of the VAR (i.e., seasons 2014/15-2016/17) and three seasons after the introduction of the VAR (i.e., seasons 2017/18-2019/20). One might assume that the audience in the arena has less influence on the VAR than it has on the field referees because the VAR is located outside the stadium. Hence, if the audience contributes to the HA in offside decisions, the HA arguably might be stronger without the VAR than with the VAR (see Dufner et al., 2023, for a similar line of reasoning). One might also expect that the VAR is less affected by differences in figure-background contrast than are the field (i.e., assistant) referees because the former has more time to inspect a critical scene.

A second variable that might influence the HA in offside decisions is the number of spectators present during a match. We performed two analyses to address the potential influence of this variable. Firstly, using the full dataset from six seasons, we analyzed the impact of the number of spectators on the size of the HA in offside decisions. If spectators influence the offside decisions of the (assistant) referees, then this effect should increase when the number of spectators increases. Secondly, we compared the size of the HA in matches with spectators to matches without spectators. Data from matches without spectators came from two seasons (2019/20 and 2020/21), when spectators were not allowed because of the Covid-19 pandemic. Here, we expected a stronger HA in offside decisions in matches with spectators as compared to matches without spectators.

Methods

Data Source and Materials. Because we planned to investigate the possible impact of the VAR on a possible HA in offside decisions, and the VAR was introduced in the German Bundesliga in season 2017/18, we decided to collect data from a total of six seasons from the internet database of the “kicker” magazine (www.kicker.de), a German football magazine. This resulted in a final sample of 1,836 matches and provided sufficient power to detect small effects in our focal analyses concerning the HA in offside decision making in a sensitivity analysis (cf. Faul et al., 2007). Three seasons (2014/15 – 2016/17) in our dataset were played without VAR, and three seasons (2017/18 – 2019/20) in our dataset were played with VAR. In the latter seasons, the VAR was supposed to correct errors in offside decisions made by the assistant referee (and the referee on the pitch) if a goal was scored by a player from an offside position. We do not know how often this occurred in our data set because the kicker database does not provide this information. We garnered a total of eight variables for each match: match result (home team win, draw, away team win), goals scored by home team, goals scored by away team, shots on opponent’s goal by home team, shots on opponent’s goal by away team, absolute number of offside decisions for home team, absolute number of offside decisions for away team, and the number of spectators present.

Season 2020/21, which followed on the last season in our primary sample, was not included in our primary analysis because it was strongly affected by the Covid-19 pandemic. In particular, whereas 96% of the matches in our primary sample were played in front of spectators, the majority (i.e. 92%) of matches in season 2020/21 took place without spectators. However, we used the data from season 2020/21 for an additional analysis in which we compared matches with spectators (in seasons 2018/19 and 2019/20) to matches without spectators (in seasons 2019/20 and 2020/21).

Design and Data Analysis. We planned three sets of analyses on our data set. The first set of analyses was intended to test for differences in performance between home and away teams in six seasons of the German Bundesliga. This was included to corroborate previous findings on the HA in the present data set. Therefore, we first analyzed the frequency distribution of three possible game outcomes, home team win, draw, and away team win. In addition, we compared the number of goals scored by home and away teams.

The second set of analyses was intended to test for differences in offside decisions against home and away teams across six seasons of the German Bundesliga. Therefore, we conducted three one-sample *t* tests on differences between home and away teams in three variables. The first test addressed the difference in offside decisions against home versus away teams. Here, a negative difference indicates a HA. The second test addressed the difference in shots on the opponent’s goal by home versus away teams. Here, a positive difference would reflect a more dominant or aggressive playing style of the home team. The third test addressed the difference in offside scores between home and away teams. The offside score was obtained by dividing the number of offside decisions against team x by the number of shots by team x on the goal of their opponent team. A negative difference in offside scores between home and away teams would indicate a HA.

We calculated the variable offside score for the following reason: When comparing the frequency of offside decisions for two different teams, the problem arises that match dominance or playing style affect the absolute frequency of offside decisions against a team. A dominant or offensive team attacks the opponent’s goal more often, and therefore creates more potential offside situations, than a less dominant or defensive team. Since home teams are known to play, on average, more dominant or more offensive than away teams (Staufenbiel et al., 2015), one should expect the absolute number of offside decisions to be higher against the home team than against the away team (e.g., Lepschy et al., 2021). Hence, to detect differences in offside decisions against home vs. away teams that are independent of match dominance or playing style, one must reduce (or eliminate) the effects of home dominance or playing style from the data. We reduced these effects by comparing offside scores, which resulted from dividing the number of offside decisions against team x by the number of shots of team x on their opponents’ goal. Number of shots is a good estimate for team dominance and/or offensive playing style because previous research has shown that the number of total shots and the number of shots on target are among the best predictors of success in football (e.g., Dufour et al., 2017; Lepschy et al., 2021; Pappalardo & Cintia, 2018).

The third set of analyses were complementary analyses intended to assess the possible impact of spectators on the presence and size of a HA in offside decisions. Firstly, we conducted a regression analysis with the number of spectators as the predictor variable, and the difference in offside scores (between home and away team) as the criterion variable. We used data from the six seasons between 2014 and 2020 for the first analysis. Secondly, we tested whether the difference in offside scores between home and away teams differed between matches with and without spectators. For the second analysis, we compared data from 351 matches without spectators (from seasons 2019/20 and 2020/21) to data from 359 matches with more than 30,000 spectators (from seasons 2018/19 and 2019/20). Hence, for this analysis, we ignored data from 208 matches (from seasons 2018/19 – 2020/21) where the number of spectators varied between 100 and 30,000.

The distributions of most variables that were analyzed for this study are presented in separate figures in the **Appendix**. The figures show that the distributions of all difference measures (goal difference, offside difference, offside-score difference) approximated a normal distribution in that they showed clear unimodality and good symmetry. We decided against transforming our raw data variables in an attempt to improve their distributional properties for several reasons. First, our previous experience has taught us repeatedly that transformations often do not improve the distributional properties of a variable. Secondly, transforming the variables have the undesirable consequence of complicating the interpretation of the results. In particular, the difference between two non-transformed means does not have the same meaning as the difference between two transformed means. Third, visual inspection revealed that the distributions of difference scores approximated a normal distribution. Fourth, sample sizes in our analyses were sufficiently large to warrant the use of parametric tests in line with the central limit theorem. Finally, we conducted our analyses using corrections for violations of the normal distribution (e.g., bootstrapping, see below).

Results

Win Rate. First, we tested whether there is a home advantage that would be reflected in a higher likelihood of home team wins. We used a χ^2 goodness-of-fit test to compare the observed frequencies of game outcomes (i.e., home team win, away team win, and draw) against equal distribution. This revealed that home team wins (n = 832, 45.3%) occurred more frequently than away team wins (n = 554, 30.2%) and draws (n = 450, 24.5%), $\chi^2 = 127.464$, $p < .001$. Thus, home teams are more likely to win than away teams, which suggests a home team advantage.

Goals Scored. Next, we tested whether there is a HA that would be reflected in the home team scoring more goals than the away team. For this test, we calculated the *goal difference* by subtracting the goals scored by the away team from the goals scored by the home team. Thus, a positive goal difference indicates a home team advantage while a negative goal difference indicates an away team advantage. A Shapiro-Wilk test indicated a violation of the normal distribution. However, distribution tests based on null-hypothesis significance testing (Cumming, 2014) are more likely to detect statistically significant effects as sample sizes increase, even for small or practically negligible deviations. Thus, we conducted visual inspection of the data, which showed that the goal difference approximated normal distribution. We further used a bootstrapped (1000 bootstrap samples) one-sample *t*-test to compare the goal difference against the value 0 (i.e., the value representing an equal goal ratio between the home team and the away team). The goal difference ($M = 0.349$, $SD = 1.950$) deviated significantly from 0, $t(1835) = 7.66$, $p < .001$, $d = 0.18$, 95% CI = [0.13; 0.23]. Home teams scored more goals than away teams. Descriptives of the analyzed variables can be found in Table 1.

Offside Decisions. Next, we tested whether there is a HA that would be reflected in fewer offside decisions against the home team. Similar to our approach with the goal difference above, we calculated the *offside decision difference* by subtracting the offside decisions against the away team from the offside decisions against the home team. A negative offside decision difference indicates a home team advantage, a positive offside decision difference indicates an away team advantage. Again, we used a bootstrapped (1000 bootstrap samples) one-sample *t*-test to compare the offside decision difference against the value 0 (i.e., the value representing an equal offside decision ratio between the home team and the away team). The offside decision difference ($M = 0.232$, $SD = 2.381$) deviated significantly from 0, $t(1835) = 4.18$, $p < .001$, $d = 0.10$, 95% CI = [0.05; 0.14]. Home teams receive more offside decisions than away teams.

Shots Taken. We tested whether there is a home advantage that would be reflected in home teams playing more aggressively (i.e., taking more shots at the away team's goal). Therefore, we calculated the *shot difference* by subtracting the number of shots taken by the away team from the shots taken by the home team. A positive shot difference indicates a home team advantage (i.e., the home team plays more aggressively), a negative shot difference indicates an away team advantage (i.e., the away team plays more aggressively). Again, we used a bootstrapped (1000 bootstrap samples) one-sample *t*-test to compare the shot difference against the value 0 (i.e., the value representing an equal shot ratio between the home team and the away team). The shot difference ($M = 2.429$, $SD = 8.133$) deviated significantly from 0, $t(1835) = 12.80$, $p < .001$, $d = 0.30$, 95% CI = [0.25; 0.35]. Home teams take more shots at the opponent's goal than away teams.

Offside Decisions Relative to Shots Taken. The number of offside decisions against a team is inextricably linked to the number of shots taken by that team. Therefore, we calculated the *offside score* by dividing the number of offside decisions by the number of shots taken. We then calculated the *offside score difference* by subtracting the offside score of the away team from the offside score of the home team. A negative offside score difference indicates a home

Table 1. Descriptive statistics of four dependent variables (scored goals, number of offside decisions, shots on goal, offside score) as a function of Team (home, away) and Season.

Variable	Team	Seasons	
		2014/15 – 2016/17	2017/18 – 2019/20
Scored Goals	Home	1.603	1.684
	Away	1.214	1.377
	Difference	0.390	0.307
Offside Decisions	Home	2.510	2.171
	Away	2.352	1.865
	Difference	0.158	0.306
Shots on Goal	Home	14.040	14.331
	Away	11.584	11.930
	Difference	2.456	2.401
Offside Scores	Home	0.217	0.176
	Away	0.248	0.196
	Difference	-0.030	-0.020

Note. Difference = Home – Away.

team advantage, a positive offside score difference indicates an away team advantage. We used a bootstrapped (1000 bootstrap samples) one-sample *t*-test to compare the offside score difference against the value 0 (i.e., the value representing equal offside scores). The offside score difference (M = -0.025, SD = 0.312) deviated significantly from 0, $t(1835) = -3.46$, $p < .001$, d = -0.08, 95% CI = [-0.13; -0.04]. Home teams receive fewer offside decisions relative to the shots they take than away teams, indicating a HA.

Influence of VAR. We tested whether the introduction of the VAR in season 2017/18 affected the number of offside decisions. Therefore, we created a dichotomous variable in which we coded whether VAR was present during the games (code 0 for seasons 2014/15, 2015/16, and 2016/17) or not (code 1 for seasons 2017/18, 2018/19, and 2019/20). A bootstrapped (1000 bootstrap samples) independent-samples *t*-test comparing the offside decision difference between VAR games (M = 0.306, SD = 2.270, n = 918) and non-VAR games (M = 0.158 SD = 2.487, n = 918) revealed no significant difference, $t(1818.907) = -1.33$, p = .183, d = -0.06, 95% CI = [-0.15; 0.03]. The introduction of the VAR had no influence on the offside decision difference.

We repeated this test, again with bootstrapping, comparing the offside score difference between VAR-games (M = -0.020, SD = 0.294, n = 918) and non-VAR games (M = -0.030, SD = 0.329, n = 918). Again, we found no significant difference, $t(1812.00) = -0.73$, p = .468, d = -0.03, 95% CI = [-0.13; 0.06]. The introduction of VAR had no influence on the offside score difference.

Complementary Analyses. In a first analysis we investigated whether the number of spectators would influence the difference in offside scores between home and away teams. Therefore, we performed a linear regression analysis, with number of spectators as the predictor variable, and the difference in offside scores between home and away team as the criterion variable. Concerning the predictor variable, we transformed the absolute number of spectators, which ranged from 0 to 80,000, into 9 levels with a step size of 10,000. This transformation does not change the qualitative pattern of results, but facilitates the interpretation of the results (e.g., of regression parameters). The fitted regression model was difference in offside scores = 0.065 - 0.024 × spectators. The overall regression model was significant, R^2 = .024, $F(1, 1834) = 44.195$, p < .001. In particular, the beta-weight for the predictor variable "spectators" was also significant, t = -6.642, p < .001. When the number of spectators increased, the difference in offside scores between home and away teams became increasingly more negative (cf. **Figure 1**). In other words, when the number of spectators increased, the HA in offside scores increased, too. In summary, the number of spectators makes a small (R^2 = .024) but significant contribution to predicting the HA in offside scores.

In a second analysis, we compared the offside score differences between matches without spectators (M = -0.002, SD = 0.36, n = 350) and matches with many spectators (> 30.000; M = -0.05, SD = 0.32, n = 359) using a bootstrapped (1000 bootstrap samples) independent-samples *t*-test. We found a significant difference, $t(707) = 1.99$, p = .047, d = 0.15, 95% CI = [0.002; 0.30]. In full stadiums (vs. empty stadiums), home teams receive fewer offside decisions relative to the shots they take at the goal than in empty stadiums, indicating a stronger home team advantage in full stadiums. Note that the offside score difference for zero spectators in this analysis (M = -0.002) differs from the one predicted by the regression model for X = 0 in Figure 1 (Y = .065). The reason for this discrepancy is that the difference in offside scores in the second analysis (M = -0.002) is the mean difference score observed in 351 games without spectators, whereas the value in Figure 1 is the prediction of a regression model for X = 0, which is based on a dataset containing only 81 matches without spectators. The discrepancy may suggest that the relationship between the number of spectators and the difference in offside scores is not

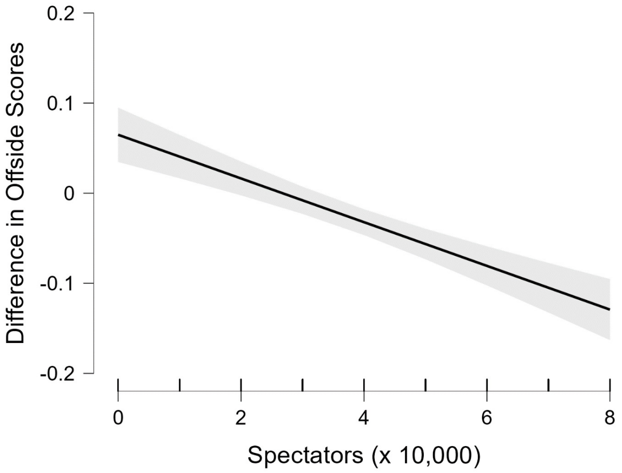

Figure 1. Linear regression line with number of spectators (x 10,000) as the predictor variable, and the difference in offside scores (between home and away teams) as the criterion variable. The shaded area shows the 95% confidence interval around the regression line.

perfectly linear, but may level off when the number of spectators decreases.

Discussion

The main purpose of this study is to investigate a possible HA in offside decisions of referees and assistant referees. Therefore, we compared performance parameters of home teams and away teams in 1,864 matches of the German Bundesliga from 2014 to 2020. We observed clear evidence for a HA in performance outcomes (i.e., goals, shots on goals). Further results showed that home teams were more dominant offensively than away teams. To investigate the HA in offside decisions, differences in playing style or match dominance must be removed from the data because these variables are correlated with the absolute number of offside situations and, thus, offside decisions. Hence, we computed offside scores by dividing the absolute number of offside decisions against team x by the number of shots of team x on their opponents' goal. These offside scores place the number of offside decisions against team x in relation to the number of attempts of scoring a goal. Comparing offside scores revealed a HA in offside decisions: Offside scores of home teams were smaller than offside scores of away teams.

Our study is the first to report evidence for a HA in offside decisions in professional football. The HA reflects the fact that referees make less offside decisions against home teams than against away teams, when differences in playing style or team dominance are controlled for. Although these effects are numerically small, they may have a strong influence on the outcome of a football match because scoring a single goal often decides a match outcome. One might object that in many football competitions, such as the German Bundesliga, the effects of HA cancel each other out because each team plays each other team both at home and away. Yet, there are other competitions, such as national cup competitions (e.g., FA cup in England, DFB cup in Germany), with only one match at each stage of the competition, where the HA may have a stronger effect on the outcome. Moreover, even two-legged matchups in knock-out competitions might not fully remove the HA because crowd size, and their effects, as well as referee bias (Page & Page, 2007) might differ between the two matches.

Another purpose of our study was to identify variables that could influence the HA in offside decisions. We considered two variables in the available data set. The first variable was the absence or presence of the VAR. Our dataset contained three seasons (2014/15, 2015/16, 2016/17) without VAR, and three seasons with VAR (2017/18, 2018/19, 2019/20). A first analysis showed that the presence or absence of the VAR did not affect the difference in offside decisions between home and away teams. Moreover, a second analysis showed that the presence or absence of the VAR did not affect the home advantage in offside decisions (i.e. the difference in offside scores between home and away teams). The latter finding might have two implications. First, the lack of an effect of the VAR on the HA in offside decisions implies that the source of this effect does not only affect (offside) judgments of field referees, but also (offside) judgments of the VAR. Second, the lack of an effect of the VAR on the HA in offside decisions also implies that the VAR cannot remove any bias in referee decisions. This reasoning stands in contrast to a recent study (Dufner et al., 2023) which suggests that the VAR reduced the HA, possibly by making referee decision-making fairer. However, as admitted by the authors, these results need to be interpreted with caution because direct assessments of the change induced by the introduction of the VAR were not statistically significant. Therefore, future research is needed to gain understanding on the potential of the VAR in reducing officiating bias as the VAR might also be susceptible to biases as indicated in the present research.

A second variable that might affect offside decisions is the audience of a match. We conducted two analyses on the impact of the spectators on the HA in offside decisions. In our first analyses, we investigated how the number of spectators affected the HA in offside decisions. Interestingly, a regression analysis showed an effect of the number of spectators on the difference between offside scores of home and away teams: The higher the number of spectators, the more negative the difference between offside scores of home and away teams was. In other words, when the number of spectators increased, the HA in offside decisions increased, too. This result provides first indication for a causal impact of the audience on the HA in offside decisions. Unfortunately, the regression analysis suffered from the problem that the number of spectators correlated with clubs. In Germany, the richer and more successful clubs (e.g., Bayern Munich, Borussia Dortmund) have larger arenas, and thus more spectators in home matches, as compared to the poorer and less successful clubs (e.g., VfL Bochum, SV Darmstadt 98). Thus, the results of our regression analysis might also mean that differences in economic power and team quality, and not differences in the number of spectators, affect the HA in offside decisions. Hence, we conducted a second analysis where we compared offside scores from home and away teams in matches with and without spectators. Matches without spectators took place during the Covid-19 pandemic (mainly in season 2020/21), and were compared to matches with spectators from the same teams in adjacent seasons. The results of the second analysis confirmed those of the first analysis: The HA was larger in matches with spectators as compared to matches without spectators. Our findings fit a recent report by Benz and Lopez (2023), reporting a similar decline of goal-related HA in the German Bundesliga during the Covid-19 pandemic.

The results of our additional analyses suggest that spectators play a role for the origin of the HA in offside decisions. There are, however, different possible ways of how spectators can influence the offside decisions of referees. A first possibility is that the spectators' *behavior* in the arena influences the referees' offside decisions. The audiences loud support (e.g., cheering) during offensive actions of the home team might prevent (assistant) referees from making an offside decision against the home team. Conversely, the audiences' loud disapproval (e.g., booing, or shouting "offside!") during offensive actions of the away team might motivate the (assistant) referee to make an offside decision against the away team. Moreover, when viewed from a learning perspective, the different consequences of offside decisions against home and away teams might also affect the relative frequencies of these decisions in the future. The home audience often punishes offside decisions against the home team, and these negative consequences might reduce the probability of such decisions in the future, particularly as the assistant referee tends to stand close to the audience. Conversely, the home audience often reinforces (e.g., applaud) offside decisions against the away team, and these positive consequences might increase the probability of such decisions in the future.

A second possibility of how spectators might affect offside decisions is that the visual *appearance* of the spectators affects the decisions. The task of judging offside requires the assistant referee to watch an (imaginary) offside line, which is defined by the position of the second last defender, and to judge if a forward or defender is closer to the goal under attack, when the ball is played. In many football matches at the professional level, many spectators wear the colors or dresses of the home team and, therefore, players of the home team are more similar to the background (of spectators) than players of the away team. In other words, in a fully packed stadium, the figure-background contrast is lower for players of the home team as compared to players of the away team. As a result, home team players are less visible for (assistant) referees than are away team players, and therefore offside positions of home team players could be missed more often than offside positions of away team players. Admittedly, the differences in figure-background contrast between home- and away team players might be subtle, and therefore might not necessarily affect all kinds of referee decisions. It is however conceivable that even subtle differences in figure-background contrast might affect offside decisions that require the detection of miniscule differences in relative position within a couple of milliseconds.

Many studies have shown that figure-background contrast is a critical variable in visual perception (cf. Harley et al., 2004, for a review), and that differences in figure-background contrast can have strong effects in many perceptual tasks, such as visual search (e.g., De Vries et al., 2013; Hunter et al., 2018). In addition, the results of more recent studies suggest that differences in figure-background contrast, between players of home and away teams, can affect the visibility of players in general (e.g., Rikkert et al., 2015), and offside judgments in particular (e.g., Wühr et al., 2020). For example, in a laboratory study, Wühr et al. (2020) showed that participants missed offside positions of forwards more often when the forwards had less figure-background contrast than the defenders, as compared to when the forwards had higher figure-background contrast than the defenders. Note that less figure-background contrast can be assumed for home teams, whereas higher figure-background contrast can be assumed for away teams.

The finding that the VAR did not affect the size of the HA in offside decisions appears surprising at first glance. In fact, regardless of whether spectator behavior (pressure on field referees) or spectator appearance (figure-background contrast) are responsible for the HA in offside decisions, one could have expected the effect to decrease when the VAR is present. One might expect spectator behavior, like cheering when the home team attacks or booing when the away team attacks, to have a stronger impact on the field referees because they are directly exposed to—and often the target of—spectator behavior, whereas the VAR is neither visible to the audience nor directly exposed to their behavior. On the other hand, VARs are watching the match on TV screens, and therefore perceive the spectators' behavior during a match. In addition, because VARs are usually well-experienced field referees, they might even identify with the actual field referees, and anticipate the positive or negative reactions of the spectators on their decisions. Hence, ways of how spectator behavior might also affect VAR decisions are conceivable. One might also expect spectator presence or appearance, which might decrease the visibility of home team players as compared to away team players, to have a stronger impact on field referees than on VARs. First, field referees are typically watching the players before a background of spectators, whereas the VAR has different viewing angles for watching the critical scene. Second, field referees must make offside decisions for a single moment in a continuously moving stream of events, whereas the VAR can stop and repeat recordings of the critical scene. Nevertheless, it cannot be excluded that perceptual variables, like figure-background contrast, may also affect offside judgments of VARs while watching video-recordings of match scenes. However, in this regards it has to be acknowledged that he main referee is the sole authority responsible for making final decisions, while the VAR holds the same status as other match officials and can only provide assistance (IFAB, 2022). Consequently, although the VAR can offer recommendations, the final judgment rests with the main referee. Notably, referees may be influenced by crowd noise, potentially leading to decisions that favor the home team over the away team. In addition, it is worth mentioning that research (Spitz et al., 2021) suggests that the VAR indeed increases correct decisions, but is far from perfect, leaving room for human error.

On the basis of the present findings, we cannot decide whether the behavior of the spectators, the appearance of the spectators, or both variables, affect offside judgments. Both variables cannot be systematically varied in real matches, and therefore experimental investigations of causal relationships in the field are not possible. Hence, the causal impact of these two variables on offside decisions should be addressed in well-controlled laboratory studies.

Past research has demonstrated that the presence (or absence) of a running track around the football ground can influence the HA in soccer (Scoppa, 2008). In particular, the HA was larger in stadiums without a running track, as compared to stadiums with a track. Scoppa (2008) explained this effect by suggesting that spectators are closer to the field, and thus, to the referee, in a stadium without a track, and therefore can exert more (social) pressure on the referee, as compared to the situation in a stadium with a running track between spectators and the field. Unfortunately, we were unable to address the possible impact of the presence/absence of a running track on the HA in our study because only two stadiums (i.e., Berlin, Nuremberg) from a total of 24 stadiums in our sample contained a running track. As a result, only 6.5% of the matches in our sample were played in a stadium with a running track, whereas the large majority of matches (93.5%) was played in a stadium without a running track. The unequal number of observations prevents meaningful statistical comparisons between the two conditions. However, investigating the impact of the presence or absence of a running track on the home advantage in offside judgments might be an interesting idea for future research.

Taken together, the present results add to the growing body of literature examining the mechanisms contributing to the HA in sports. The findings support the contemporary theorizing that the HA is a multi-causal phenomenon that is explained by several factors and their interplay (see, Gómez-Ruano et al., 2021, for a review). In line with studies demonstrating the influence of spectators/fans (e.g., booing and cheering; Armatas & Pollard, 2014) on the HA and their corresponding influence on the referee's decision making (Downward & Jones, 2007; Garicano et al., 2005; Goumas, 2014a; Scoppa, 2008; Sutter & Kocher, 2004; Unkelbach & Memmert, 2010), the present results appear to point to a similar causal mechanism affecting ARs' offside calls. Hence, social factors associated with playing at home or away affect a variety of decisions like the amount of extra time awarded, penalties given, yellow and red cards given, and offside calls, which cumulatively contribute to home team favoritism of officials and the HA in sports.

Author Contributions

P. W.: Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing - Original Draft, Writing - Review & Editing, Visualization, Project administration. M. M.: Formal analysis, Writing – Review & Editing. P. F.: Conceptualization, Writing – Original Draft, Writing – Review & Editing. D. M.: Conceptualization, Writing – Original Draft, Writing – Review & Editing.

Competing Interests

The authors have no competing interests to declare that are relevant to the content of this article.

Availability of Data and Materials

The data reported in this article is publicly available at www.kicker.de. The data is neither owned nor collected by the authors. We confirm that (at least until May 15, 2024) others are able to access these data in the same manner as the authors. We confirm that we did not have any special access privileges. The match statistics of a particular match can be accessed by performing the following steps: (1) access the subpage for matchdays (https://www.kicker.de/bundesliga/spieltag), (2) select the desired season (e.g., 2018/19), (3) select the desired matchday (e.g., matchday 1), (4) select the desired match (e.g., Bayern Munich vs. Hoffenheim, (5) click on the link "Spieldaten" (match data). Here, you will find the match statistics that were used for our analyses.

Submitted: November 12, 2024 PDT. Accepted: March 21, 2025 PDT. Published: April 01, 2025 PDT.

References

Agnew, G. A., & Carron, A. V. (1994). Crowd effects and the home advantage. *International Journal of Sport Psychology*, *25*, 53–62.

Allen, M. S., & Jones, M. (2014). The "Home Advantage" in Athletic Competitions. *Current Directions in Psychological Science*, *23*, 48–53. https://doi.org/10.1177/0963721413513267

Armatas, V., & Pollard, R. (2014). Home advantage in Greek football. *European Journal of Sport Science*, *14*, 116–122. https://doi.org/10.1080/17461391.2012.736537

Avugos, S., & Bar-Eli, M. (2021). The Home Advantage Bias in Sport Referees' Decisions. In M. A. Gómez-Ruano, R. Pollard, & C. Lago-Peñas (Eds.), *Home Advantage in Sport* (1st ed., pp. 107–117). Routledge. https://doi.org/10.4324/9781003081456-13

Benz, L. S., & Lopez, M. J. (2023). Estimating the change in soccer's home advantage during the Covid-19 pandemic using bivariate Poisson regression. *AStA Advances in Statistical Analysis*, *107*, 205–232. https://doi.org/10.1007/s10182-021-00413-9

Bilalić, M., Gula, B., & Vaci, N. (2021). Home advantage mediated (HAM) by referee bias and team performance during covid. *Scientific Reports*, *11*(1), 21558. https://doi.org/10.1038/s41598-021-00784-8

Boyko, R. H., Boyko, A. R., & Boyko, M. G. (2007). Referee bias contributes to home advantage in English Premiership football. *Journal of Sports Sciences*, *25*(11), 1185–1194. https://doi.org/10.1080/02640410601038576

Courneya, K. S., & Carron, A. V. (1992). The home advantage in sport competitions: A literature review. *Journal of Sport and Exercise Psychology*, *14*, 28–39.

Cumming, G. (2014). The new statistics: why and how. *Psychological Science*, *25*(1), 7–29. https://doi.org/10.1177/0956797613504966

De Vries, J. P., Hooge, I. T. C., Wertheim, A. H., & Verstraten, F. A. J. (2013). Background, an important factor in visual search. *Vision Research*, *86*, 128–138. https://doi.org/10.1016/j.visres.2013.04.010

Downward, P., & Jones, M. (2007). Effects of crowd size on referee decisions: Analysis of the FA Cup. *Journal of Sports Sciences*, *25*, 1541–1545. https://doi.org/10.1080/02640410701275193

Dufner, A.-L., Schütz, L.-M., & Hill, Y. (2023). The introduction of the Video Assistant Referee supports the fairness of the game – An analysis of the home advantage in the German Bundesliga. *Psychology of Sport and Exercise*, *66*. https://doi.org/10.1016/j.psychsport.2023.102386

Dufour, M., Phillips, J., & Ernwein, V. (2017). What makes the difference? Analysis of the 2014 World Cup. *Journal of Human Sport and Exercise*, *3*, 616–629. https://doi.org/10.14198/JHSE.2017.123.06

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. https://doi.org/10.3758/BF03193146

Garicano, L., Palacios-Huerta, I., & Prendergast, C. (2005). Favoritism Under Social Pressure. *Review of Economics and Statistics*, *87*, 208–216. https://doi.org/10.1162/0034653053970267

Gómez-Ruano, M. A., Pollard, R., & Lago-Peñas, C. (Eds.). (2021). *Home Advantage in Sport: Causes and the Effect on Performance*. Routledge. https://doi.org/10.4324/9781003081456

Goumas, C. (2014a). Home advantage and referee bias in European football. *European Journal of Sport Science*, *14 Suppl 1*, S243-9. https://doi.org/10.1080/17461391.2012.686062

Goumas, C. (2014b). Home advantage in Australian soccer. *Journal of Science and Medicine in Sport*, *17*, 119–123. https://doi.org/10.1016/j.jsams.2013.02.014

Harley, E. M., Dillon, A. M., & Loftus, G. R. (2004). Why is it difficult to see in the fog? How stimulus contrast affects visual perception and visual memory. *Psychonomic Bulletin & Review*, *11*, 197–231. https://doi.org/10.3758/BF03196564

Hunter, M., Godde, B., & Olk, B. (2018). Effects of absolute luminance and luminance contrast on visual search in low mesopic environments. *Attention, Perception, & Psychophysics*, *80*, 1265–1277. https://doi.org/10.3758/s13414-018-1512-0

IFAB. (2022). *Laws of the Game 22/23*. Zurich, Switzerland. https://www.fifplay.com/downloads/documents/laws-of-the-game-2022-2023.pdf

IFAB. (2023). *Laws of the Game. Football laws, rules, and regulations*. https://www.theifab.com/laws/latest/offside/

Jamieson, J. P. (2010). The Home Field Advantage in Athletics: A Meta-Analysis. *Journal of Applied Social Psychology*, *40*, 1819–1848. https://doi.org/10.1111/j.1559-1816.2010.00641.x

Johnston, R. (2008). On referee bias, crowd size, and home advantage in the English soccer Premiership. *Journal of Sports Sciences*, *26*(6), 563–568. https://doi.org/10.1080/02640410701736780

Jones, M. B. (2013). The home advantage in individual sports: An augmented review. *Psychology of Sport and Exercise*, *14*, 397–404. https://doi.org/10.1016/j.psychsport.2013.01.002

Lago-Peñas, C., & Gómez-Ruano, M. A. (2021). How Does Playing without an Audience Affect the Home Advantage? In M. A. Gómez-Ruano, R. Pollard, & C. Lago-Peñas (Eds.), *Home Advantage in Sport* (1st ed., pp. 85–95). Routledge. https://doi.org/10.4324/9781003081456-11

Lepschy, H., Woll, A., & Wäsche, H. (2021). Success factors in the FIFA 2018 World Cup in Russia and FIFA 2014 World Cup in Brazil. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.638690

Lovell, G. P., Newell, R., & Parker, J. K. (2014). Referees' Decision Making Behavior and the Sport Home Advantage Phenomenon. *Research in Psychology and Behavioral Sciences*, *2*(1), 1–5. https://doi.org/10.12691/rpbs-2-1-1

Moore, J. C., & Brylinsky, J. A. (1993). Spectator effect on team performance in college basketball. *Journal of Sport Behavior*, *16*, 77–85.

Nevill, A. M., Balmer, N., & Williams, M. A. (2002). The influence of crowd noise and experience upon refereeing decisions in football. *Psychology of Sport and Exercise*, *3*, 261–272. https://doi.org/10.1016/S1469-0292(01)00033-4

Nevill, A. M., & Holder, R. L. (1999). Home advantage in sport. *Sports Medicine*, *28*, 221–236. https://doi.org/10.2165/00007256-199928040-00001

Nevill, A. M., Newell, S. M., & Gale, S. (1996). Factors associated with home advantage in English and Scottish soccer matches. *Journal of Sports Sciences*, *14*(2), 181–186. https://doi.org/10.1080/02640419608727700

Page, L., & Page, K. (2007). The second leg home advantage: Evidence from European football cup competitions. *Journal of Sports Sciences*, *25*(14), 1547–1556. https://doi.org/10.1080/02640410701275219

Pappalardo, L., & Cintia, P. (2018). Quantifying the relation between performance and success in soccer. *Advances in Complex Systems*, *21*, 1750014. https://doi.org/10.1142/S021952591750014X

Pettersson-Lidbom, P., & Priks, M. (2010). Behavior under social pressure: Empty Italian stadiums and referee bias. *Economics Letters*, *108*, 212–214. https://doi.org/10.1016/j.econlet.2010.04.023

Pollard, R. (2006). Worldwide regional variations in home advantage in association football. *Journal of Sports Sciences*, *24*, 231–240. https://doi.org/10.1080/02640410500141836

Pollard, R. (2008). Home Advantage in Football: A Current Review of an Unsolved Puzzle. *The Open Sports Sciences Journal*, *1*, 12–14. https://doi.org/10.2174/1875399X00801010012

Pollard, R., & Gomez, M. A. (2014). Components of home advantage in 157 national football leagues worldwide. *International Journal of Sport and Exercise Psychology*, *12*, 218–233. https://doi.org/10.1080/1612197X.2014.888245

Pollard, R., & Pollard, G. (2005). Long-term trends in home advantage in professional team sports in North America and England (1876-2003). *Journal of Sports Sciences*, *23*, 337–350. https://doi.org/10.1080/02640410400021559

Recht, L. D., Lew, R. A., & Schwartz, W. J. (1995). Baseball teams beaten by jet lag. *Nature*, *377*(6550), 583. https://doi.org/10.1038/377583a0

Rikkert, J. O., De Haes, V., Barsingerhorn, A. D., Theelen, T., & Rikkert, M. G. M. O. (2015). The colour of a football outfit affects visibility and team success. *Journal of Sports Sciences*, *33*, 2166–2172. https://doi.org/10.1080/02640414.2015.1064156

Scoppa, V. (2008). Are subjective evaluations biased by social factors or are subjective evaluations biased by social factors or connections. An economic analysis of soccer referee decisions. *Empirical Economics*, *35*, 123–140.

Scoppa, V. (2021). Social pressure in the stadiums: Do agents change behavior without crowd support? *Journal of Economic Psychology*, *82*, 102344. https://doi.org/10.1016/j.joep.2020.102344

Spitz, J., Wagemans, J., Memmert, D., Williams, A. M., & Helsen, W. F. (2021). Video assistant referees (VAR): The impact of technology on decision making in association football referees. *Journal of Sports Science*, *39*, 147–153. https://doi.org/10.1080/02640414.2020.1809163

Staufenbiel, K., Lobinger, B., & Strauss, B. (2015). Home advantage in soccer–A matter of expectations, goal setting and tactical decisions of coaches? *Journal of Sports Sciences*, *33*(18), 1932–1941. https://doi.org/10.1080/02640414.2015.1018929

Strauss, B. (2002). The impact of supportive spectator behavior on performance in team sports. *International Journal of Sport Psychology*, *33*, 372–390.

Sutter, M., & Kocher, M. G. (2004). Favoritism of agents – The case of referees' home bias. *Journal of Economic Psychology*, *25*, 461–469. https://doi.org/10.1016/S0167-4870(03)00013-8

Unkelbach, C., & Memmert, D. (2010). Crowd noise as a cue in referee decisions contributes to the home advantage. *Journal of Sport & Exercise Psychology*, *32*, 483–498. https://doi.org/10.1123/jsep.32.4.483

Wolaver, D. A. M., & Magee, D. C. (2022). Ghost Games: Crowds, Referee Bias, and Home Advantage in European Football Leagues. *Journal of Sport Behavior*, *45*(3), 91–107.

Wühr, P., Fasold, F., & Memmert, D. (2020). The impact of team preferences on soccer offside judgments in laypersons: A quasi-experimental study. *Cognitive Research: Principles and Implications*, *5*. https://doi.org/10.1186/s41235-020-00253-2

Wunderlich, F., Furley, P., & Memmert, D. (2021). Home Sweet Home. In M. A. Gómez-Ruano, R. Pollard, & C. Lago-Peñas (Eds.), *Home Advantage in Sport* (1st ed., pp. 44–50). Routledge. https://doi.org/10.4324/9781003081456-6

Wunderlich, F., Weigelt, M., Rein, R., & Memmert, D. (2021). How does spectator presence affect football? Home advantage remains in European top-class football matches played without spectators during the COVID-19 pandemic. *PloS One*, *16*, e0248590. https://doi.org/10.1371/journal.pone.0248590

Appendix

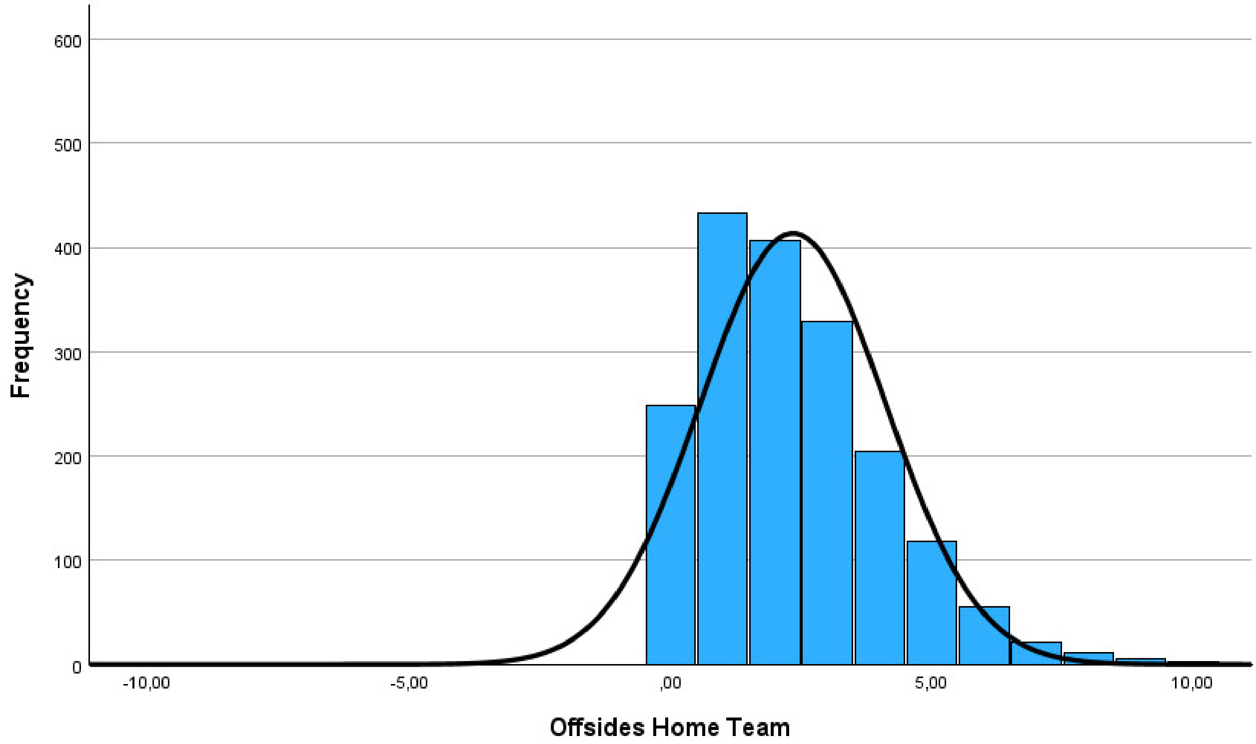

Figure A1. Histogram of offside decisions against home team. The solid line represents a normal distribution.

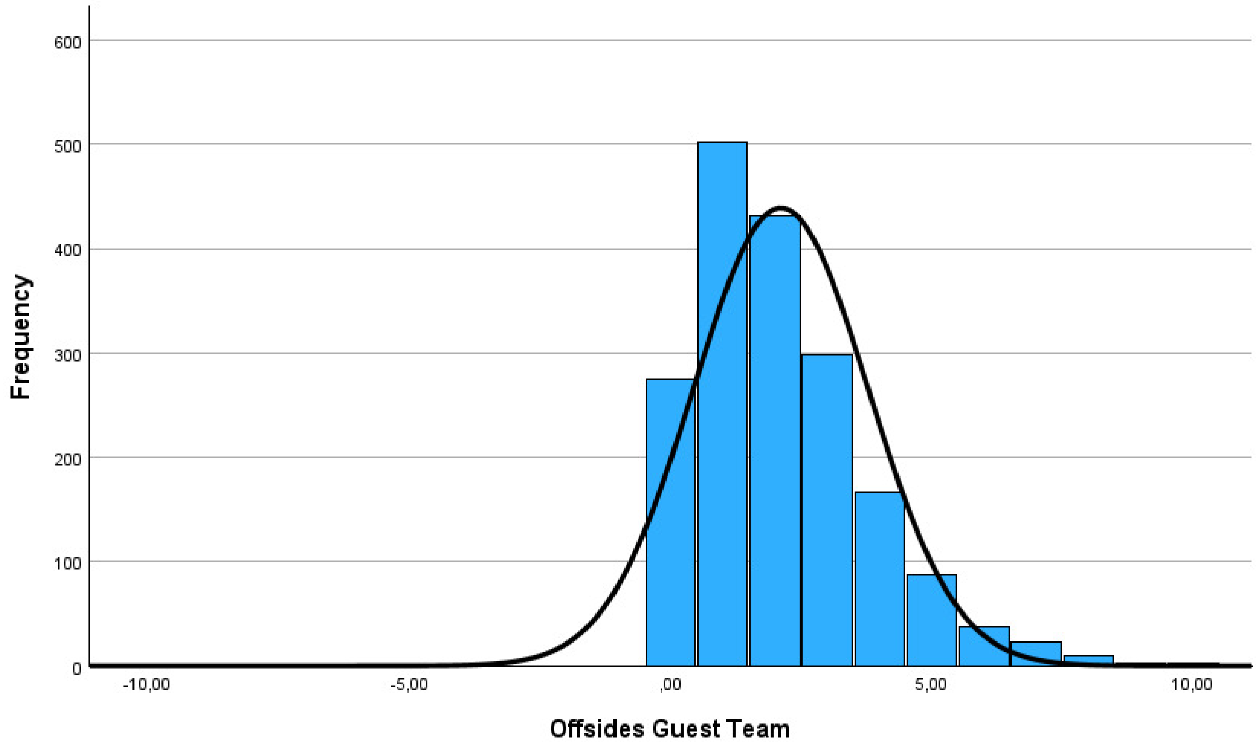

Figure A2. Histogram of offside decisions against guest (away) team. The solid line represents a normal distribution.

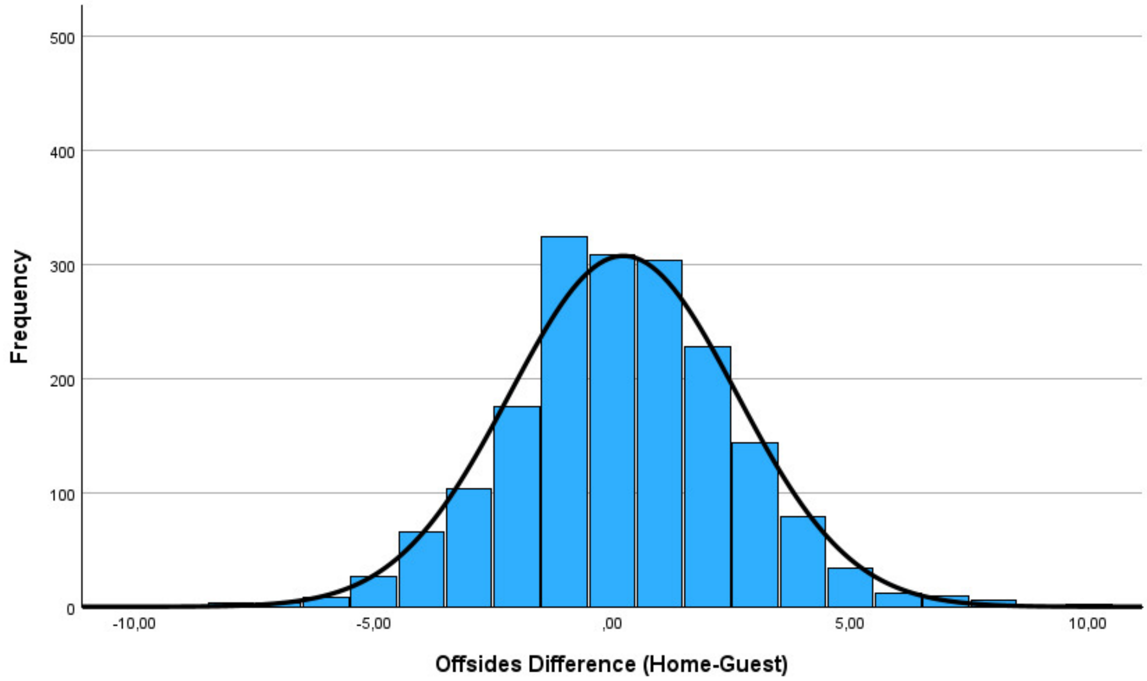

Figure A3. Histogram of differences in offside decisions against home versus guest (away) team. The solid line represents a normal distribution.

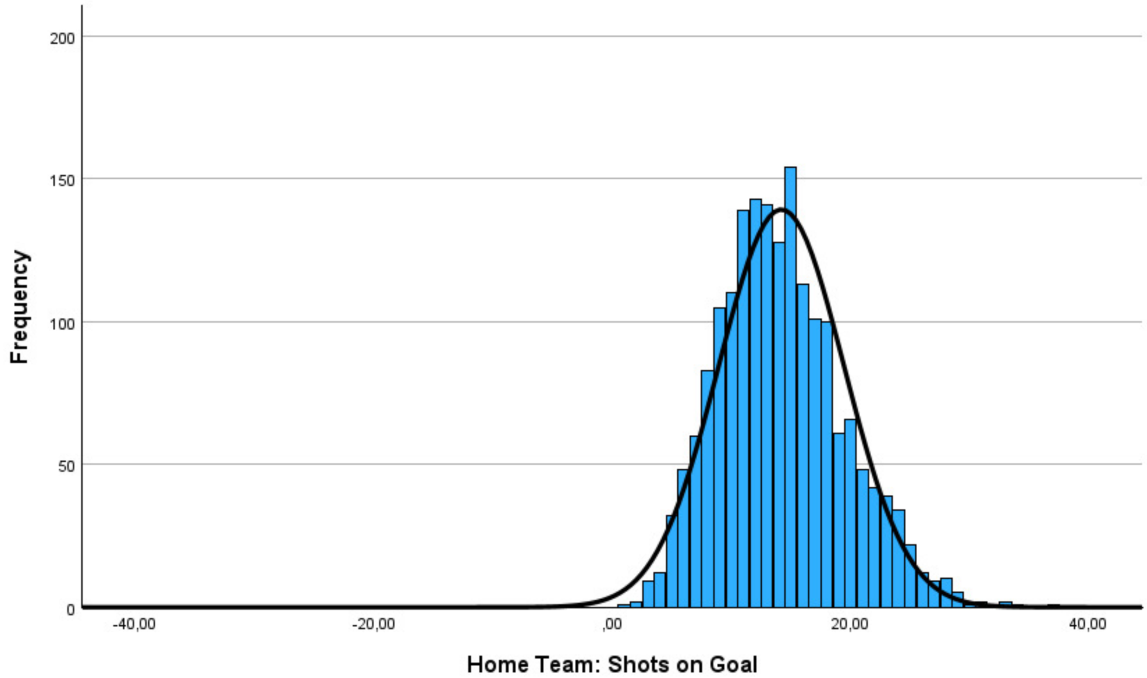

Figure A4. Histogram of shots on goal made by the home team. The solid line represents a normal distribution.

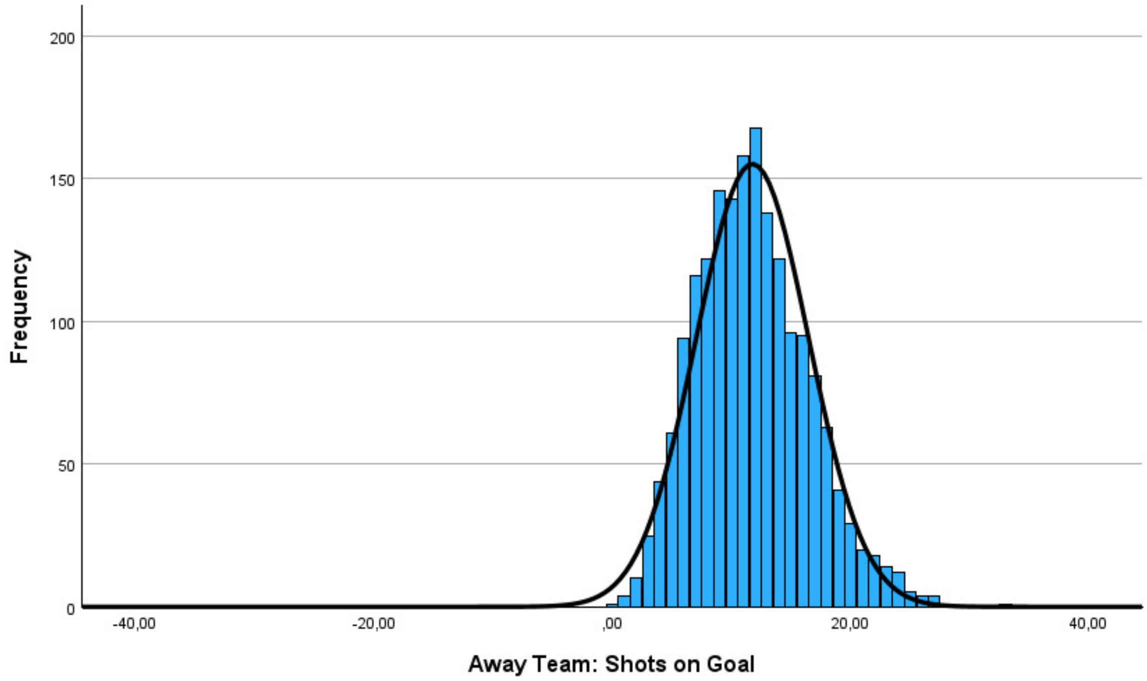

Figure A5. Histogram of shots on goal made by the away (guest) team. The solid line represents a normal distribution.

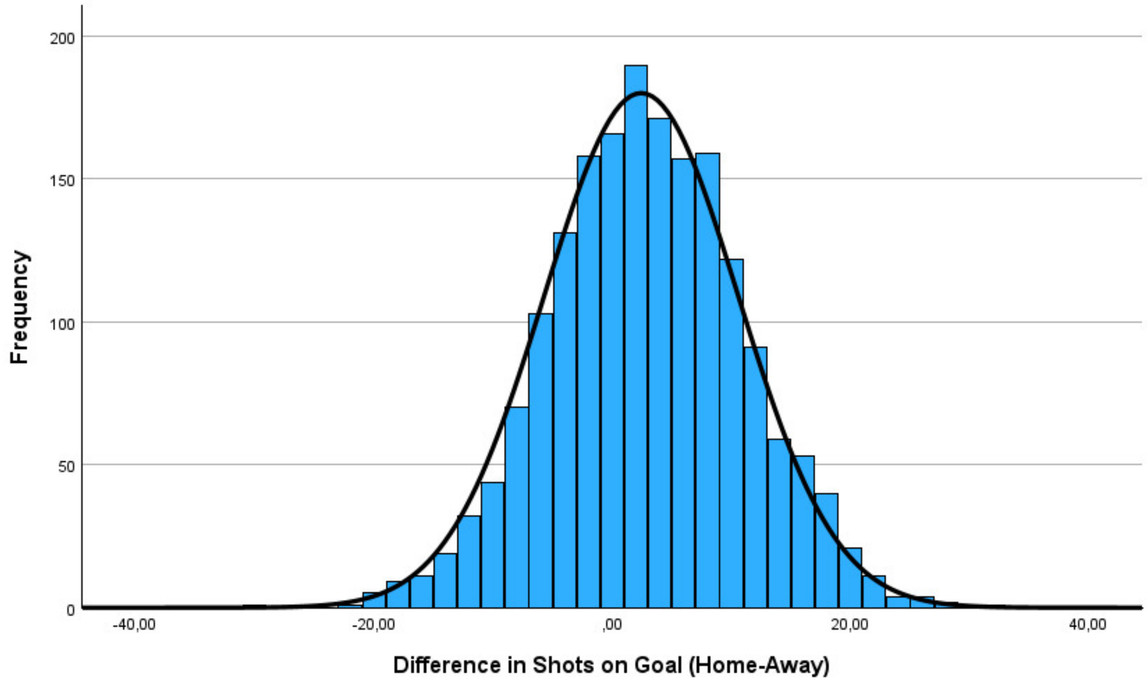

Figure A6. Histogram of differences in shots on goal made by the home versus the away (guest) team. The solid line represents a normal distribution.

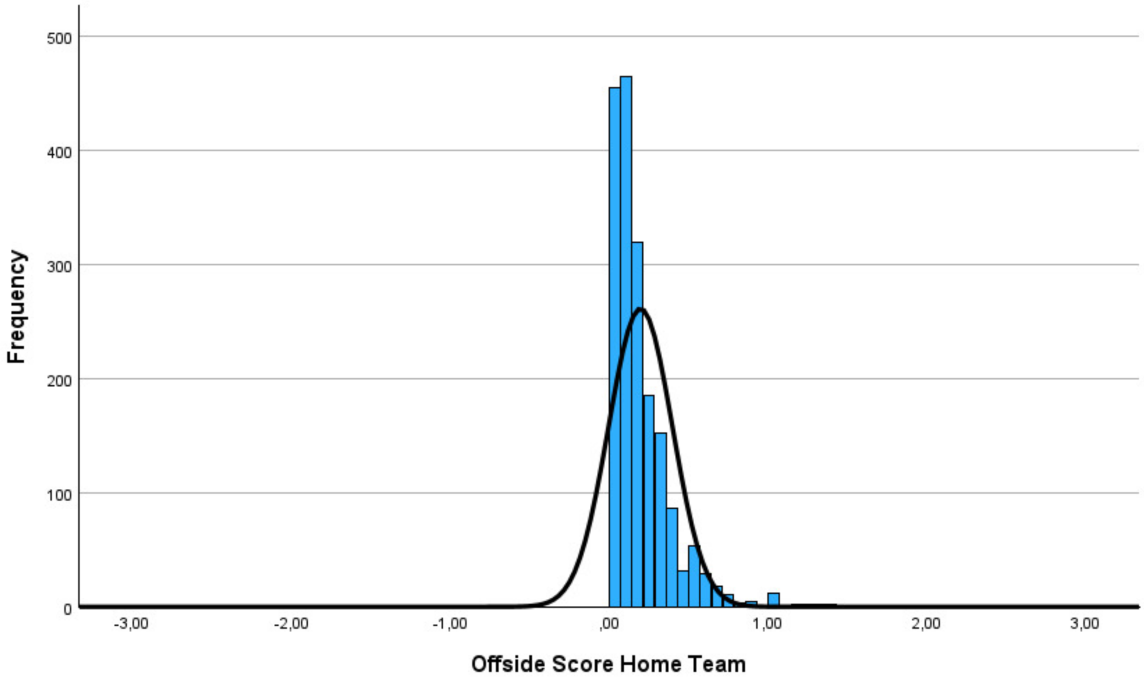

Figure A7. Histogram of offside scores for home teams. The solid line represents a normal distribution.

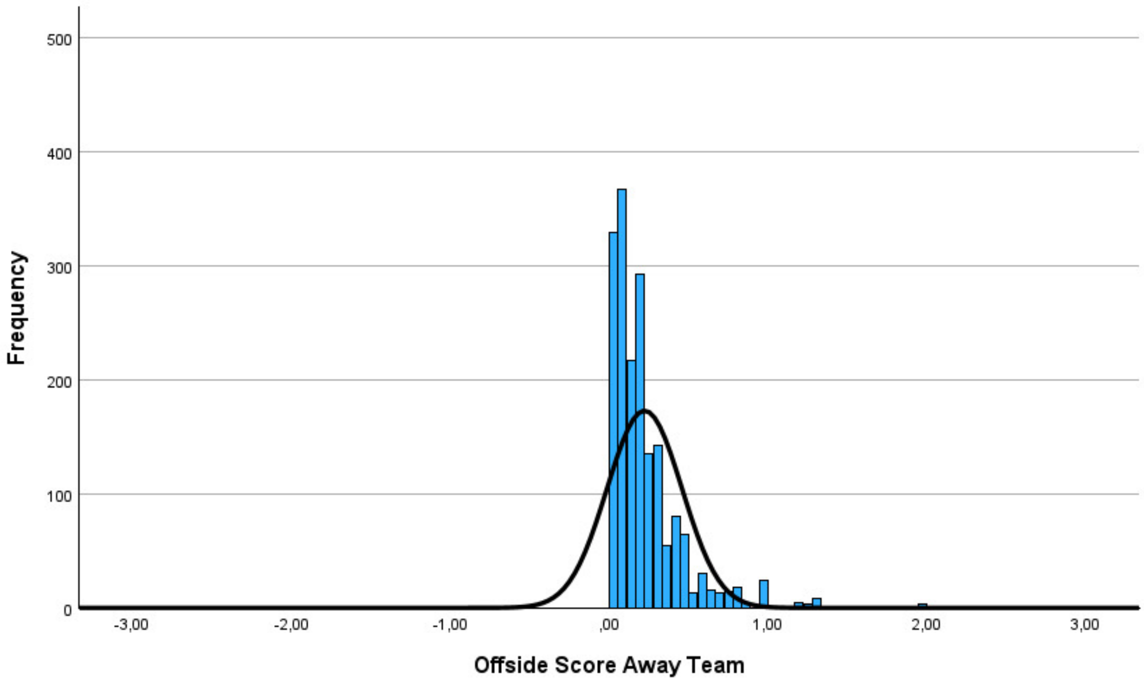

Figure A8. Histogram of offside scores for away (guest) teams. The solid line represents a normal distribution.

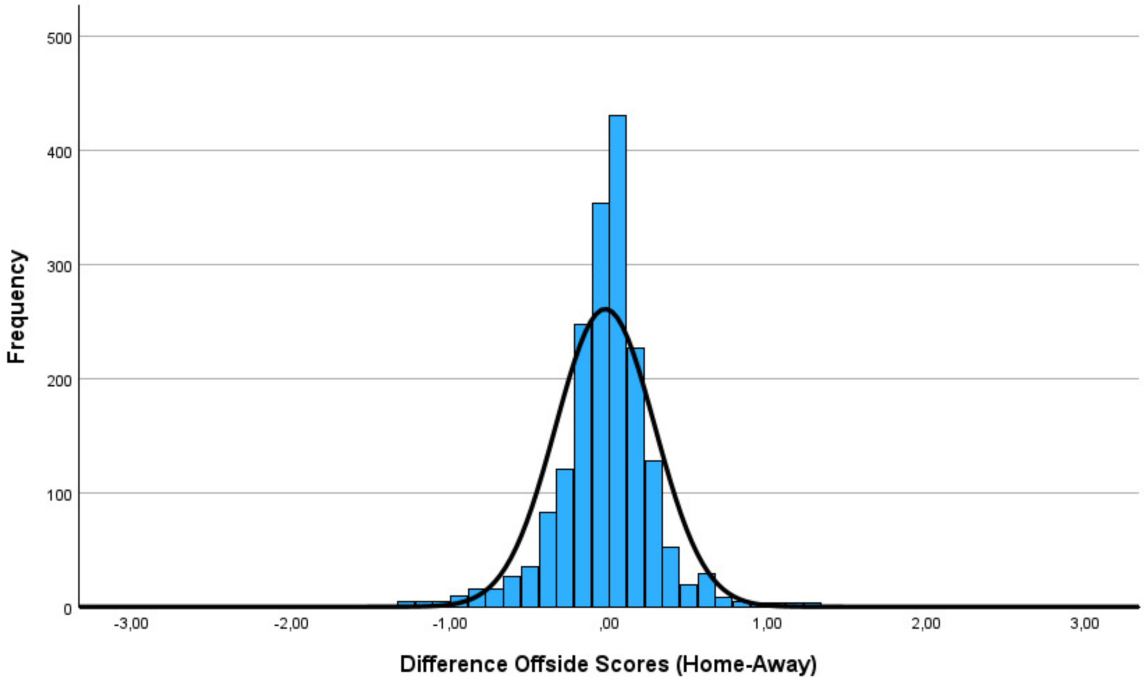

Figure A9. Histogram of differences in offside scores between home and away (guest) teams. The solid line represents a normal distribution.

Supplementary Materials

Peer Review Communication

Download: https://collabra.scholasticahq.com/article/133671-a-home-advantage-in-offside-decisions-in-german-professional-football-soccer/attachment/274363.docx?auth_token=E5TtBjagPQikPlyf5XcK