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Performing without Pressure? The Effect of Ghost Games on Effort-based and Skill-based Tasks in the German Football Bundesliga

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Abstract: This study examines how the absence of crowds affects effort-based and skill-based performance in professional football. Using "ghost games" from the 2019/2020 season of the German football Bundesliga as a natural experiment, the analysis follows a within-subject design. It employs Wilcoxon signed-rank tests and linear regression models, including the interaction between home advantage and ghost games. Previous studies showed a decline in home advantage when matches are played without fans. Distinguishing between effort-based and skill-based performance, we argue that this effect is primarily driven by tasks involving physical effort, whereas the technical precision of home teams rather improves in ghost games. This study advances the behavioral understanding of home advantage and highlights how crowd presence can simultaneously motivate and constrain performance.

Keywords: *Home advantage, crowd effect, natural experiment, ghost games, Bundesliga*

1. Introduction

Home teams consistently outperform away teams, a phenomenon known as home advantage. For instance, Pollard and Gómez (2014) found that in European football, home teams win between 50.6% and 78.5% of matches. Scholars attribute home advantage to travel effects, psychological comfort, and crowd effects on player motivation and referees (Pollard, 2008). Spectators may boost players' motivation and effort, consistent with social facilitation theory (Strauss, 2002), yet their presence can also increase pressure and impair skill-based tasks (Dohmen, 2008). Referees are influenced as well, with discretionary decisions such as fouls, cards, and penalties more likely to favor home teams under vocal crowd conditions (Bilalić, 2021). However, despite extensive research, the mechanisms underlying home advantage remain debated.

We argue that the effects of crowds extend beyond officiating and interact directly with player motivation and execution. The complexity of crowd effects on players' performance requires analyses that distinguish between effort-based and skill-based performance. These analyses should examine whether fans primarily boost physical exertion or increase the pressure that undermines technical performance. Supportive crowds could act as a non-monetary incentive, enhancing effort-based performance (Lazear & Rosen, 1981; Rosen, 1986). At the same time, audiences can increase anxiety, impairing precision in skill-based tasks (Baumeister & Steinhilber, 1984). Performance under pressure may follow an inverted-U pattern, with optimal arousal levels (Yerkes & Dodson, 1908). These dynamics could explain why crowd effects appear contradictory.

This paper leverages German football Bundesliga data during the COVID-19 season to compare effort-based and skill-based performance under conditions with and without spectators. By examining whether the absence of fans differentially affects physical exertion and technical execution, we provide new insights into the psychological and behavioral mechanisms that underlie the home advantage. Beyond theoretical contributions, distinguishing between effort and skill offers guidance for training, tactical preparation, stadium management, and strategies for managing high-pressure situations. The remainder of the paper is structured as follows: Section 2 reviews theoretical foundations as well as previous studies and develops hypotheses; Section 3 presents data and empirical methods; Section 4 reports the results; and Section 5 discusses implications for behavioral economics, sport management, and future research.

2. Theoretical Background and Hypotheses

Social facilitation theory (Triplett, 1898) suggests that the presence of others can enhance performance on simple or well-practiced tasks by increasing physiological arousal and motivation (Zajonc, 1965). Building on this, evaluative pressure (Cottrell, 1972) and heightened attentional focus (Baron, 1986) have been shown to

further strengthen performance in social settings. Together, these mechanisms highlight the generally beneficial impact of social presence on well-learned behaviors.

In contrast, behavioral and sports economics, as well as (sports) psychology, describe performance decrements despite high incentives as 'choking under pressure.' According to Hebb's (1955) theory on the optimal level of arousal, performance may be impaired when the pressure perceived by a person is too high, which corresponds to the Yerkes-Dodson law (Yerkes & Dodson, 1908). Choking under pressure is either explained by the distraction theory (Mullen et al., 2005) or by the self-focus theory (Baumeister, 1984; Masters, 1992; Mesagno et al., 1992). When anxiety levels rise, for example, during crucial penalty kicks (Jordet et al., 2007), players may perform suboptimally either because they are distracted from their task or because they focus too much on executing it. The latter theory finds more support in experimental settings, see e.g., Kent et al. (2018) for an overview. A conscious focus can interfere with the automatic processes that are essential in sports, where deliberate decision-making is typically too time-consuming (Gigerenzer & Todd, 1999). This can lead players to underperform compared to their usual standard of skill.

In a behavioral field experiment conducted in India, Ariely et al. (2009) observe that very high incentives improve performance in effort-based tasks but diminish performance in skill-based tasks. Similarly, in professional biathlon, Harb-Wu and Krumer (2019) find evidence for choking under pressure that results in a home disadvantage: Whereas home biathletes' skiing performance is slightly better on average (effort-based task), their shooting performance is much worse than that of away biathletes (skill-based task). Harb-Wu and Krumer (2019) rule out that these poor shooting results are explained by faster skiing. In line with Wallace et al. (2005), home biathletes appear to underperform because they feel under pressure to perform especially well in front of a supportive audience.

Previous studies on "ghost games" during the COVID-19 pandemic provide mixed evidence regarding the mechanisms behind the decline in home advantage. Systematic reviews (Leitner et al., 2023; Wang & Qin, 2023) conclude that while most leagues experienced a significant reduction in home advantage, the underlying drivers differ across studies. Some studies attribute this decline primarily to the elimination of referee bias under spectator absence (Bryson et al., 2021; Reade et al., 2022), whereas others emphasize changes in player motivation and effort (Santana et al., 2021; Fischer & Haucap, 2021). More recent work suggests that crowd effects may not only influence external factors such as officiating but also directly affect athletes' psychological states, arousal levels, and task performance (Ferraresi & Gucciardi, 2023).

Despite growing empirical evidence, the literature lacks a systematic differentiation between how crowd presence affects various dimensions of player performance. Most of the prior studies measure aggregate outcomes (e.g., goals, points, or win probabilities) without distinguishing between the effort exerted and the precision required for successful execution. Building on insights from behavioral economics and sport psychology (Ariely et al., 2009; Baumeister & Steinhilber, 1984), this study addresses this gap by separating effort-based from skill-based performance indicators. This distinction allows for a more nuanced understanding of the behavioral and psychological mechanisms underlying home advantage and extends existing work on pressure and performance in professional sports.

Whereas social facilitation theory offers arguments for a home advantage in relatively simple effort tasks (Triplett, 1898), experimental evidence from behavioral economics and sport psychology rather suggests a home disadvantage for relatively complex skill tasks (Baumeister & Showers, 1986; Harb-Wu & Krumer, 2019). Based on this literature, we hypothesize that:
H1: For effort-based tasks, the absence of a crowd decreases the home team's performance in professional football.
H2: For skill-based tasks, the absence of a crowd does not decrease the home team's performance in professional football.

3. Method

The German football Bundesliga was the first major European league to resume play under closed-door conditions during the COVID-19 pandemic. To investigate the impact of crowd absence on home advantage, we

employ a within-season matched-pairs design using data from the Bundesliga during the 2019/2020 season. Specifically, we compare performance metrics from ghost games matches – played behind closed doors due to COVID-19 restrictions (matchdays 26–34) – with their corresponding fixtures earlier in the season (matchdays 9–17), which were played under normal conditions with spectators. This within-league design avoids the confounding impact of cross-country heterogeneity on the estimated crowd effects.

This procedure results in a dataset of 81 matched fixtures, where each team pair played once with fans (first half of the season) and once without (second half), albeit at reversed venues. By focusing on the same opponents in the same season, we reduce the risk of confounding factors that often plague between-season comparisons, such as regulatory changes (e.g., the introduction of the Video Assistant Referee) or evolving league-wide tactical trends.

However, a key limitation of this design is that it is not possible to keep the location of the match constant. The corresponding fixtures are played at different stadiums, which introduces a source of variation that may interact with the crowd effect. While this spatial asymmetry is controlled to some extent by including interaction terms in our regressions (see below), balancing internal validity (via within-season control) against potential location-driven confounds remains an inherent trade-off in the design.

Our data is drawn from the F24 event feed provided by Opta, a reputable sports analytics company. This data stream offers highly granular event-level information on professional football matches, including player movements, ball touches, passes, shots, and defensive actions. Open access to such detailed football data is limited, making the use of this dataset a unique strength of our study.
In line with prior research (Hughes et al., 2012; Rampinini et al., 2009), we classify match actions into two main categories:
Effort-based tasks: These are predominantly physiological in nature, involving physical exertion such as speed, stamina, and strength.
Skill-based tasks: These require technical proficiency, precision, and cognitive processing, often under time pressure.

Table 1 summarizes the variables and their classification.

Table 1: Categorization of effort-based vs. skill-based variables

Category	Variables	Description
Effort-based tasks	Sprints	Number of high-intensity runs
	Distance	Kilometers covered
	Clearances	Defensive actions where a player kicks the ball away from his own goal with no intended recipient of the ball
	Tackles[a]	Dispossessing the opponent, whether the tackling player comes away with the ball or not
Skill-based tasks	Ground duels Won[b]	Successful 50-50 contests between two players of opposing sides in the match
	Crosses	Accurate deliveries from a wide position to a central attacking area
	Passes	Successful transfer of the ball between two players
	Shots on target	Attempts to score a goal, made with any (legal) part of the body, which hits the target

Notes: [a]: It can be argued that tackles are not only effort-based but also skill-based. [b]: It can be argued that ground duels are not only skill-based but also effort-based, especially for defenders.

In football, the action variables associated with a successful result are physical activity and greater accuracy in both defense and attack (e.g., Carling, 2013; Hossini et al., 2012; McGarry, 2009). However, a clear distinction between effort-based and skill-based tasks is difficult. Assigning action variables to effort-based and skill-based

tasks, we generally follow Rampinini et al. (2009). We apply their classification of physiological actions to group effort-based tasks and assign technical actions to skill-based tasks. If it is unclear to which category an action variable predominantly belongs, we exclude it from further analysis. As a result, we identify four effort-based and four skill-based tasks out of our dataset (see Table 1).

While physical tasks, such as running (e.g., distance covered and sprints), are inherently effort-based, defensive tasks such as clearances, ground duels, and tackles require both physical strength and skill. Following Hughes et al. (2012), physiological actions are based on height, strength, power, speed, and stamina. Thus, clearances and tackles are considered to be predominantly effort-based. On the other hand, winning ground duels requires technical skills rather than physiological attributes to snatch the ball from the opponent. Finally, the offensive tasks of shooting and passing are based on individual skills.

Our analysis focuses on effort-based vs. skill-based performances of home teams in ghost vs. regular games. Additionally, we compare the results with the same performances of away teams. For better interpretability, we use ratios for all of the skill-based variables. According to one sample Kolmogorov-Smirnov test, we cannot assume that the analyzed performance data of home and away teams in ghost and regular games are normally distributed. Our statistical analysis exploits the within-subject experimental design and uses nonparametric Wilcoxon signed-rank tests. However, we also estimate a set of ordinary least squares (OLS) regression models, one for each performance variable. The following specification is applied:

$$Performance_{ij} = \alpha + \beta_1 Home_{ij} + \beta_2 Ghost_{ij} + \beta_3 (Home\ x\ Ghost)_{ij} + \varepsilon_{ij},$$

where $Performance_{ij}$ Is the performance outcome of team *i* in match *j*, $Home_{ij}$ It is a binary variable indicating whether the team played at home (1) or away (0), $Ghost_{ij}$ It is a binary variable indicating whether the match was a ghost game (1) or a regular game (0), $(Home\ x\ Ghost)_{ij}$ captures the interaction effect – i.e., whether the home advantage changes in the absence of a crowd, and ε_{ij} Is the error term.

This model allows us to isolate the effect of playing at home, the effect of playing without fans, and the differential impact of home advantage in the absence of crowd support. Nonetheless, the non-random assignment of crowd conditions – a limitation of all observational studies – introduces potential bias. Although the COVID-19 pandemic offers a quasi-experimental setup, teams may have adapted their strategies or line-ups in the post-lockdown period for reasons unrelated to crowd effects.

4. Results

This section presents the performance results of the home and away teams in the 2019/20 German football Bundesliga season. We distinguish between regular games (matchdays 9–17 before the COVID-19 pandemic) and ghost games (matchdays 26–34 during the pandemic). Figures 1 to 8 show the team averages for all football-specific action variables to which effort-based and skill-based tasks are assigned.

Figures 1 and 4 present evidence for the effort-based tasks:
Sprints: While home teams run at a higher intensity in regular matches (227 to 222 sprints | p=0.166), away teams cover more ground in high intensity without a crowd (221 to 225 sprints | p=0.517). However, these differences are not statistically significant according to the Wilcoxon signed-rank tests. Comparing home and away teams, home teams outperform away teams in regular games (p=0.094) and are not significantly worse in ghost games (p=0.434).
Distance: Both home and away teams cover more kilometers in front of a crowd than in ghost games (Home: 116.67 to 115.23 | p=0.011; Away: 116.18 to 115.30 | p=0.083). For home teams, this effect is statistically significant at the 5% level. For regular matches, this finding is in line with the existing literature, according to which home teams generally run more kilometers (Lago et al., 2010). However, the differences between home and away teams are not statistically significant (p=0.298 in regular and p=0.863 in ghost games).
Clearances: While the number of clearances by home teams does not statistically significantly increase from regular to ghost matches (17.01 to 17.37 | p=0.889), the number of clearances by away teams decreased significantly by around 20 percent (23.12 to 18.56 | p=0.010). In regular games, the number of clearances by

away teams is significantly higher than by home teams (p=0.003), which is not the case for ghost games (p=0.612)
Tackles: Both home and away teams perform more tackles in front of a crowd than in ghost games. The difference is statistically significant for away but not for home teams. (Home: 16.54 and 15.79 | p=0.249; Away: 17.05 and 15.11| p=0.047). Comparing home vs. away teams' tackles, the number of tackles by home teams is not significantly lower in regular games than by away teams (p=0.453) and not significantly higher in ghost games (p=0.280)

Figures 5 to 8 depict the performance measures in skill-based tasks:
Ground duels won: Home teams win fewer ground duels in front of a crowd compared to ghost games (50 to 56 percent | p=0.054), statistically significant at the 10% level. For away teams, it is the other way around. In ghost games, home teams win significantly more ground duels than away teams (p=0.035).
Crosses: Whereas home teams' crosses are less successful in regular matches (21 to 24 percent | p=0.196), the opposite applies to away teams. They deliver more precise crosses in front of the crowd (24 to 21 percent | p=0.256). However, these differences are not statistically significant, and the precision also does not significantly differ between home and away teams (p=0.193 in regular and p=0.248 in ghost games).
Passes: The passes in front of a crowd are less precise compared to the corresponding ghost games (Home: 77 to 78 percent | p=0.254; Away: 75 to 77 percent p=0.021), statistically significant for away but not for home teams. According to Tucker et al. (2005), high accuracy of passes is associated with a successful outcome. In regular games, home teams significantly outperform away teams in terms of pass accuracy (p=0.048), but not in ghost games (p=0.386).
Shots on target: Both teams show reduced accuracy in shots on target in regular games compared to ghost games (Home: 59 to 61 percent | p=0.495; Away: 58 to 60 percent | p=0.737), but these associations and the differences between home and away teams' shot accuracy are not statistically significant according to Wilcoxon signed-rank tests.

Taken together, the nonparametric tests offer limited support for our two hypotheses. To further analyze whether the absence of the crowd has an impact on the home team's performance, Table 2 presents the results of OLS regressions with each effort-based and skill-based task as one of the dependent variables and Home, Ghost, as well as the interaction between Home and Ghost as the independent variables. A positive coefficient of Home suggests a home advantage. Following H1, the impact of Ghost would be negative for effort-based tasks and, in line with H2, zero or positive for skill-based tasks. A positive coefficient of Home with a negative coefficient of the interaction between Home and Ghost suggests a reduction in home advantage in ghost games.

Concerning effort-based tasks, Table 2 displays a significant negative association of Home and clearances, Ghost and clearances, as well as Ghost and tackles, and a significant positive interaction of Home and Ghost with clearances. According to the regression results, ghost games have, ceteris paribus, a negative impact on the effort-based performances, tackles and clearances, but not on sprints and the distance covered. Furthermore, they suggest a home disadvantage for clearances, which is reduced during ghost games. Looking at skill-based tasks, Table 2 shows null results for Home and Ghost concerning ground duels, crosses and shots, as well as for the interaction of Home and Ghost on passes and shots. Yet it indicates a positive impact of playing at home and ghost games on pass accuracy, as well as positive interaction effects of Home and Ghost on ground duels and the accuracy of crosses. This indicates a home advantage with respect to passing accuracy as well as an increase in this performance metric in ghost games, with no distinction between home and away teams. Moreover, the results suggest that home teams have an advantage in skill-based tasks such as ground duels and crosses only in ghost games.

In sum, the regression results complement the descriptive statistics and nonparametric tests in this section. They offer weak support for H1 and confirm H2.

Table 2: OLS regressions

	Effort-based tasks				Skill-based tasks			
	Sprints	**Distance covered**	**Clearances**	**Tackles**	**Ground duels**	**Crosses**	**Passes**	**Shots on target**
Home	5.79 (4.84)	0.49 (0.73)	-6.11*** (1.43)	-0.51 (0.79)	-0.02 (0.21)	-0.03 (0.02)	0.02** (0.01)	0.01 (0.02)
Ghost	3.35 (4.84)	-0.88 (0.73)	-4.57*** (0.09)	-1.94** (0.79)	-0.08 (0.21)	-0.03 (0.02)	0.02** (0.01)	0.02 (0.02)
Home#Ghost	-8.54 (6.84)	-0.56 (1.03)	4.93** (2.02)	1.19 (1.12)	0.06** (0.00)	0.05* (0.03)	-0.01 (0.01)	0.00 (0.04)
Constant	221.18*** (3.42)	116.18*** (0.51)	23.12*** (1.01)	17.05*** (0.56)	0.52*** (0.01)	0.24*** (0.02)	0.75*** (0.01)	0.58*** (0.02)
N	324	324	324	324	324	323	324	324
R^2	0.0057	0.017	0.0681	0.0211	0.0207	0.0093	0.0351	0.0050
Adj. R^2	-0.0036	0.0078	0.0594	0.0120	0.0115	-0.0001	0.0261	-0.0043
F, Prob>F	0.61 p=0.6094	1.84 p=0.1390	7.79 p<0.0001	2.30 p=0.0768	2.25 p=0.0820	0.99 p=0.3962	3.88 p=0.0095	0.54 p=0.6556

Notes: Standard deviations in parentheses; significance levels * p<0.1, ** p<0.05, *** p<0.01.

Figures 1-8: Effort-based (upper panel) and skill-based (lower panel) performance of home vs. away teams in regular vs. ghost games

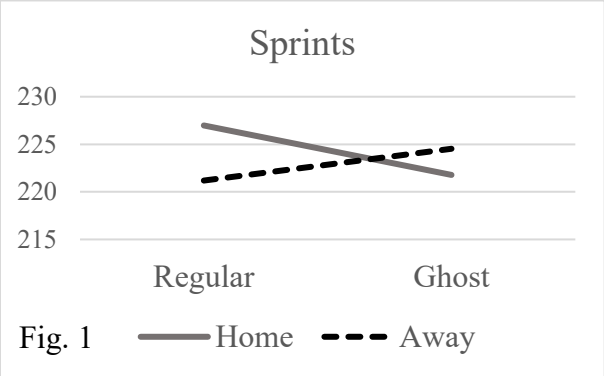

Fig. 1

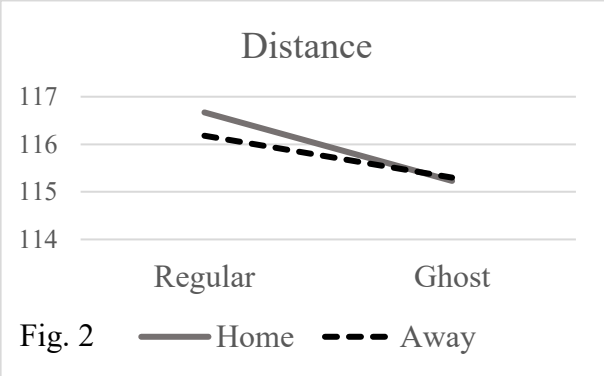

Fig. 2

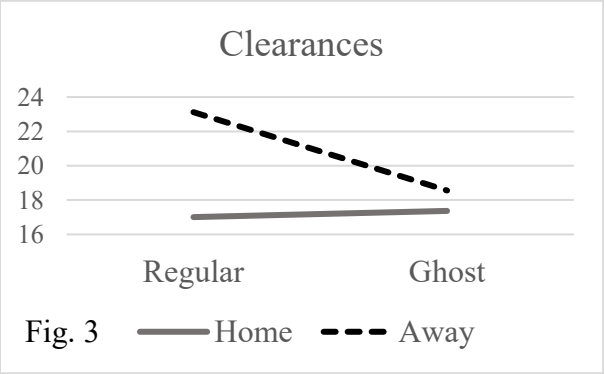

Fig. 3

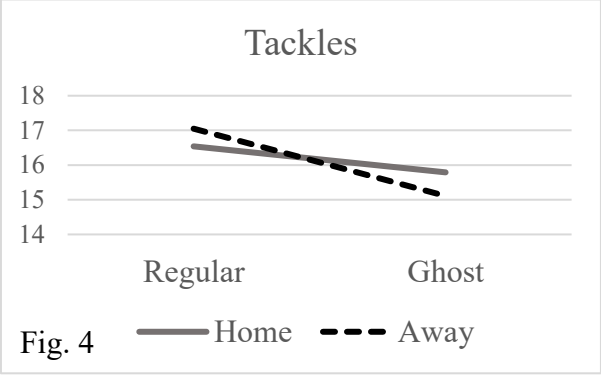

Fig. 4

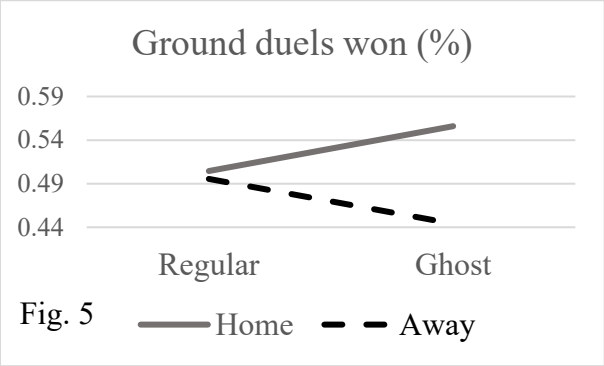

Fig. 5

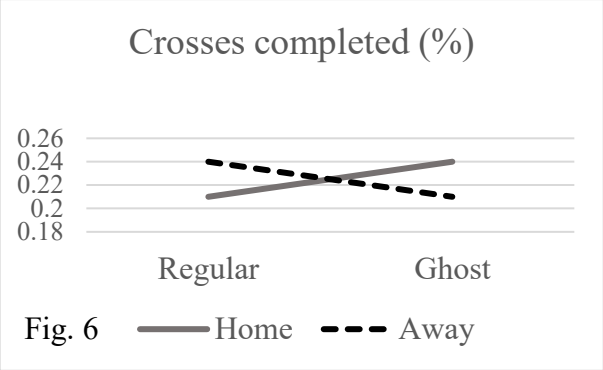

Fig. 6

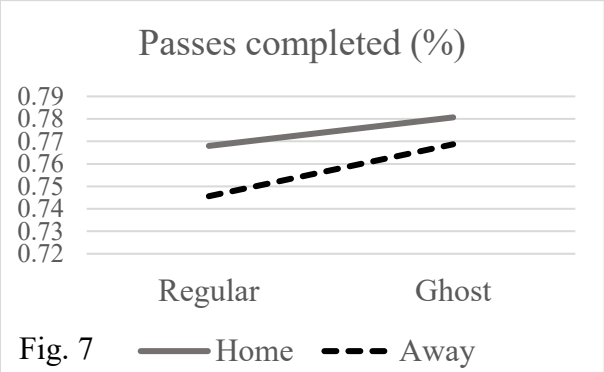

Fig. 7

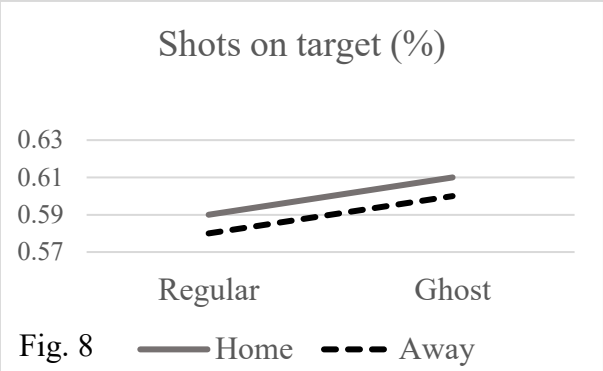

Fig. 8

5. Conclusion and Discussion

This study examines how spectator absence during the German football Bundesliga's 2019/2020 season affected home-team performance. Leveraging this quasi-natural experiment allows us to isolate the causal impact of crowd presence – avoiding biases inherent in studies that rely on endogenous variation in crowd size (Pollard & Armatas, 2017). Contributing to research on the diminished home advantage in ghost games (Leitner et al., 2023; Wang & Qin, 2023), we distinguish between effort-based and skill-based performance indicators. While previous work attributes the diminished home advantage to a reduction in referee bias (Bryson et al., 2021; Cueva, 2020; Reade et al., 2021) and offensive activity (Ferraresi & Gucciardi, 2023; Santana et al., 2021; Scoppa, 2021), our results show that crowd effects are shaped by the type of task.

The results of our nonparametric tests suggest that home teams outperform away teams in the effort-intensive metric sprints during regular games but not during ghost games. Furthermore, home teams cover a greater distance in regular games compared to ghost games. However, these results are not significantly confirmed in our regression analyses, which show a general decline of clearances and tackles in ghost games compared to regular games. While crowds may boost physical exertion (Triplett, 1898; Lazear & Rosen, 1981; Rosen, 1986), their influence is task dependent.

Skill-based performance shows a different pattern: the nonparametric statistics and regression results imply that home teams in fact win more ground duels in ghost games compared to regular games. Moreover, the regression analyses revealed that home teams' accuracy in cross is higher in ghost games than in regular games. However, there were no significant interaction effects of home advantage and crowd attendance on passes and shots on target. This suggests that crowd-induced pressure does not help with skill-based tasks and may even hinder performance (Baumeister & Steinhilber, 1984; Dohmen, 2008).

Our evidence highlights that home advantage is not uniform but varies systematically with the performance dimension. This task-specific perspective challenges simplified models of home advantage and offers practical

implications for coaching, tactical preparation, and stadium design. For instance, club managers could consider how elements like the proximity of fans to the field and the acoustics and atmosphere of standing sections (Edensor, 2015) influence player motivation and pressure. Additionally, sports marketing campaigns could emphasize the impact of fans on effort-based tasks, encouraging attendance to boost team performance. Conversely, situations that require skill – such as penalty kicks or free throws – a quieter or neutral environment may confer an advantage.

As with any empirical analysis, our study has several limitations. Firstly, the dataset is confined to a single season (2019/2020) in the German football Bundesliga, which restricts how widely the findings can be generalized across time, leagues, and sports. For instance, the extraordinary context of the COVID-19 pandemic may have introduced confounding psychological or physiological variables unrelated to crowd effects. Secondly, although we categorize performance tasks as either effort-based or skill-based, many football actions involve both components to varying degrees, making strict classification difficult. Thirdly, our analysis is based on observable match statistics, which may not capture more subtle psychological or tactical dynamics.

The limitations of this study open up several avenues for future research. One promising direction would be to extend this analysis to other major European leagues, such as the Premier League, Serie A, La Liga, and Ligue 1, to examine whether league-specific contexts – such as tactical culture, stadium design, or fan behavior – moderate the relationship between crowd presence and player performance. Another direction for future studies could be to examine subsequent seasons, particularly those in which fans were gradually allowed back into the stadiums. This would allow researchers to assess how quickly players readapt to crowd presence and whether performance patterns observed during ghost games persist or revert. Fischer and Haucap (2021) suggest that adaptation may vary by league level and previous exposure to large crowds, an idea that could be explored in further depth. A third direction would be to test whether the task-specific effects identified also apply to other sports. Jane (2022), for instance, finds that crowd presence negatively impacts batting performance in baseball, a highly skilled task. This lends weight to the notion of a more comprehensive framework in which task type and crowd context interact to influence performance outcomes. Finally, experimental research using biometric data or controlled psychological studies could help to isolate the underlying mechanisms, such as stress, motivation, or attention.

Overall, our findings support a more nuanced understanding of the behavioral mechanisms underlying home advantage and crowd effects, taking into account the nature of the performance task. This refined perspective could inform more targeted fan engagement strategies in professional sports, more effective coaching, and fairer competition design.

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