No crowds, no home advantage in football during the COVID-19 season: Are crowds able to manipulate all but the best referees' behaviour?

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Abstract

This study confirmed that without crowds there was no home advantage in association football during the COVID-19 2020-21 season. Consequently, we sort to answer the obvious question, "Are crowds influencing referees' behaviour?" The number of home and away red and yellow cards awarded in the "no crowd" COVID-19 2020-21 season (all 4 top English divisions) were compared with the home and away cards awarded during the previous 10 "crowd" seasons (2010-11 to 2019-20). Results revealed that there was no home advantage in red and yellow cards awarded by referees in all 4 English leagues/divisions during the COVID-19 2020-21 season. Referees awarded significantly more cards to away players when adjudicating with crowds (seasons 2010-11 to 2019-20). However in more recent "crowd" seasons, Premier League referees are less susceptible to such influences with a narrowing of the gap between home and away yellow cards, suggesting that their preparation, management and training provides them with an element of "crowd immunity". It would appear that home crowds are able to influence all but the very best referees' behaviour. These new insights provide important information for the training and management of referees.

Keywords: soccer; spectators; Premier League; sports officials, crowd immunity.

Introduction

The COVID-19 pandemic has provided a unique opportunity to assess the influence of crowds (or more accurately, their absence) on the home advantage. The evidence that the absence of crowds has reduced the home advantage is reasonably convincing (e.g., Sors et al., 2020) although not entirely conclusive, as their results were based on an incomplete season. The fact that team quality (a far more dominant and influential effect than home advantage) cannot be satisfactorily removed until both teams in the league have played each other both home and away (in a balanced league/season set of fixtures), can the effect of home advantage be more clearly determined (see Clarke & Norman, 1995). For example, as explained by Clark and Norman (1995), if Team A beats Team B by 5-0 at home, but Team B beats Team A 1-0 at home, both teams benefit from home advantage but team A's quality is 4 goals better than team B but with an average home advantage of 3 goals. These insights and calculations can only be achieved when the COVID-19 2020-21 season's set of fixtures was completed. Now that this COVID-19 season finally ended on 20th May 2021, the evidence is much clearer and convincing. The Premier League final results table ended with 144 home wins and 153 away wins (83 draws), suggesting that home advantage was absent in this strange recent COVID-19 season (see Table 1).

The COVID-19 pandemic appears to help us to answer one of the enduring questions in sport, that being "what is the cause of home advantage?" Clearly the absence of crowds in the COVID-19 2020-21 season appears to have influenced the outcome of games, although we cannot be certain whether this "crowd" effect has influenced the behaviour of either the players or referees. In an attempt to understand and answer this intriguing question as to whether crowds can influence referees' behaviour (via their judgements) objectively, we can observe whether the number or proportion of home and away red and yellow cards changed when referees were adjudicating behind closed doors (without crowds during the complete

COVID-19 season) or in front of crowds (in 10 complete seasons prior to COVID-19). It is this gap in the literature that the current study will attempt to solve. Hence, the purpose of the current article is to assess the impact of crowds (their presence or absence) on home advantage, by comparing the number of red and yellow cards awarded in the recent no crowd COVID-19 2020-21 season with the number of red and yellow cards awarded in the 10 previous crowd seasons 2010-11 to 2019-20 across the four professional divisions in England.

Literature Review

Referees Decisions and Home Advantage

Covid-19 presented a unique opportunity to examine football fixtures and referee decision making without the presence of crowds. This decision-making process, often considered through the lens of home advantage in sport, can operate with referees performing in high stress, high consequence professional sporting environments, such as those with crowds (Grabowski & Sanford, 2003). However, because of the high stress performance environment, there can be unconscious errors in thinking and decision making, namely cognitive bias, which can be applied to describe people's systematic but purportedly flawed patterns of responses to judgment and decision problems (Wilke & Mata, 2012).

In individuals, cognitive bias can be related to decision-making as people learn and develop thinking patterns. Often, these patterns are positive and reflect rational decision-making behaviour. However, other patterns can lead to poor choices and compromised decision making (Phillips-Wren et al., 2019a). Individuals can overcome some of their biases through learning new decision-making approaches or techniques, although there is an individual difference component that influences how people process and use information (Phillips-Wren et al., 2019b). Moreover, ensuring effective decision-making means making

decisions that result in attaining desired goals from an initial or original decision in order to understand bias in judgments and how to prevent or minimise any such bias (Plessner & Harr, 2006). Recent research has attempted to further develop this area of literature. The decision-making variability of officials has been linked to expertise, with the importance of game/situation based opportunities for decision-making practice identified as essential (Russell et al., 2021). Moreover, Raab and colleagues (2021) have introduced a threshold process model in officiating, derived from Decision Field Theory. This model attempts to shift the discussion towards a dynamic model, focused on the intra-individual and inter-individual level, and contends that referees move from applying the rules of the game to 'managing' the game when a subjective threshold of aggressive play is reached.

Consideration of decision making in officiating has examined different sports (Hancock, et al., 2020; Samuel et al., 2021). Research has considered referee and sports official bias in football (Albanese et al., 2020; Erikstad & Johansen, 2020). Moreover, O'Brien and Mangan (2021) focused on the potential causes of unconscious bias between 1978 and 2019 in Australian rugby league. This research identified that home advantage was the most likely indicator of any unconscious bias, even among the elite professional rugby league referees. In addition, home advantage varied widely around the average or expected values and that clubs fared significantly better or worse under particular referees.

The introduction of technology has also affected the decision-making and performance of sports officials, although not always in a positive manner. Dawson and colleagues (2020) contended that there were unintended consequences associated with the introduction, and subsequent extended role of the television match official (a technology-aided referee system in rugby union) in connection to the incidence of sanctionable offences in the group stages of the European Rugby Cup (ERC) and European Rugby Champions Cup (ERCC) over 15 seasons from 2000/01 to 2015/16. The role of technology and the

introduction of the television match official has increased the number of yellow cards awarded to away teams, whilst also increasing home bias or advantage (Dawson et al., 2020). Dawson et al. (2020, p. 452) state that the constant scrutiny of officials and their judgements during fixtures in rugby union, "…has prompted the use of the television match official to help to remove subjective judgment". However, in football, Video Assistant Referees (VAR) were introduced in the Premier League in 2019, but the home advantage gap had narrowed long before this date (Nevill et al., 2013).

Empirical evidence

The phenomena of home advantage has been studied from a range of academic disciplines, and over a number of years (see Courneya & Carron, 1992; Nevill & Holder, 1999; Schwartz & Barsky, 1977), although there are still significant gaps in understanding. Literature has historically focused on the reasons for the existence of any home advantage. For example, a number of studies have considered concepts such as the familiarity with playing surroundings (Pollard & Pollard, 2005), crowd effects on players and match officials (Nevill, et al., 2002; Nevill et al., 1996) and also potential travel fatigue (Pollard, 1986; Pollard & Pollard, 2005). Many of these studies have identified that crowds do influence referees' decision making (Nevill, et al, 1996; Nevill, et al, 1999; Nevill, et al, 2002), although, until now, researchers have not been able to substantiate these claims in stadia where crowds were absent.

Research on home advantage has also taken place across various sports and in a number of different countries. For example, declines in home advantage have been observed in basketball and ice hockey in the United States and association football in England (Koyama & Reade, 2009; Pollard & Pollard, 2005), as well as home advantage in the summer and winter Olympic Games held in various countries (Balmer et al., 2001; Balmer et al.,

2003). Some explanations regarding declining home advantage have been attributed to trends around travel and the familiarity of playing surroundings (Pollard & Pollard, 2005) and also the increasing coverage of English Premier League (EPL) matches on television. This suggests that, due to this increased coverage, players are likely to put in as much effort away from home as they do during home fixtures, because supporters can follow every fixture irrespective of location and stadia (Koyama & Reade 2009). Ramchandani et al. (2021), meanwhile, considered the relationship between team ability on the home advantage of teams over 24 seasons from 1995/96 to 2018/19, including 48,864 matches across the four professional divisions in England, with statistically significant home advantage found in all four divisions and for teams of all abilities within each division.

Recently, research has focused on the impact of COVID-19 and any associated impact from the absence of crowds. For example, Matos et al. (2021) focused on the home advantage score in the last ten rounds in the 2019–2020 Portuguese season with the first 24 rounds in same season, identifying that the absence of a crowd in the last 10 rounds of the season, due to the COVID-19 pandemic, did not affect home advantage. Other scholars have also considered the role of COVID-19 on home advantage. Wunderlich and colleagues (2021) identified factors contributing to home advantage, analysing over 40,000 matches before and during the pandemic and more than 1,000 matches without spectators across the European football leagues. Findings supported crowd-induced referee bias, but only a non-significant decrease in home advantage was discovered, meaning that spectators did not appear to be the principal factor of home advantage. Moreover, McCarrick et al. (2021) compared team performance and referee decisions pre-COVID and during-COVID across 15 European leagues, identifying that home advantage was significantly reduced during the COVID impacted season. Furthermore, in games without fans, the home team created fewer attacking opportunities and referee-bias was reduced with the number of fouls and yellow cards for

away teams reduced and there were no effects observed for red cards (McCarrick et al., 2021).

Further evidence suggests that the absence of crowds has reduced home advantage (e.g., Reade et al., 2020; Sors et al., 2020), with the support of the crowd identified as a considerable cause of home advantage when measured from a variety of aspects (points, goals, shots), although this advantage is almost halved when matches are behind closed door (Scoppa, 2021). Thus, the COVID-19 pandemic appears to be helping us to answer one of the enduring questions in sport, "what is the cause of home advantage?" Clearly, the absence of crowds seems to have influenced the outcome of games, although to date we have been unable to ascertain whether or how crowds influence the referee in this scenario. Nevill and colleagues (2013) identified a systematic decline in home advantage in the professional English and Scottish leagues post-WW2, with the steepest decline identified in lower divisions with smaller crowds. Nevill et al. postulated that of the factors that are thought to influence home advantage, that crowd support appeared the most plausible explanation, with crowds thought to influence referees' decisions and lead to favouritism towards the team playing at home. However, Nevill et al. (2013) also focused on the role of referees within this home advantage relationship, contending that the improved training and development of referees since World War II has contributed to an improved ability to make objective decisions and, therefore, a greater resilience to crowd influence, therefore clarifying the decline in home advantage and the steeper decline observed with smaller crowds.

The purpose of this research was to develop our understanding of the subject of home advantage further through confirming the absence of home advantage in association football during the COVID-19 2020-21 season, and to explain whether large crowds might influence referees' behaviour when awarding red and yellow cards.

Materials and Methods

Home Advantage Calculation

home advantage was calculated for each team at the end of the season using the end-of-season tables, methods described in detail by Clarke and Norman (1995) and more recently by Nevill et al. (2013). Recognizing the need to separate the teams' ability from their home advantage, Clark and Norman proposed the following mathematical model to describe the goal difference at the end of each game w_{ij} (the home and away team effects being identified by the subscripts i and j respectively),

$$w_{ij} = u_i + h_i - u_j + e_{ij},$$

where u_i is the home team's ability (u_j being the away team's ability), h_i is the home team's advantage when playing at home and e_{ij} is the unexplained random error. The proposed calculations to obtain the h_i and u_i for each team in the league using the Premier League's end-of-season table for the COVID-19 2020-21 season are given in 4 steps below.

Step 1. Observed the number of teams in the league (N)
Step 2. Calculate H, the total of all the team's HGD-column, divided by N - 1, given by H = (sum HGD_i) / (N - 1)
Step 3. Calculate for each team $h_i = (HGD_i - AGD_i - H) / (N - 2)$ (note that the subscript $_i$ refers to an individual team).
Step 4. Calculate for each team $u_i = (HGD_i - (N - 1) * h_i) / N$
Note that in the titles of columns in Table 1, we use the abbreviations; H = home; A = away; W = win; D = draw; L = loss; f = goals for; a = goals against; GD = goal difference; h_i = each individual team's HA; u_i = each individual team's team rating

e.g. For Manchester City's results in row 1 Table 1, where $HGD_i = 26$ and $AGD_i = 25$.
Step 1: We observe the number of teams in the league, N = 20
Step 2: We calculate H = (sum HGD) / (N - 1) = 4 / 19 = 0.21 (common to all teams in the league table)
Step 3: We calculate $h_i = (HGD_i - AGD_i - H) / (N - 2) = (26 – 25 - .21) / 18 = 0.04$ (where $_i$ = 1, Manchester City)
Step 4: We calculate $u_i = (HGD_i - (N - 1) * h_i) / N = (26 - (19) * .044)/20 = 1.26$ (where $_i$ = 1, Manchester City)

Table 1 about here

We used the home advantage estimates (h_i) from the four top English Leagues during the most recent COVID-19 2020-21 season (Premier League details in Table 1) and compared the results with the top four English Leagues seasons from 1946-7 to 2019-20, data obtained from Statto.com (n.d.) and more recently Sportsmole.co.uk (n.d.). In all, we calculated a total of 5644 home advantage estimates (h_i) and team ability estimates (u_i) over the four leagues and 74 seasons since WW2.

Statistical methods

One sample t-tests were used to assess the difference between home advantage using the estimated hi values and the null hypothesis taken as zero from all four top English leagues/divisions (Premier League, Championship, Division 1 and Division 2) for the 2020-21 season.

These results were also compared with the results obtained from the four top English Leagues seasons from 1946-7 to 2019-20. Including the most recent COVID-19 season, a total of 5644 home advantage estimate (h_i) and team ability estimates (u_i) over the four leagues and 74 seasons since WW2 were calculated.

Since all teams appear more than once over the range of seasons, the h_i observations are unlikely to be independent (repeated measures). For this reason, multilevel modelling was used to explore trends and differences in the h_i data using seasons (by decade) and the 4 divisions as independent variables. Multilevel modelling is an extension of ordinary multiple regression and ANCOVA where data have a hierarchical or clustered structure. The hierarchy consist of units or measurements grouped at different levels. Multilevel analyses were

performed using Statistical Software MLwiN version 3.05, allowing the different teams to be the level 2 (between-team) variation and their repeated performances over the various seasons to be the level 1 (within-team) variation.

To evaluate whether the presence (vs absence) of crowds can influence referees' behaviour, we recorded the number of home and away red and yellow cards awarded by referees in the four top English divisions during the "crowds absent" COVID-19 season (2020-21) and compared them with the equivalent red and yellow cards awarded in the 4 top divisions during the 10 previous "crowds present" seasons 2010-11 to 2019–2020. These data were obtained from Statbunker.com (n.d.).

The chi-square tests of independence (see Bland, 2015) were used to compare the home vs away red and yellow cards-by-seasons (the "no crowd" COVID-19 2020-21 season vs the 10 "crowd present" seasons, entered either separately or combined/summed). We also compared the proportion of red and yellow cards awarded against the away players (as a proportion of the total number of red and yellow cards) when referees were adjudicating with crowds (seasons 2010-11 to 2019-20), and compared these with the proportion of red and yellow cards when referees were adjudicating without crowds (COVID-19 2020-21 season), using the test of independent proportions in Christensen (1996).

Results

The lack of home advantage associated with minimal crowds for the COVID-19 2020-21 season was confirmed when the h_i values were assessed using a one-sample t-test (Null hypothesis assumes home advantage (h_i) = zero) for the mean h_i from all four divisions (Table 2).

Table 2 about here

The trend in the decline in home advantage (in goals per game, h_i) since-WW2 can be seen in Figure 1. Observing the mean in the final COVID-19 2020-21 season compared with the previous decades, there is strong evidence that home advantage has dropped further (approximately 0.1 goals per game) when almost all of the fixtures were played without crowds behind closed doors.

Figure 1 about here

The multilevel regression analysis of h_i is presented in Table 3. The multilevel regression analysis of h_i adopted the Premier League (2020-21) as its baseline or intercept term, estimated to be $h_i = 0.0995$ (SE = 0.056, $p > 0.05$). This confirms that there was no significant home advantage in the Premier League during COVID-19 2020-21 season. Although the other 3 leagues were marginally higher, e.g., Championship (2020-21) $\Delta h_i = 0.0215$ (0.0191), there was still no significant home advantage in all 4 divisions during COVID-19 2020-21 season. Note that the home advantage of the Championship (2020-21) can be calculated as $h_i = 0.0995 + 0.0215 = 0.121$. This absence of home advantage was also confirmed by our t-tests in Table 2. In complete contrast, significant home advantage was identified in all season/decades prior to 2020-21 when crowds were present, e.g., seasons (1946-49) $\Delta h_i = 0.5428$ (SE = 0.0641, $p < 0.001$)), and more recently, in seasons (2010-19) $\Delta h_i = 0.1789$ (0.0566, $p < 0.001$). Once again, we can calculate the home advantage for the seasons/decade (1946-49) as $h_i = 0.0995 + 0.5428 = 0.6423$, and for seasons/decade (2010-19) as $h_i = 0.0995 + 0.1789 = 0.2784$. Note that home advantage was at its greatest soon after WW2, after which there was a systematic decline by seasonal/decade until the most recent season in 2020-21. This decline can be seen clearly in Figure 1.

Table 3 about here

The number of red and yellow cards awarded by referees during the "no crowds" COVID-19 2020-21 season to both home and away teams for all four divisions, together with the equivalent home and away red and yellow cards awarded in the 10 previous "crowds" seasons are illustrated in Figure 2 and presented in Tables 4 (red) and Table 5 (yellow) respectively. With crowds, the difference in home and away yellow cards (Table 5) is clear and consistent (in all 10 seasons), in marked contrast to little or no difference in home and away yellow cards in the COVID-19 2020-21 season (in the absence of crowds).

Figure 2 and 3 about here

The chi-square test of independence values (comparing the COVID-19 2020-21 season with all 10 seasons separately and compared with the 10 season summed) are reported at the foot of Tables 4 and 5. For yellow cards, the significant chi-square test of independence results in Table 5 suggest the ratio of home vs. away yellow cards is significantly different (fewer away card) with no crowds (season 2020-21) compared with either the 10 crowd seasons combined (more away cards) (1 df) or separately (with 10 df).

Table 4 and table 5 about here

The proportion of red cards awarded against the away players by referees adjudicating *without* crowds was 142 / 263 = 0.54 (see row 1 of Table 4). The proportion of red cards awarded against the away players by referees adjudicating *with* crowds was 1871 / 3160 = 0.592 (see Total crowds row at the bottom of Table 4). The difference in these proportions is (0.52 – 0.592) = -0.052 or 5.2% assuming a normal approximation z = -1.63 (p = 0.051). Note that the proportion of away red cards in the Premier League during the COVID-19 2020-21 season 28 / 48 = 0.58, which was identical to the proportion of away red cards awarded by Premier League referees in the previous 10 season (with crowd) p = 312 / 537 = 0.58 (see Table 4). Crowds appear to have little or no effect on the top Premier League

referees to penalize the away side (either with or without crowds) when awarding red cards ($\chi^2 = 0.001$; $p = 0.975$).

Note that the chi-square tests of independence reported at the foot of the Table 5 were more significant in lower divisions, with the least significant χ^2 effect being in the Premier League ($\chi^2 = 5.552$, $p = 0.018$) with greater significant χ^2 effects observed in the Championship ($\chi^2 = 17.74$, $p < 0.001$), Division 1 ($\chi^2 = 30.5$, $p < 0 .001$) and Division 2 ($\chi^2 = 21.07$, $p < 0.001$). This effect can be seen clearly in Figure 3 when the number of yellow cards awarded to the home and away players are plotted for the Premier League vs the Championship over the past 11 seasons. The effect of crowds had considerably less influence on top Premier League referees (with a significant narrowing of the gap between home and away yellow cards in more recent seasons, chi-square test for linear trend $\chi^2 = 12.1$; $p = 0.001$). These were compared with the gap observed with Championship referees (chi-square test for linear trend $\chi^2 = 0.52$; $p = 0.47$), both assessed over the 10 "crowd" seasons.

The proportion of yellow cards awarded against the away players by referees adjudicating *without* crowds was 2984/6016 = 0.496 (see row 1 of Table 5). The proportion of yellow cards awarded against the away players by referees adjudicating *with* crowds was 34800 / 62951 = 0.553 (see Total crowds row Table 5). This difference in proportions is -0.057 or 5.7% assuming a normal approximation is $z = -8.42$ ($p < 0.001$). The number of yellow cards awarded to away players *without* crowds during the COVID-19 2020-21 season ($p = 2984/(3032+2984)=0.496$) is the same as those awarded to home players ($p = 3032/(3032+2984)=0.504$ see Figure 2), suggesting that referees penalize home and away players equitablyCrowds appear to be able to influence referees' behaviour to favour the home team, although the Premier League referees appear to be less vulnerable to such influences.

Discussion

The decline in home advantage and crowds' influence on referees' behaviour

This paper has focused on the sustained decline of home advantage in the four top English leagues (including the old English First Division League), seasons from 1946-7 to 2020-21 and whether crowds are more likely to influence referees or players. Findings suggest that not only has home advantage continued to decrease up to and including the 2020-21 season, there was no significant home advantage in the recent COVID-19 2020-21 season (see Table 2) when the majority of games were played behind closed doors, without crowds. The absence of crowds is clearly associated with little or no home advantage as previously anticipated (Nevill et al., 1999; Nevill et al., 2002), with the analysis of referee's behaviour in awarding home and away red and yellow cards in front of, and in the absence of crowds, contributing to our understanding of the reduction of home advantage without crowds. This effect can be seen clearly in Figure 2. The fact that we identified no significant home advantage in any of the four English leagues during the COVID-19 2020-21 season, that the Premier League demonstrated negative home advantage in the same season, and that the chi-squared tests of independence and test for trend showed all but the very best referees operating in the Premier League awarded significantly more red and yellow cards to away players when performing in front of crowds (see Figure 3), suggests that the training, development and preparation of these Premier League referees contributes to their enhanced decision making. Across the four divisions, referees awarded 5.7% more yellow ($p < 0.001$) and 5.2% more red cards ($p = 0.051$) against away players when officiating in front of crowds (seasons 2010-11 to 2019-20), although the Premier League referees showed less bias, awarding fewer yellow cards (3.7%, $p = 0.01$) and fewer, indeed no difference in red cards (0.0%, $p = 0.98$) in front of crowds. As such top Premier League referees were considerably less likely to be influenced when officiating in front of crowds (see Tables 4 and 5).

Our findings suggest that the better referees are more likely to avoid any home advantage favouritism. As the data suggests, the Premier League referees have given less advantage to the home team through red and yellow cards, and in the case of red cards, the difference between matches with crowds and without crowds was minimal. Therefore, it is evident that Premier League referees have been able to resist much of the influence of crowds, especially in more recent years (χ^2 test for linear trend = 12.1: p = 0.001), see Figure 2. They are less likely to be intimidated and it is less likely that crowd behaviour will impact upon their decision making. Conversely, in the Championship and lower professional leagues, where accomplished referees still operate although not the very best, our results demonstrate that referees are more likely to be susceptible to the influence of the crowds (see Figure 3). Moreover, Dawson et al. (2020) discuss the notion of video technology and the introduction of such advancements into rugby union in order to remove subjectivity from the decision making of the on-field referee. VAR was introduced into the Premier League in 2019, but our findings suggest that the home advantage gap reduced long before this intervention (approx. 2016-17) and, as such, VAR cannot be the catalyst for this further reduction in home advantage (see Figure 3). However, as discussed in the theoretical contribution section, unconscious bias may well be initiated by the crowd providing an audio cue to reinforce referees' decisions to penalize the away side (Nevill et al. 2002).

The training of elite referees, predominantly those operating in the Premier League in England, and the development and evolution of this training has been well documented (Webb, 2014; Webb, 2017; Webb et al., 2018; Webb & Thelwell, 2015). For example, in the Premier League psychologists have been introduced to work with the referees (Nevill et al., 2013), training is constantly evaluated in order to improve the provision to the referees (Webb, 2017) and technological innovations such as goal line technology and video assistant referees (VAR) have been introduced to assist referees in their performance (Webb, in press).

Some of these advancements have considerably assisted the elite Premier League referees. For example, the introduction of a full-time psychologist to support the referees, it could be argued, has had a direct influence on home advantage. The psychologist works on the decision making of referees and how to make decisions under pressure, including pressure from the crowd in the stadium. This psychological provision is provided on a full-time basis for the Premier League referees that operate in Select Group 1, the same full-time support is not available for the referees that officiate in the Championship, based in Select Group 2. This could help to explain why the Premier League referees have not been influenced as much as referees at other professional levels, in terms of favouring the home team. They receive greater and sustained psychological support, whilst those referees in the lower leagues do not receive the same full-time psychological support.

Furthermore, the growth of the Premier League has led to increased investment in the professional referees and the potential for a wider gap to emerge between these referees and those referees operating within the professional game in the lower leagues (Webb, in press). This has led to investment in the Professional Game Match Officials Limited (PGMOL – the organisation that manages and trains the referees in the Premier League and Championship predominantly) that included £10.2m from the Premier League, £5.3m from the Football League and £3.7m from the FA, according to the 2018/2019 season annual accounts (PGMOL, 2019), a significant investment in professional refereeing in England.

The Premier League referees are also used to officiate high profile fixtures, whereas those referees at lower levels are not used to the same exposure at fixtures with such profile. Therefore, this means that it is difficult to train and prepare for high profile fixtures for these referees at lower levels. Matches at lower levels are not as well attended, stadiums are smaller and therefore crowd size is reduced, media exposure is also not as big (Webb, 2018). This means that referees at this level, not only do not have the same psychological support,

but are not used to repeatedly performing in front of bigger crowds and blocking these crowds out during the decision-making process. In short, it is difficult to train, replicate and prepare for high profile matches without larger crowds at lower levels.

As with all studies, we must acknowledge some possible limitations. It is possible that the crowd can affect the home/away players' on-field performance, as well as the referee's decisions simultaneously. This might also lead to the observed differences in red and yellow cards. For example, crowds might influence away players to become more aggressive, justifying the referees to be more likely to penalize the away player compared with home players. Clearly, this is a topic for future research.

Managerial implications and recommendations

The findings that have been uncovered as part of this research provide a number of vital training points and implications for referee managers, referee administrators, governing bodies, and leagues. The findings demonstrate how advanced and effective the training provision is for referees that operate in the Premier League. A sentiment echoed in previous research (Nevill et al., 2013; Webb, 2017). However, clearly there are training implications for referees at the levels below the Premier League, and this also extends to the wider referee talent identification and talent development pathway (Webb et al., 2021). First, training on the subject of home advantage specifically and decision making should be introduced for referees who are part of the talent development pathway and who operate in the professional game. The introduction of this type of training could lead to further reductions in home advantage within the professional leagues in England, and in other countries around the world as knowledge is shared and disseminated.

Second, referees at lower levels and in the talent development pathway should be trained to shut out the crowd, or at least minimise the impact of the crowd on their performance (Webb et al., 2021) and to deal with hostile crowds when officiating. The concept of crowds affecting performance has been considered previously, but the focus has been on player performance, rather than that of referees (Boyko et al., 2007; Nevill et al., 2002; Unkelbach & Memmert, 2010). If referees can achieve this, evidence demonstrates that it could help to improve their performance away from home, lead to reduced home advantage in the Championship, League 1 and League 2 and therefore improve the authenticity of the leagues in England, as well as the quality of referees being provided to the Premier League.

Third, referees at these lower levels should be part of a wider and more structured mentoring programme. This would involve greater engagement with more experienced officials, teams of officials and placement at matches in higher leagues as part of the development process. Referees operating in League 2 or League 1 could be placed in the Championship or the Premier League as part of the match-day team of referees in order to observe the preparation, performance and techniques utilised to deal with decision making and the noise of the crowd. This would mean that when referees were promoted to the Championship and the Premier League, the environment would not be alien to them. The benefits of such mentoring programmes are well noted within pertinent literature (e.g., Ridinger et al., 2017; Slack et al., 2013).

Fourth, in order to achieve the continuous improvement in training and consequently performance related to home advantage, further financial investment is required in refereeing. Since the formation of the Premier League in 1992 financial investment in refereeing has increased, particularly after the professionalisation of refereeing in 2001 (Webb, 2017). This investment should continue and be targeted to ensure that referees continue to develop their decision-making skills. Further psychological support could be provided for referees

operating in League 1 and League 2. Currently full-time psychologists work with Select Group 1 and the referees that operate in the Premier League, but to better prepare referees for officiating in the Premier League, psychologists could also be employed full time at lower levels. Moreover, further research into the reduction or removal of subjectivity in referee decision making (see Raab et al., 2021), how this effects the game and the associated emotional intensity (Dohmen, 2008), particularly following the COVID-19 pandemic, would be beneficial to further enhance understanding of the role of the referee.

Fifth, clearly home advantage has decreased further, demonstrated by our findings and those of other recent publications (McCarrick, 2021; Nevill et al., 2013; Scoppa, 2021; Sors et al., 2020). This means that it is likely that referee improvement has continued, and their decision making has been further enhanced, enabling home advantage to decrease further (Webb et al., 2018). This improvement in home advantage should be monitored on a season-by-season basis, and any training should be delivered and adjusted in order to maintain any gains and improvements, as well as identify and address any increases in home advantage that might become apparent.

Conclusion

This paper has presented novel research which builds on our understanding of home advantage in sport as well as concepts related to the nuances between the performances of referees within the professional game in England when in front of crowds compared to when officiating without crowds. Little or no home advantage exists in the absence of crowds. However, over the four divisions, referees award 5.7% more yellow ($p < 0.001$) and 5.2% more red cards ($p = 0.051$) against away players in front of crowds (seasons 2010-11 to 2019-20), compared to when crowds are absent (season 2020-21). Therefore, it would appear that home crowds are able to influence all but the very best referees' behaviour to favour their

home team, an effect that disappears when supporters are absent (season 2020-21), see Figure 2.

These findings have the potential to influence the training and development of referees at many levels of the game and to provide referee educators with the information to focus future training initiatives aimed at reducing home advantage further in all professional leagues in England.

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Legend for figures

Figure 1. The decline in home advantage by decade since WW2 including the most recent COVID-19 season.

Figure 2. The number of red and yellow cards (H and A) awarded by referees during the "no crowds" COVID-19 2020-21 season and in the 10 previous "crowds" seasons.

Figure 3. The number of yellow cards (H and A) awarded by the Premier League vs the Championship over the past 11 seasons.

Legend for tables

Table 1. End-of-season table for the English Premier League, for the COVID-19 2020-21 season .

Table 2. Mean home advantage (h_i), standard deviation (SD) and standard error of estimate (SEE) plus the one-sample t-test results for the home advantage (h_i) for the 4 English leagues for 2020-21

Table 3 The multilevel regression-analysis parameters for h_i, using 4 English league divisions and seasons by decade.

Table 4. The number of red cards (H and A) awarded by referees during the "no crowds" COVID-19 2021-22 season and in the 10 previous "crowds" seasons.

Table 5. The number of yellow cards (H and A) awarded by referees during the "no crowds" COVID-19 2021-22 season and in the 10 previous "crowds" seasons.

Table 1. End-of-season table for the English Premier League, for the COVID-19 2020-21 season.

	P	HW	HD	HL	Hf	Ha	HGD	AW	AD	AL	Af	Aa	AGD	GD	Pts	hi	ui
Manchester City	38	13	2	4	43	17	26	14	3	2	40	15	25	51	86	0.04	1.26
Manchester United	38	9	4	6	38	28	10	12	7	0	35	16	19	29	74	-0.51	0.99
Liverpool	38	10	3	6	29	20	9	10	6	3	39	22	17	26	69	-0.46	0.88
Chelsea	38	9	6	4	31	18	13	10	4	5	27	18	9	22	67	0.21	0.45
Leicester City	38	9	1	9	34	30	4	11	5	3	34	20	14	18	66	-0.57	0.74
West Ham United	38	10	4	5	32	22	10	9	4	6	30	25	5	15	65	0.27	0.25
Tottenham Hotspur	38	10	3	6	35	20	15	8	5	6	33	25	8	23	62	0.38	0.39
Arsenal	38	8	4	7	24	21	3	10	3	6	31	18	13	16	61	-0.57	0.69
Leeds United	38	8	5	6	28	21	7	10	0	9	34	33	1	8	59	0.32	0.04
Everton	38	6	4	9	24	28	-4	11	4	4	23	20	3	-1	59	-0.40	0.18
Aston Villa	38	7	4	8	29	27	2	9	3	7	26	19	7	9	55	-0.29	0.38
Newcastle Und	38	6	5	8	26	33	-7	6	4	9	20	29	-9	-16	45	0.10	-0.44
Wolves Wanderers	38	7	4	8	21	25	-4	5	5	9	15	27	-12	-16	45	0.43	-0.61
Crystal Palace	38	6	5	8	20	32	-12	6	3	10	21	34	-13	-25	44	0.04	-0.64
Southampton	38	8	3	8	28	25	3	4	4	11	19	43	-24	-21	43	1.49	-1.26
Brighton & Hove A	38	4	9	6	22	22	0	5	5	9	18	24	-6	-6	41	0.32	-0.31
Burnley	38	4	6	9	14	27	-13	6	3	10	19	28	-9	-22	39	-0.23	-0.43
Fulham	38	2	4	13	9	28	-19	3	9	7	18	25	-7	-26	28	-0.68	-0.31
West Bromwich A	38	3	6	10	15	39	-24	2	5	12	20	37	-17	-41	26	-0.40	-0.82
Sheffield United	38	5	1	13	12	27	-15	2	1	16	8	36	-28	-43	23	0.71	-1.43
Totals		144	83				4	153	83				--4			0.21	0

Note that in the titles of columns in Table 1, we use the abbreviations; H = home; A = away; W = win; D = draw; L = loss; f = goals for; a = goals against; GD = goal difference; h_i = each individual team's HA; u_i = each individual team's team rating

Table 2. Mean home advantage (h_i), standard deviation (SD) and standard error of estimate (SEE) plus the one-sample t-test results for the home advantage (h_i) for the 4 English leagues for the COVID-19 2020-21season.

League	N	Means h_i	SD	SEE	t (df)	Sig. (2-tailed)
Premier	20	0.0100	0.534	0.120	0.084 (19)	0.934
Championship	24	0.196	0.511	0.104	1.88 (23)	0.073
Div 1	24	0.074	0.510	0.104	0.71 (23)	0.482
Div 2	24	0.161	0.423	0.086	1.87 (23)	0.075

Note that the raw Premier league h_i data are reported in Table 1.

Table 3. The multilevel regression-analysis parameters for h_i, using 4 English league divisions and seasons by decade.

Fixed Explanatory Variables	**Estimate**	**±SE**	**p**
Premier League (2020-21)	0.0995	0.0560	>0.05
Championship (2020-21) Δ	0.0215	0.0191	>0.05
Div1 (2020-21) Δ	0.0120	0.0210	>0.05
Div2 (2020-21) Δ	0.0225	0.0216	>0.05
Season (1946-49) Δ	0.5428	0.0641	<0.001
Season (1950-59) Δ	0.6198	0.0578	<0.001
Season (1960-69) Δ	0.5803	0.0564	<0.001
Season (1970-79) Δ	0.4893	0.0564	<0.001
Season (1980-89) Δ	0.4216	0.0565	<0.001
Season (1990-99) Δ	0.3196	0.0565	<0.001
Season (2000-09) Δ	0.2616	0.0567	<0.001
Season (2010-19) Δ	0.1780	0.0566	<0.001
Random variation			
Level 2 (between teams)	0.0031	0.0010	<0.001
Level 1 (within teams)	0.2681	0.0045	<0.001

The baseline group were the h_i data from Premier league 2020-21 season, from which all other leagues and seasons were compared, indicated by (Δ).

Table 4. The number of red cards (H and A) awarded by referees during the "no crowds" COVID-19 2020-21 season and in the 10 previous "crowds" seasons.

Number of red cards										
Divisions	Premier		Championship		Division 1		Division 2		Total	
Seasons	H	A	H	A	H	A	H	A	H	A
2020-21 (no crowds)	20	28	34	37	32	31	35	46	121	142
2019-20 (crowds)	22	23	27	38	29	37	31	43	109	141
2018-19 (crowds)	18	29	21	48	30	50	33	57	102	184
2017-18 (crowds)	17	22	30	52	40	43	51	48	138	165
2016-17 (crowds)	21	20	30	58	36	63	43	46	130	187
2015-16 (crowds)	25	34	40	38	25	47	37	49	127	168
2014-15 (crowds)	26	45	43	45	36	55	40	61	145	206
2013-14 (crowds)	16	37	26	70	36	59	51	59	129	225
2012-13 (crowds)	26	26	32	37	27	50	38	59	123	172
2011-12 (crowds)	25	40	38	49	42	52	38	60	143	201
2010-11 (crowds)	29	36	37	62	40	62	37	62	143	222
Total (crowds)	225	312	324	497	341	518	399	544	1289	1871
	$\chi 2$	p-value	$\chi 2$	p-value	$\chi 2$	p-value	$\chi 2$	p-value		
Chi-square (df = 10)	8.383	0.59	21.82	0.02	9.13	0.52	8.89	0.54		
Chi-square (df = 1)	0.001	0.98	1.93	0.17	3	0.08	0.03	0.88		

Table 5. The number of yellow cards (H and A) awarded by referees during the "no crowds" COVID-19 2020-21 season and in the 10 previous "crowds" seasons.

Number of yellow cards										
Divisions	Premier		Championship		Division 1		Division 2		Total	
Seasons	H	A	H	A	H	A	H	A	H	A
2020-21 (no crowds)	548	559	791	787	883	843	810	795	3032	2984
2019-20 (crowds)	612	687	820	1006	644	763	661	802	2737	3258
2018-19 (crowds)	588	651	858	1025	808	1059	761	967	3015	3702
2017-18 (crowds)	573	606	885	1068	739	912	768	955	2965	3541
2016-17 (crowds)	677	732	855	1087	826	1032	850	1017	3208	3868
2015-16 (crowds)	551	655	791	985	762	943	736	864	2840	3447
2014-15 (crowds)	626	770	831	1015	749	931	652	915	2858	3631
2013-14 (crowds)	548	682	753	1000	725	910	699	844	2725	3436
2012-13 (crowds)	511	660	727	909	702	858	657	853	2597	3280
2011-12 (crowds)	523	654	695	879	688	866	715	856	2621	3255
2010-11 (crowds)	541	702	729	885	645	923	670	872	2585	3382
Total (crowds)	5750	6799	7944	9859	7288	9197	7169	8945	28151	34800
	$\chi 2$	p-value	$\chi 2$	p-value	$\chi 2$	p-value	$\chi 2$	p-value		
Chi-square (df = 10)	21.38	0.019	21.58	0.017	39.44	<0.001	31.38	0.001		
Chi-square (df = 1)	5.552	0.018	17.74	<0.001	30.5	<0.001	21.07	<0.001		

Figure 1. The decline in home advantage by decade since WW2 including the most recent COVID-19 season.

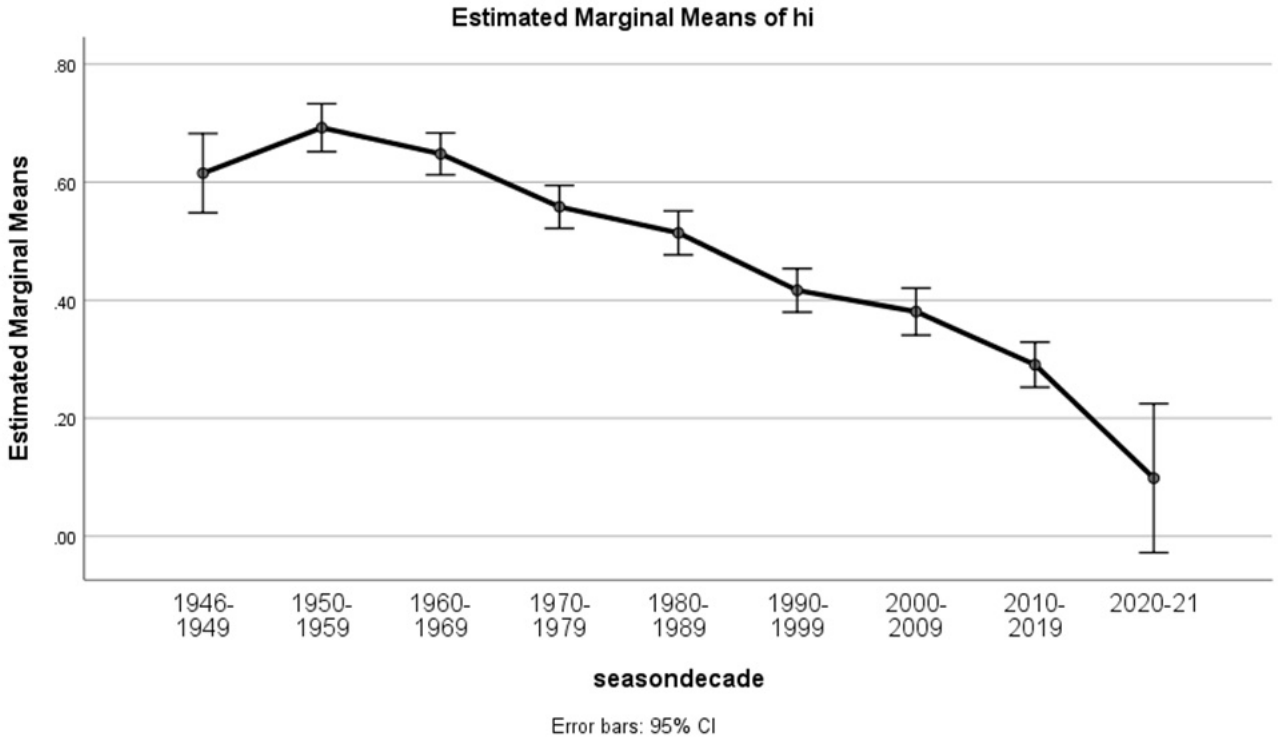

Figure 2. The number of red and yellow cards (H and A) awarded by referees during the "no crowds" COVID-19 2020-21 season and in the 10 previous "crowds" seasons.

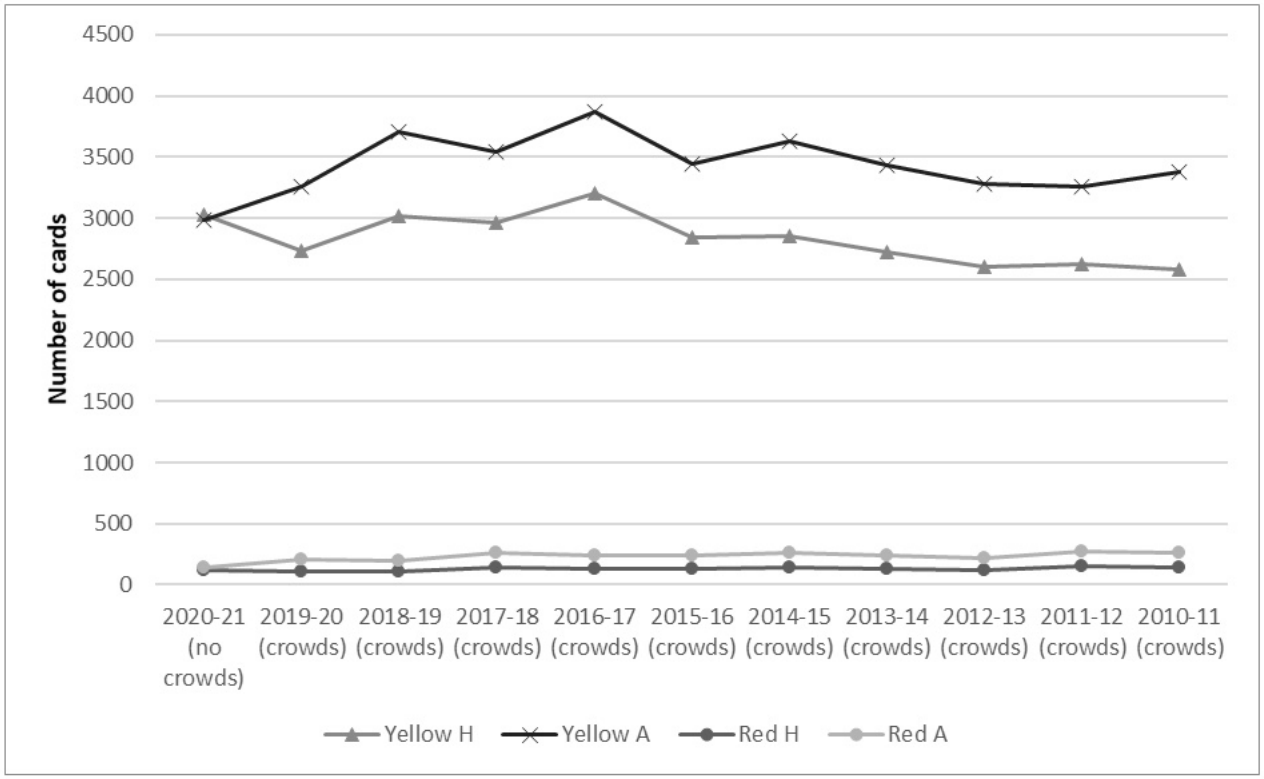

Figure 3. The number of yellow cards (H and A) awarded by the Premier League vs the Championship over the past 11 seasons.