

University of Groningen

Waiting to score. Conversion probability and the video assistant referee (VAR) in football penalty kicks

Veldkamp, Joran; Koning, Ruud H.

Published in:
Journal of Sports Sciences

DOI:
[10.1080/02640414.2023.2292893](https://doi.org/10.1080/02640414.2023.2292893)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2023

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Veldkamp, J., & Koning, R. H. (2023). Waiting to score. Conversion probability and the video assistant referee (VAR) in football penalty kicks. *Journal of Sports Sciences*, 41(18), 1692-1700. <https://doi.org/10.1080/02640414.2023.2292893>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Waiting to score. Conversion probability and the video assistant referee (VAR) in football penalty kicks

Joran Veldkamp & Ruud H. Koning

To cite this article: Joran Veldkamp & Ruud H. Koning (2023) Waiting to score. Conversion probability and the video assistant referee (VAR) in football penalty kicks, Journal of Sports Sciences, 41:18, 1692-1700, DOI: [10.1080/02640414.2023.2292893](https://doi.org/10.1080/02640414.2023.2292893)

To link to this article: <https://doi.org/10.1080/02640414.2023.2292893>



© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 10 Jan 2024.



Submit your article to this journal [↗](#)



Article views: 789




View related articles [↗](#)



View Crossmark data [↗](#)

Waiting to score. Conversion probability and the video assistant referee (VAR) in football penalty kicks

Joran Veldkamp^a and Ruud H. Koning^b 

^a Atlas Research, Amsterdam, Netherlands; ^bDepartment of Economics, Econometrics & Finance, Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands

ABSTRACT

The VAR has introduced a new element to football. Before, a decision to award a penalty kick could not be reversed. The player taking the penalty could take it relatively quickly after the referee called the foul. After the introduction of the VAR, every penalty kick decision is replayed by the VAR and also quite often reviewed on-field. As a consequence, time between the initial decision by the referee and the actual penalty kick has increased substantially. We examined the influence of the time-interval duration between the foul and the actual penalty kick on the conversion probability using a logit model. Also, we assessed the consequences of a VAR intervention, if any. We used data on all 2888 penalties awarded in top leagues in England, Spain, Germany, Italy, the Netherlands, and the UEFA Champions League, over the course of five seasons (2015/2016–2019/2020). We found that the duration between the foul and the moment the penalty is taken does not impact the conversion probability. However, whether or not the VAR intervenes with the referee's decision has a negative effect on the conversion probability of penalty kicks. Football teams and coaches should incorporate this element of uncertainty in training.

ARTICLE HISTORY

Received 10 September 2022
Accepted 23 November 2023

KEYWORDS

Uncertainty; penalty kicks;
football; video assistant
referee

1 Introduction



Penalty kicks are an important event in a professional football match, and could play a decisive role for the outcome of a match. To illustrate their relevance, consider the fact that the World Cup finals in 1990, 1994, and 2006 and the UEFA Champions League finals of 1996, 2001, 2003, 2005, 2008, and 2012 all needed a penalty shoot-out to decide the winner. Of course, a shoot-out in a final is not the same as a penalty in regulation time. Since the average number of goals scored in a football match is approximately 2.5, a penalty can make a huge difference in the outcome of a match. Occasionally, it happens that a penalty kick is the only goal scored in a match. The significant impact of penalty kicks on the final match result has also been demonstrated in recent empirical studies (Crnjac et al., 2016; Dalton et al., 2015).

With more data becoming available, penalty kicks have been the subject of a noticeable number of papers. Studies investigating penalty kick conversion focus on a variety of aspects, such as goalkeeper behaviour or movement (Bar-Eli et al., 2007; Berger & Hammer, 2007; Dicks et al., 2010), the kickers' shooting strategies (Castillo et al., 2010; Lopes et al., 2012; Van der Kamp, 2006), the behavioural interaction between the kicker and the goalkeeper (Bar-Eli & Azar, 2009; Furley et al., 2017; Greenlees et al., 2008), and even refereeing bias tendencies (Erikstad & Johansen, 2020; Schwarz, 2011). There has also been research that investigates the wide range of situational and individual effects on the conversion of penalties (Almeida et al., 2016; Jamil et al., 2020; Mahoney, 2018). The most pronounced examples of such effects are the psychological factors related to

pressure (Arrondel et al., 2019; Horikawa & Yagi, 2012), like playing at home, the current score of the match, or the time left to play. Penalty kicks have also been analysed in a game-theoretic context (Chiaporri et al., 2002; Palacios-Huerta, 2003, 2023).

The Video Assistant Referee (VAR) was added to the Laws of the Game in 2018 (IFAB, 2018) and has introduced a new element to football in general and to penalty kicks more specifically. The VAR enables referees to correct "clear and obvious errors" through the principle of "minimum interference – maximum benefit" (IFAB, 2018), and we already know from other sports that technological developments like these support the accuracy of judgements by referees (Leveaux, 2010). Spitz et al. (2020) demonstrated that the video referee did indeed increase the number of correct decisions in professional football in the last years from 92.1% to 98.3%, based on 2195 competitive matches across 13 different countries.

Essentially, the VAR replays everything that happens on the pitch but only interferes when the referee makes a clear and obvious error at certain "match-changing situation". Four different match-changing mistakes are possible, in relation to: (1) goals, (2) penalties, (3) direct red cards, and a (4) mistaken identity – when the referee gives a yellow or red card to the wrong player. The decision can be altered based solely on the information provided by the VAR, when the result is factual in the sense that it is not prone to subjective judgements, for example offside before a penalty is awarded. This is called a VAR-only review. However, it is also possible that the VAR advises the official to re-assess the situation by reviewing the

CONTACT Ruud H. Koning  r.h.koning@rug.nl  Department of Economics, Econometrics & Finance, Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

situation on the monitor at the side of the pitch. Then a final decision is taken by the referee. This procedure is followed at more subjective decisions like whether or not it is a foul leading to a penalty, or whether a foul should lead to a red card. This procedure is referred to as an on-field review. Related to penalties, there are a few different reasons why the VAR could interfere. For example, the referee could have missed a handball by a defender in the box when a shot was blocked in a packed penalty area. The VAR can replay this situation over and over from different angles, allowing better judgements to make the call if it was an actual handball or not. The referee can then, based on the advice of the VAR, give the penalty in retrospect or re-watch the situation on the monitor on the sidelines before making the final call.

As mentioned earlier, a penalty kick decision is one of the four events at which the VAR can interfere. Once a penalty was given in the pre-VAR era, it could not be reversed. The player taking the subsequent penalty could take it relatively quickly after the referee had called the foul. However, since nowadays every penalty kick decision is always replayed by the VAR and also quite often officially reviewed (see Spitz et al. (2020)), the time between the initial decision by the referee and the actual penalty kick has increased substantially. Spitz et al. (2020) showed that 43.9% of all official reviews are for penalties, and that the median duration of an on-field review was 62 seconds. This has introduced a new element for the players taking penalty kicks, because they now are exposed to uncertainty whether or not a penalty will be given, and they will have to wait for a longer time before they can take the penalty kick – if given. Psychological insights have suggested that people experience feelings of dread when they have to wait longer for nerve-racking events (Loewenstein, 1987), and that the outcome is considered less satisfying the lengthier the wait for such an unpleasant event (Berns et al., 2006). Jordet and Hartman (2008) found support for these notions as penalty takers are showing more hastening behaviour when their team is behind in a penalty shoot-out, and that this behaviour is negatively related to penalty conversion rates. The demonstrated hastening behaviour illustrates thus that people experience feelings of dread when they have to wait longer for a certain nerve-racking event, because the players choose to “get over with it quickly” due to the stressful nature of the penalty shoot-out (Berns et al., 2006; Jordet & Hartman, 2008). Nonetheless, one could also assume that longer waiting times result in more accurate decisions and tradeoffs for certain penalty kick strategies, following the dual-process models of cognition (Kahneman, 2003). Essentially, the cognitive processes of human beings can be divided into “System 1” and “System 2” thinking (ibid). System 1 works fast, automatically and intuitively, while System 2 is more slowly, regulatory and emotionally neutral in nature (Frankish, 2010; Kahneman, 2003). We can therefore assume that System 2 thinking will generally come into play more often once players have more time to think about their penalty kick, resulting in more rational decisions and hence a higher likelihood of a positive outcome of the penalty. In addition, the fact that there is a VAR examination means that in most cases it is not a clear-cut situation. Players therefore might also be in doubt if they really deserve the penalty kick, which could also affect performance (Lackner &

Sonnabend, 2021). Therefore, it remains unclear how the introduction of the VAR and the corresponding increased waiting times for penalty kicks has impacted the conversion rates of penalties in professional football.

In this study, we addressed this issue empirically by estimating the relation between conversion probability and duration of the waiting time to take the penalty kick. Also, we looked at the effect of a VAR intervention – with its associated uncertainty whether or not a penalty will be given – on the conversion probability.

This study contributes to the literature in an important way. Any significant impact of the waiting times on the conversion rates of penalty kicks would signify an unintended effect of the VAR. If increased waiting times result in lower conversion rates, it means the VAR unintentionally disadvantages penalty takers. Increased waiting times leading to higher conversion rates instead would have broader consequences, because that means every penalty taker should consider taking more time before walking up to the 12-yards (11-metre) spot.

2 Data and methods

2.1 Data collection

We used data on matches and penalty kicks from various leagues from the seasons 2015/2016 up and until 2019/2020, provided by Gracenote Sports. Gracenote Sports is a sports data company that has existed since 1995 and is a highly respected provider of sports data, both live and non-live, to hundreds of media clients around the world as well as around 25 National Olympic Committees. An example of another study using Gracenote data is Weber et al. (2017), and an example of a media publication based on Gracenote data is BBC (2023). The following information was provided by Gracenote Sports for each penalty: league, season, match date, home- and away-team, line-ups including captains, attendance, full-time score, interim-score before penalty, timestamp of penalty, timestamp of foul, timestamp of video referee intervention (if applicable), the player conceding the penalty, the player drawing the penalty, and, of course, the kicker and the outcome of the penalty. Further information was available on the footedness of the kicker, his position on the field, if he was the captain, if he was a substitution, if he was the fouled player, and lastly, the reason if he missed the penalty (i.e., saved by goalkeeper, hitting the post/bar, or shooting wide). Additional individual player information for the penalty kick takers was extracted manually from Transfermarkt (www.transfermarkt.com), and specifically the variables age at the time of the penalty (i.e., difference date of birth and match date) and nationality. We only used objective rather than subjective information from Transfermarkt, such as nationality of a player. Other papers that have used Transfermarkt as a source of data include Peeters (2018) and Lepschy et al. (2020).

2.2 Sample and reliability

The sample of this study consisted of all penalty kicks taken in regulation time in matches played in five consecutive seasons (2015/2016 to 2019/2020), for the following six professional

football competitions across Europe: Premier League (England), LaLiga (Spain), Bundesliga (Germany), Serie A (Italy), Eredivisie (The Netherlands), and the UEFA Champions League (group stage and later). These leagues were selected for data availability and the choice of the Dutch league reflect the nationality of the authors. The total number of matches was 9329. The matches ranged from 8 August 2015 to 23 August 2020, i.e., from the start of the 2015/2016 Premier League until the Champions League final of 2019/2020. A total of 2888 penalties have been awarded in this period. Important to note is that only the penalties in regulation time – in 90 min – were taken into account, so penalties of a cup/tournament shoot-out or penalties awarded in extra-time were excluded.

The timing of penalty-related events is best illustrated by an example. Consider the match Arsenal-Watford, played on 26 July 2020. After 34 seconds of play, Watford defender Dawson made a foul on Arsenal player Lacazette. A VAR check started at 1:40, and the check was concluded at 3:26. The referee awarded a penalty kick to Arsenal, and the penalty was taken at 4:18. The waiting time between the foul and the penalty kick itself is 3:44. In that same match, Arsenal defender Luiz made a foul on Watford player Welbeck at 41:13. There was no VAR check. The penalty was taken at 42:32, the waiting time is 1:19.

In order to improve the reliability of these time-interval values, we manually checked video footages of the penalties with either very low or very high waiting times. Videos of these matches/penalties were inspected on Internet sites such as www.youtube.com, www.dailymotion.com, www.bbc.com, www.espn.com, www.beinsports.com, and club websites. Based on the timing in these videos, the time of the foul or the time of the penalty were corrected for a limited number of cases. The change in timing was in general no more than 10–20 seconds. For the cases in which the time of the foul was later than the time of the video referee intervention, we took the time of the foul equal to the time of the video referee intervention (this applies to 28 penalties). The longest waiting time, 518 seconds or more than 8 minutes, and other atypical values were checked and were deemed correct (see for this particular penalty Gazetta Dello Sport (2019)). Virtually all of the high waiting times were caused by a video referee consultation.

2.3 Statistical methods

We estimated the relation between the probability of successful conversion of a penalty kick (dependent variable) and covariates using a simple logit model (Harrell, 2015). We provide both point estimates and the corresponding odds ratios with a 95% confidence interval (based on profile likelihood). All

Table 1. Sample of matches and penalty kicks given, by competition.

Competition	Matches	Penalty kicks	Matches with at least one penalty kick
Premier League	1900	472	0.22
LaLiga	1900	610	0.27
Bundesliga	1530	440	0.25
Serie A	1900	693	0.31
Eredivisie	1480	452	0.26
Champions League	619	221	0.30
All matches	9329	2888	0.27

calculations have been made using R 4.1.2 (R Core Team, 2021). Throughout this paper, we used a level of significance $\alpha = 0.05$.

3 Results

First, we present descriptive statistics, and then we proceed to give the estimation results of the relation between the conversion probability and the covariates.

In 6853 matches (73.46%) no penalty was given, a single penalty was given in 2094 matches (22.45%), two penalties were given in 349 matches (3.74%), and three penalties were awarded in 32 matches (0.34%). The number of matches, penalties given, and the proportion of matches in which at least one penalty was given is displayed in Table 1, separately for each of the competitions.

The differences in the total number of matches between the domestic leagues lied in the fact that the Premier League, La Liga and Serie A had 20 teams in total, while the Bundesliga and Eredivisie had 18 teams in total. The Eredivisie season 2019/2020 was cancelled in March 2020 due to the COVID-19 pandemic, while the Bundesliga resumed its 2019/2020 season in May. Therefore, there were 50 more Bundesliga matches present in the data than Eredivisie matches. On average, in slightly more than one out of every four matches in the 2015–2020 period at least one penalty was given. Between leagues, the variation in the fraction of matches with at least one penalty was statistically significant ($\chi^2 = 43.6$ with 5 degrees of freedom so that $p < 0.001$). Cramers V measure of association is 0.07.

The dependent variable of the present study is the binary outcome of the penalty, thus whether the penalty resulted in a goal or not (0 = penalty missed, 1 = penalty scored). Table 2 shows an average conversion rate of 77%. Interestingly, we saw an indication that the number of penalties awarded per season is starting to increase. 2019/2020 was the first season in which every league in the sample has implemented the use of the VAR, with the English Premier League being the last one to start doing so (in August 2019). This is indicated in the right-most column of Table 2 which gives the fraction of

Table 2. Overview of number and conversion of penalties.

Season	Number of penalties	Number converted	Conversion rate	Fraction of VAR matches
2015/2016	521	394	0.76	0.00
2016/2017	596	432	0.72	0.00
2017/2018	537	395	0.74	0.35
2018/2019	595	484	0.81	0.71
2019/2020	639	518	0.81	1.00
Total	2888	2223	0.77	0.41

matches in a given season using a VAR. We immediately observed that in the last season available the highest number of penalties were awarded, with 639 kicks awarded between all the leagues in this study. In that season, all leagues used VAR. Somewhat more surprising is the third column of [Table 2](#), where the fraction of scored penalties is displayed. This shows that the conversion rates in the last two seasons, 2018/2019 and 2019/2020, were on average 6–9% higher than the three seasons before. Thus, it seems that both the number of penalties given as well as the percentage of penalties that result in a goal is increasing and/or has increased during the implementation period of the VAR (see last column [Table 2](#)).

[Table 3](#) further shows that our assumption about the increased time-interval is validated, because the mean time-interval between the foul and the penalty is sharply increasing over the seasons. The mean value is slightly more than 1 minute in the 2015/2016 and 2016/2017 seasons, but already increases to 70 seconds in the 2017/2018 season – when the first competitions, Bundesliga and Serie A started to use VAR. The average time between the foul and the taking of the penalty kick increases from 62 seconds when no leagues used a VAR (2015/2016) to 114 seconds when all leagues used a VAR (2019/2020). Thus, the average time between foul and penalty is almost two minutes when all leagues used a VAR, as opposed to one minute. We also give the median value over the course of the seasons, because the mean is very sensitive for outliers. The conclusion is similar: the median waiting time interval is increasing over the seasons.

In [Appendix A](#) we formally compared the distributions of waiting times with and without VAR intervention. As expected, waiting times between foul and taking the penalty kick is longer in case of VAR intervention when compared to no intervention (the medians are 156 s and 62 s, respectively).

Gracenote Sports has provided us with an extensive set of control variables (see above). In simple analyses, where we estimated a univariate logit model with one covariate at a time, we found that the conversion probability varies significantly with season (later seasons have a higher conversion probability), and age (older players tend to be more successful). Other variables (league, home or away, first or second half, footedness of the penalty taker, and whether the fouled player takes the penalty) are all not significant in the univariate analyses.

Next, we tested our main hypotheses. First, we tested whether the time interval between the foul and the penalty kick determines the conversion probability. In [Table 4](#) we provide the estimation results of a logit model, with the time between as the only covariate, and the probability of conversion as the dependent variable. The positive slope coefficient suggests that longer waiting times increase the conversion probability. However, the effect is not statistically significant ($p = 0.08$).

In a second step, we looked at the effect of the VAR intervention: are penalty kicks awarded after a VAR intervention more likely to be converted to a goal, or not? 77% of all 2511 penalty kicks are converted if there is no VAR intervention. On the other hand, 78% are converted when there is a VAR intervention (377 penalty kicks). The very small difference of approximately one percentage point is not statistically different from 0.

However, as we alluded to above, the conversion rate has increased substantially over time. As later matches are more likely to have VAR interventions (only in the 2019/2020 season all matches have had a VAR), it is important to separate this increase in the conversion probability from the gradual implementation of VAR technology. Also other covariates may be relevant in modelling the conversion probability. Therefore, we estimated a logit model (dependent variable is the conversion probability) with a rich set of control variables besides the two variables of main interest (time between and VAR intervention). The results are in [Table 5](#). The reference categories for the categorical variables were: 2015/2016 (season), Bundesliga (league), gain 0 points if scored (scoreline).

The estimation results showed that the time between foul and penalty kick is not a significant determinant of the conversion probability. However, it matters how the penalty is awarded: penalties awarded after a VAR intervention have a significantly lower conversion probability than penalties that are given without a VAR intervention. The results in [Table 5](#) also show that penalties taken in 2018/2019 and 2019/2020 have a significantly higher conversion probability when compared to the seasons 2015/16 (omitted reference category), 2016/2017, and 2017/2018. As far as variation between leagues is concerned, we noted that penalties in the Champions League have a significantly lower conversion probability when compared to the Bundesliga (the reference league), Eredivisie, and

Table 3. The mean time-interval between the foul and the penalty, by season.

Season	Mean (sec.)	Median (sec.)	St. Dev. (sec.)	Range (sec.)
2015/2016	62.47	57	24.07	31–224
2016/2017	63.28	58	23.90	32–233
2017/2018	69.62	60	36.44	31–309
2018/2019	97.01	74	60.01	32–518
2019/2020	113.59	95	59.76	33–382
Total	82.39	66	49.35	31–518

Table 4. Logistic regression results, without control variables ($n = 2888$).

	estimate	st. error	p-value	odds	95% conf.int	
(Intercept)	1.07	0.09	0.00	2.92	2.45	3.46
time between (min.)	0.10	0.06	0.08	1.11	0.99	1.24

Table 5. Logistic regression results, with control variables ($n = 2888$).

	estimate	st. error	p-value	odds	95% conf.int	
(Intercept)	1.22	1.83	0.51	3.38	0.10	128.12
time between (min.)	0.11	0.08	0.16	1.12	0.96	1.30
VAR intervention	-0.45	0.19	0.02	0.64	0.44	0.92
season2016/2017	-0.15	0.14	0.27	0.86	0.65	1.12
season2017/2018	-0.14	0.14	0.33	0.87	0.66	1.15
season2018/2019	0.39	0.16	0.01	1.48	1.09	2.00
season2019/2020	0.34	0.17	0.04	1.41	1.01	1.97
Champions League	-0.39	0.19	0.04	0.68	0.47	0.99
Eredivisie	0.18	0.17	0.28	1.20	0.86	1.67
LaLiga	-0.13	0.15	0.38	0.87	0.65	1.18
Premier League	-0.01	0.16	0.96	0.99	0.72	1.36
Serie A	-0.13	0.15	0.39	0.88	0.66	1.17
gain 1 point if scored	-0.11	0.12	0.40	0.90	0.71	1.15
gain 2 points if scored	-0.14	0.10	0.17	0.87	0.71	1.06
home penalty	-0.16	0.09	0.09	0.86	0.71	1.02
empty stadium	0.12	0.23	0.60	1.13	0.72	1.80
fouled	-0.07	0.12	0.52	0.93	0.74	1.17
substitute	-0.07	0.17	0.68	0.93	0.68	1.31
age	-0.03	0.13	0.85	0.98	0.75	1.26
age ²	0.00	0.00	0.68	1.00	1.00	1.01

Premier League. Other covariates are not significant in modelling the conversion probability, also not age.

To interpret the effect size of the VAR intervention on the conversion probability, we took a hypothetical penalty kick, with values of the covariates at their mean, or mode (time between 97 s, 2019/2020 season, Premier League, gain 2 points if penalty is converted, home penalty, stadium with audience, penalty taker is not the fouled player, nor a substitute, and the age of the taker is 27.37 years). The conversion probability is 0.81 in case of no VAR intervention and it decreases to 0.73 in case of a VAR intervention.

To check whether our results are driven by the fact that our dataset contains both matches with a VAR, and without a VAR, we estimated the same model on the matches with a VAR present. As a consequence, the number of seasons included in that subsample varied by league, reflecting the gradual roll-out of the VAR (see also the rightmost column in [Table 2](#)). The sample size reduces to 1133 penalty kicks. The results are given in [Table 6](#). The reference categories for the categorical variables were: 2017/2018 (season), Bundesliga (league), gain 0 points if scored (scoreline).

As far as our main variables of interest are concerned, the conclusions are very similar to the ones above: the time between foul and actual penalty kick does not matter, whether or not a VAR intervention has taken place does matter. To illustrate the effect size, we used the same values for the covariates as earlier. The probability of conversion decreases from 0.81 (no VAR intervention) to 0.71 (VAR intervention). These probabilities are very similar to the ones obtained using the model of the full sample, and hence, indicate robustness of the results. In another specification, we removed all knock-out matches from our dataset, as pressure may be different in these matches. Again, the results did not change materially.

4 Discussion

We found a conversion rate of penalty kicks of 77%, which is comparable to other empirical studies investigating penalty kicks in professional football (Almeida et al., 2016; Bar-Eli et al., 2007; Palao et al., 2010; White & O'Donoghue, 2013). What emerged from the empirical analysis is that not the time interval between the foul and the penalty, but whether or not

Table 6. Logistic regression results, VAR matches only ($n = 1133$).

	estimate	st. error	p-value	odds	95% conf.int	
(Intercept)	-0.10	3.28	0.97	0.90	0.00	672.47
time between (min.)	0.17	0.10	0.10	1.19	0.98	1.46
VAR intervention	-0.52	0.21	0.01	0.59	0.39	0.89
season2018/2019	1.37	1.44	0.34	3.95	0.15	102.98
season2019/2020	1.35	1.44	0.35	3.86	0.15	101.03
Champions League	-0.26	0.33	0.43	0.77	0.40	1.49
Eredivisie	0.08	0.28	0.78	1.08	0.62	1.89
LaLiga	-0.05	0.26	0.84	0.95	0.56	1.58
Premier League	-0.21	0.34	0.53	0.81	0.42	1.58
Serie A	-0.17	0.25	0.50	0.84	0.51	1.37
gain 1 point if scored	0.05	0.22	0.81	1.05	0.69	1.62
gain 2 points if scored	-0.14	0.18	0.43	0.87	0.62	1.23
home penalty	-0.02	0.16	0.88	0.98	0.72	1.33
empty stadium	0.10	0.24	0.67	1.10	0.70	1.78
fouled	-0.02	0.22	0.91	0.98	0.65	1.51
substitute	-0.37	0.27	0.17	0.69	0.41	1.19
age	-0.02	0.22	0.93	0.98	0.63	1.48
age ²	0.00	0.00	0.79	1.00	0.99	1.01

a VAR intervention was conducted before the penalty – regardless of the time it took – impacted the conversion probability of a penalty kick. When the VAR intervened with the decision of the referee and either confirmed the initial decision or advised the referee to award a penalty (if initially not given) instead, the probability that the subsequent penalty was scored, was significantly lowered. This is independent of how long the VAR intervention actually took. We found this negative effect of a VAR intervention also when we restricted ourselves to matches with a VAR available. This negative effect of a VAR intervention on the conversion probability of a penalty kick signifies an unintended effect of the introduction of the VAR in professional football. The VAR is implemented with the goal of “minimum interference – maximum benefit” (IFAB, 2018) to correct obvious errors by the referees to achieve more fairness in the game. One could argue that it succeeds in its goal, since studies showed the implementation of the VAR did lead to more correct decisions (Spitz et al., 2020) and hardly changes the game of elite football based on the number of certain important match events like goals, fouls, and yellow/red cards (Errekaigorri et al., 2020; Koning & Van Steen, 2021; Kubayi et al., 2021; Lago-Peñas et al., 2021). However, the current study shows that the VAR system unintentionally disadvantages penalty takers (and the teams they represent), because they have a lower probability of scoring when the VAR intervenes with the decision of the referee.

As far as other determinants of the probability of conversion are concerned, we did not find evidence that a player who is fouled should not take the subsequent penalty kick himself (Drösser, 2003; Eichler, 2002). Our result is in line with Kuss et al. (2007), who also refuted this hypothesis using 835 penalties awarded (due to a foul) in the Bundesliga between 1993 and 2005. Interestingly, we also found no significant impact of other external or situational effects on the penalty conversion probability, such as playing at home, the current score or age. A possible explanation could be that penalty takers are selected a priori and typically chosen because of their ability to cope with high pressure and stressful situations (Kuss et al., 2007). The absence of an effect of playing at home on the scoring probabilities of penalty kicks is also in agreement with mixed evidence in previous studies (Dohmen, 2007; Kuss et al., 2007). The results revealed some indication that there might be differences in scoring probabilities between leagues, most notably a significant lower probability to score in the Champions League when compared to some national leagues. A potential explanation is that the stakes (and associated pressure) are even higher in the Champions League, as there is less time to brush off bad results than in a regular league. Nonetheless, this effect became non significant in the model with VAR matches only.

In this paper, we focused mainly on the penalty kick taker and not on the opposing goalkeeper, while it is quite clearly a (psychological) game between the two (Palacios-Huerta, 2003, 2023). Literature shows that the interaction between the goalkeeper and the penalty taker and the emotional state of the latter are of vital importance for the outcome of the penalty. There is clear evidence of a decrease in successful penalty kicks when the pressure is high and anxiety crops up (Horikawa & Yagi, 2012; Jordet & Hartman, 2008). More anxious

players tend to focus on the goalkeeper (Wilson et al., 2009), which in turn leads to a decline in performance (Furley et al., 2017). Goalkeepers can even nudge players to focus on them (and thereby decrease performance) by employing distraction strategies, like moving and waving their arms (Wood & Wilson, 2010). Of further relevance is that goalkeepers make use of the non-verbal information exhibited by the penalty taker, both during the run-up (Dicks et al., 2010; Lopes et al., 2014) and the time prior to the run-up (Furley et al., 2012, 2020). Penalty takers that look away instead of at the goalkeeper for more time before initiating their run-up and/or used less preparation time, are perceived by both goalkeepers and outfield players as less skilful and were more likely to perform poorly (Furley et al., 2012; Greenlees et al., 2008; Jordet & Hartman, 2008). Goalkeepers facing players that showed these types of hastening and hiding behaviours started their endeavours to stop the penalty later (Furley et al., 2020), for which there is increasing evidence this can result in more successful save attempts (Dicks et al., 2010). In our case, we did not find that players miss penalty kicks differently after a VAR intervention. Our dataset provides three possible reasons for missing a penalty kick: it is against the crossbar or post, it is wide, or it is saved by the goalkeeper. The distributions of missed penalty kicks over all matches with VAR available are 11%, 15%, 74% (penalties without VAR intervention) and 11%, 16%, and 73% (penalties with VAR intervention). The distributions are almost identical, so there is no *prima facie* reason to suppose that the VAR intervention helps the goalkeeper to prepare better (using non-verbal cues) for the upcoming penalty kick.

There are two more additional (related) limitations to the present study. First, we did not take into account any information about the abilities of the two players involved. It is possible that better teams and players have a higher chance of scoring (or saving) a penalty, although Almeida and Volossovitch (2023) found no such evidence in the Portuguese First League. Although it may be unsatisfactory to some because it challenges the widespread belief that penalty shoot-outs are a game of chance, Krumer (2020) demonstrated that teams of one division higher have a 8 point percentage higher likelihood of winning a penalty shoot-out. Some attempts have been made to improve upon relative conversion frequency measures (as many players are involved in only a few penalties) using Bayesian models (Bornkamp et al., 2009; Hanck & Arnold, 2023), but both called for further research on the matter. Secondly, players likely differ in psychological characteristics related to performance in high-pressure moments, like penalty kicks. Horikawa & Yagi (2012) showed experimentally that high trait anxiety individuals evaluate anxiety due to pressure more negatively as opposed to low trait anxiety individuals, which in turn negatively impacted their penalty kicker performance. Unfortunately, it is extremely difficult to study emotional characteristics like this in real-world high-stake penalty kicks, but it still demonstrates that players could and probably do differ in this regard, and the current study treated them as if this was not the case.

The negative effect of the VAR intervention variable has an additional practical implication. Football teams and clubs practicing to optimize the quality of their penalty kick takers should thus take into account that a VAR intervention in the game

reduces the scoring probability, and think about ways in which they could anticipate on this finding and apply it in their training sessions. Focusing on the uncertain nature of penalty kicks (in combination with the exposing non-verbal information) awarded after a VAR check is advisable. The coaching staff could for example unexpectedly interrupt an 11 versus 11 training match, wait a random amount of time (mimicking a VAR check), and possible – but not always – have a penalty kick taken.

5 Conclusion

This study has investigated the impact of the video assistant referee (VAR) on the conversion rates of penalty kicks in six professional European football competitions, across five consecutive seasons (2015/2016–2019/2020). We have examined how the increased waiting times between the foul and the penalty and whether or not a VAR intervention occurred, influenced the conversion probability. The results indicated that the waiting times did not influence the conversion probability of penalty kicks, but whether or not a VAR intervention is conducted before the penalty – regardless of the time it took – did. We found this negative effect of a VAR intervention also when we restricted ourselves to matches with a VAR available. Although the decisions to award a penalty are more often correct using VAR (Spitz et al., 2020), we showed that the VAR system unintentionally and controversially impairs the penalty taker's performance. Football teams and coaches could offset this disadvantage moving forward by incorporating the ingredient of uncertainty related to penalty kicks with VAR checks into their training sessions. With the VAR, there is a second chance in life, but coaches and players should learn to take it.

Acknowledgments

We are very grateful to Gracenote Sports for making the dataset available to us. We thank participants at the 12th ESEA Conference on Sports Economics, hosted by Bielefeld University (Germany) on 25–27 August 2021, and those at the XVIth Gijon Conference on Sports Economics on 6–7 May 2022 for their helpful comments on the paper. We thank two anonymous referees for helpful comments and suggestions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Ruud H. Koning  <http://orcid.org/0000-0002-3083-2284>

References

Almeida, C., & Volossovitch, A. (2023). Multifactorial analysis of football penalty kicks in the Portuguese first league: A replication study.

- International Journal of Sports Science & Coaching*, 18(1), 160–175. <https://doi.org/10.1177/17479541221075722>
- Almeida, C. H., Volossovitch, A., & Duarte, R. (2016). Penalty kick outcomes in UEFA club competitions (2010-2015): The roles of situational, individual and performance factors. *International Journal of Performance Analysis in Sport*, 16(2), 508–522. <https://doi.org/10.1080/24748668.2016.11868905>
- Arrondel, L., Duhautois, R., & Laslier, J. F. (2019). Decision under psychological pressure: The shooter's anxiety at the penalty kick. *Journal of Economic Psychology*, 20, 22–35. <https://doi.org/10.1016/j.joep.2018.10.008>
- Bar-Eli, M., & Azar, O. H. (2009). Penalty kicks in soccer: An empirical analysis of shooting strategies and goalkeepers' preferences. *Soccer and Society*, 10(2), 183–191. <https://doi.org/10.1080/14660970802601654>
- Bar-Eli, M., Azar, O. H., Ritov, I., Keidar-Levin, Y., & Schein, G. (2007). Action bias among elite soccer goalkeepers: The case of penalty kicks. *Journal of Economic Psychology*, 28(5), 606–621. <https://doi.org/10.1016/j.joep.2006.12.001>
- BBC. (2023). *Premier League relegation battle: Three teams, one day - who will stay up?* Retrieved May 29, 2023, from <https://www.bbc.com/sport/football/64985188>
- Berger, R., & Hammer, R. (2007). *Links oder rechts; das ist hier die frage*. Technical report, Institut für Soziologie der Universität Leipzig.
- Berns, G. S., Chappelow, J., Celic, M., Zink, C. F., Pagnoni, G., & Martin-Skurski, M. E. (2006). Neurobiological substrates of dread. *Science*, 312(5774), 754–758. <https://doi.org/10.1126/science.1123721>
- Bornkamp, B., Fritsch, A., Kuss, O., & Ickstadt, K. (2009). Penalty specialists among goalkeepers: A nonparametric Bayesian analysis of 44 years of the German Bundesliga. In B. Schipp & W. Krämer (Eds.), *Statistical inference, Econometric Analysis and matrix algebra* (pp. 63–76). Physica-Verlag.
- Castillo, J. M., Oña, A., Raya, A., Bilbao, A., & Serra, E. (2010). Tactical skills and ball speed during a field simulation of penalty kick strategies in soccer. *Perceptual and Motor Skills*, 111(3), 947–962. <https://doi.org/10.2466/05.23.24.27.PMS.111.6.947-962>
- Chiapoori, P.-A., Levitt, S., & Groseclose, T. (2002). Testing mixed-strategy equilibria when players are heterogeneous: The case of penalty kicks in soccer. *American Economic Review*, 92(4), 1138–1151. <https://doi.org/10.1257/00028280260344678>
- Crnjac, D., Dizdar, D., & Basic, D. (2016). Importance of penalty kicks in football considering final outcome of the match and league system of competition. *Acta Kinesiológica*, 10(2), 7–9.
- Dalton, K., Guillon, M., & Naroo, S. A. (2015). An analysis of penalty kicks in elite football post 1997. *International Journal of Sports Science & Coaching*, 10(5), 815–827. <https://doi.org/10.1260/1747-9541.10.5.815>
- Dicks, M., Davids, K., & Button, C. (2010). Individual differences in the visual control of intercepting a penalty kick in association football. *Human Movement Science*, 29(3), 401–411. <https://doi.org/10.1016/j.humov.2010.02.008>
- Dohmen, T. (2007). Do professionals choke under pressure? *Journal of Economic Behavior and Organization*, 65(3–4), 636–653. <https://doi.org/10.1016/j.jebo.2005.12.004>
- Drösser, C. (2003). Stimmt's? Verschossen. *Die Zeit*, 32, 25.
- Eichler, C. (2002). *Lexikon der Fussballmythen*. Eichborn.
- Erikstad, M. K., & Johansen, B. T. (2020). Referee bias in professional football: Favoritism toward successful teams in potential penalty situations. *Frontiers in Sports and Active Living*, 2, 1–5. <https://doi.org/10.3389/fspor.2020.00019>
- Errekegorri, I., Castellano, J., Etxezarza, I., & Lago Peñas, C. (2020). The effects of the video assistant referee system (VAR) on the playing time, technical-tactical and physical performance in elite soccer. *International Journal of Performance Analysis in Sport*, 20(3), 11–10. <https://doi.org/10.1080/24748668.2020.1788350>
- Frankish, K. (2010). Dual-process and dual-system theories of reasoning. *Philosophy Compass*, 5(10), 914–926. <https://doi.org/10.1111/j.1747-9991.2010.00330.x>
- Furley, P., Dicks, M., & Jordet, G. (2020). The psychology of penalty kicks: T influence of emotions on penalty taker and goalkeeper performance. In J. Dixon, J. Barker, R. Thelwell, & I. Mitchell (Eds.), *The psychology of soccer*. Chapter 3. (pp. 20–51). Routledge.

- Furley, P., Dicks, M., Stendtko, F., & Memmert, D. (2012). "Get it out the way. The wait's killing me." hastening and hiding during soccer penalty kicks. *Psychology of Sport and Exercise*, 13, 454–465. <https://doi.org/10.1016/j.psychsport.2012.01.009>
- Furley, P., Noël, B., & Memmert, D. (2017). Attention towards the goalkeeper and distraction during penalty shootouts in association football: A retrospective analysis of penalty shootouts from 1984 to 2012. *Journal of Sports Sciences*, 35(9), 873–879. PMID: 27292083. <https://doi.org/10.1080/02640414.2016.1195912>
- Gazzetta Dello Sport. (2019). *Frosinone-Parma 3-2: decide il rigore con VAR di ciofani al 103*. Retrieved February 2, 2021, from <https://www.gazzetta.it/Calcio/Serie-A/03-04-2019/frosinone-parma-3-2-decide-rigore-var-ciofani-103-330452867912.shtml>
- Greenlees, I., Leyland, A., Thelwell, R., & Filby, W. (2008). Soccer penalty takers' uniform colour and pre-penalty kick gaze affect the impressions formed of them by opposing goalkeepers. *Journal of Sports Sciences*, 26(6), 569–576. <https://doi.org/10.1080/02640410701744446>
- Hanck, C., & Arnold, M. (2023). Hierarchical Bayes modelling of penalty conversion rates of Bundesliga players. *AStA Advances in Statistical Analysis*, 107(1–2), 177–204. <https://doi.org/10.1007/s10182-021-00420-w>
- Harrell, F., Jr. (2015). *Regression Modelling Strategies* (Second ed.). Springer.
- Horikawa, M., Yagi, A. (2012). The relationships among trait anxiety, state anxiety and the goal performance of penalty shoot-out by university soccer players. *PloS One*, 7(4), e35727. <https://doi.org/10.1371/journal.pone.0035727>
- IFAB. (2018). *Historic step for greater fairness in football*. Retrieved October 30, 2020, from <https://www.theifab.com/news/historic-step-for-greater-fairness-in-football>
- Jamil, M., Littman, P., & Beato, M. (2020). Investigating inter-league and inter-nation variations of key determinants for penalty success across European football. *International Journal of Performance Analysis in Sport*, 20(5), 892–907. <https://doi.org/10.1080/24748668.2020.1794720>
- Jordet, G., & Hartman, E. (2008). Avoidance motivation and choking under pressure in soccer penalty shootouts. *Journal of Sport and Exercise Psychology*, 30(4), 450–457. <https://doi.org/10.1123/jsep.30.4.450>
- Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review*, 93(5), 1449–1475. <https://doi.org/10.1257/000282803322655392>
- Koning, R., & Van Steen, L. (2021). Red cards (mis)carriage of justice? In R. Koning & S. Kesenne (Eds.), *A modern Guide to sports economics* (Ch. 18, pp. 269–280). Edward Elgar.
- Krumer, A. (2020). Pressure versus ability: Evidence from penalty shoot-outs between teams from different divisions. *Journal of Behavioral and Experimental Economics*, 89, 101578. <https://doi.org/10.1016/j.socec.2020.101578>
- Kubayi, A., Larkin, P., & Toriola, A. (2021). The impact of video assistant referee (VAR) on match performance variables at men's FIFA World Cup tournaments. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering & Technology*, 236(3), 187–191. <https://doi.org/10.1177/1754337121997581>
- Kuss, O., Kluttig, A., & Stoll, O. (2007). "The fouled player should not take the penalty himself": An empirical investigation of an old German football myth. *Journal of Sports Sciences*, 25(9), 963–967. PMID: 17497396. <https://doi.org/10.1080/02640410600944568>
- Lackner, M., & Sonnabend, H. (2021). Coping with advantageous inequity—field evidence from professional penalty kicking. *Journal of Behavioral and Experimental Economics*, 91(101678), 1–9. <https://doi.org/10.1016/j.socec.2021.101678>
- Lago-Peñas, C., Gómez, M. A., & Pollard, R. (2021). The effect of the video assistant referee on referee's decisions in the Spanish LaLiga. *International Journal of Sports Science & Coaching*, 16(3), 824–829. <https://doi.org/10.1177/1747954120980111>
- Lepschy, H., Wäsche, H., & Woll, A. (2020). Success factors in football: An analysis of the German Bundesliga. *International Journal of Performance Analysis in Sport*, 20(2), 150–164. <https://doi.org/10.1080/24748668.2020.1726157>
- Leveaux, R. (2010). Facilitating referee's decision making in sport via the application of technology. *Communications of the IBIMA*, 1–8. <https://doi.org/10.5171/2010.545333>
- Loewenstein, G. (1987). Anticipation and the valuation of delayed consumption. *The Economic Journal*, 97(387), 666–684. <https://doi.org/10.2307/2232929>
- Lopes, J. E., Araújo, D., Duarte, R., Davids, K., & Fernandes, O. (2012). Instructional constraints on movement and performance of players in the penalty kick. *International Journal of Performance Analysis in Sport*, 12(2), 331–345. <https://doi.org/10.1080/24748668.2012.11868602>
- Lopes, J. E., Jacobs, D. M., Travieso, D., & Araújo, D. (2014). Predicting the lateral direction of deceptive and non-deceptive penalty kicks in football from the kinematics of the kicker. *Human Movement Science*, 36, 199–216. <https://doi.org/10.1016/j.humov.2014.04.004>
- Mahoney, T. (2018). *Does Match Location and Status Affect the Success Rate of Penalty Kicks in the English Premier League?* [Ph. D. thesis]. University of Chichester.
- Palacios-Huerta, I. (2003). Professionals play minimax. *Review of Economic Studies*, 70(2), 395–415. <https://doi.org/10.1111/1467-937X.00249>
- Palacios-Huerta, I. (2023). Maradona plays Minimax. *Sports Economics Review*, 1, 100001. <https://doi.org/10.1016/j.serev.2022.100001>
- Palao, J. M., López-Montero, M., & López-Botella, M. (2010). Relación Entre eficacia, lateralidad y zona de lanzamiento del penalti en función del nivel de competición en fútbol. (relationship between efficacy, laterality of foot strike, and shot zone of the penalty in relation to competition level in soccer). *The International Journal of Sport Science*, 6(19), 154–165. <https://doi.org/10.5232/ricyde2010.01905>
- Peeters, T. (2018). Testing the wisdom of crowds in the field: Transfermarket valuations and international soccer results. *International Journal of Forecasting*, 34(1), 17–29. <https://doi.org/10.1016/j.ijforecast.2017.08.002>
- R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.
- Schwarz, W. (2011). Compensating tendencies in penalty kick decisions of referees in professional football: Evidence from the German Bundesliga 1963–2006. *Journal of Sports Sciences*, 29(5), 441–447. <https://doi.org/10.1080/02640414.2010.538711>
- Spitz, J., Wagemans, J., Memmert, D., Williams, A., & Helsen, W. (2020). Video assistant referees (VAR): The impact of technology on decision making in association football referees. *Journal of Sports Sciences*, 39(2), 147–153. <https://doi.org/10.1080/02640414.2020.1809163>
- Van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alterations of kick direction increase errors and reduce accuracy. *Journal of Sports Sciences*, 24(5), 467–477. <https://doi.org/10.1080/02640410500190841>
- Weber, A., De Bosscher, V., & Kempf, H. (2017). Positioning in Olympic Winter sports: Analysing national prioritisation of funding and success in eight nations. *European Sport Management Quarterly*, 18(1), 8–24. <https://doi.org/10.1080/16184742.2017.1336782>
- White, S., & O'Donoghue, P. (2013). Factors influencing penalty kick success in elite soccer. In H. Nunome, B. Drust, & B. Dawson (Eds.), *Science and Football VII: The Proceedings of the Seventh World Congress on Science and Football* (pp. 237–242). Routledge.
- Wilson, M. R., Wood, G., & Vine, S. J. (2009). Anxiety, attentional control, and performance impairment in penalty kicks. *Journal of Sport and Exercise Psychology*, 31(6), 761–775. <https://doi.org/10.1123/jsep.31.6.761>
- Wood, G., & Wilson, M. (2010). A moving goalkeeper distracts penalty takers and impairs shooting accuracy. *Journal of Sports Sciences*, 28(9), 937–946. <https://doi.org/10.1080/02640414.2010.495995>

Appendix

A Distribution of waiting times

In [Figure A1](#) we graph the survival distributions of the waiting time between the foul and the moment the penalty is taken, separately for cases of no VAR intervention and VAR-intervention. As expected, the waiting times in the case of VAR-intervention are longer. This is formally confirmed by a log-rank test that shows the distributions differ significantly ($p < 0.001$).

The longest waiting time, 518 seconds or more than 8minutes (!), and other atypical values have been checked using public sources. For this particular very long waiting time, see [Gazetta Dello Sport \(2019\)](#)). Virtually all of the high waiting times are caused by a video referee consultation. In the case of no VAR intervention, 50% of the penalties are taken within 62 seconds, and 75% are taken within 79 seconds. The corresponding quantiles for penalties given after a VAR intervention are 156 and 202 seconds respectively.

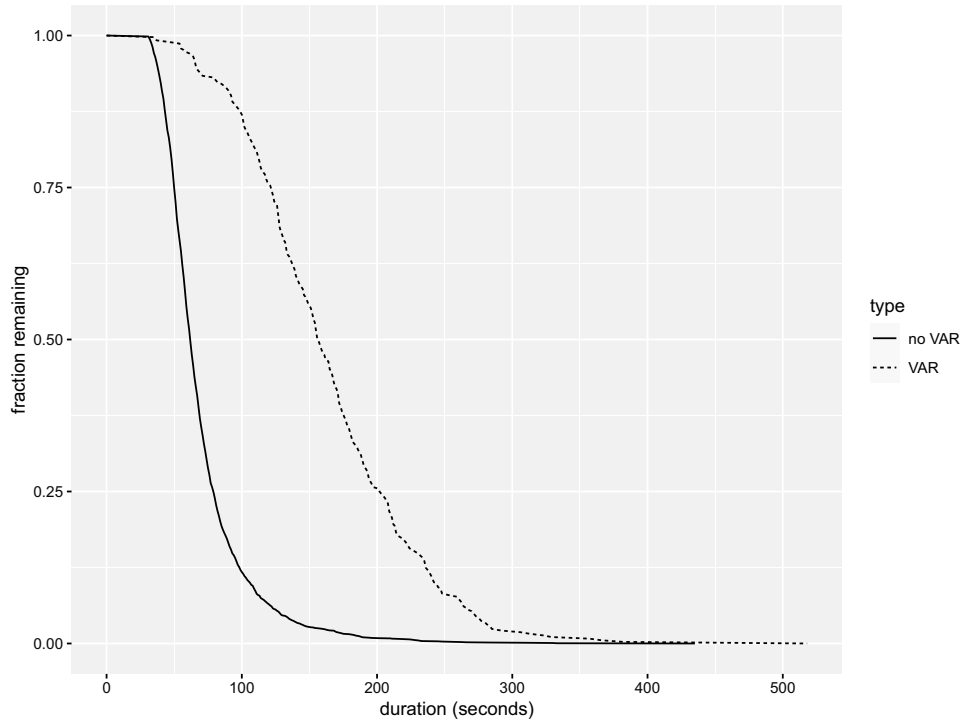


Figure A1. Kaplan-Meier survival curves of the time between the foul and the penalty, displayed separately for penalties without (solid line) and with (dotted line) a VAR event (data: gracernote Sports).