Goal Side Selection of Penalty Shots in Soccer:

A Laboratory Study and Analysis of Men's World Cup Shoot-Outs.

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Portions of this work have formed the basis of a poster presentation at the Fechner Day 2018 meeting of the International Society of Psychophysics. The raw data for Study I and Study II along with the R scripts used for data analyses are available from < https://github.com/GeoffPatching/Soccer >.

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Abstract

Penalty kicks in soccer provide a unique scenario to examine human choice behavior under competitive conditions. Here, two studies are reported examining the tendency for kickers to select the goal side with the largest area to the left or right of the goalkeeper's veridical midline, when the goalkeeper stands marginally off-center. In Study I participants viewed realistic images of a soccer goal and goalkeeper, and were instructed to choose the left or right side of the goalmouth to best score a goal. The goalkeeper's position was systematically displaced along the goal line and, to simulate changes in the viewing position of the kicker, the lateral position of the goalmouth was systematically displaced in each image. Overall, participants tended to choose the left over right goal side, but this depended on the goalkeeper's position relative to the center of the goal and jointly the lateral position of the goalmouth relative to participants' body midline. In Study II analysis of men's world cup shoot-outs again revealed a small tendency for kickers to aim the ball to the left goal side, but showed barely any effect of changes in the goalkeeper's position and no effect of changes in the kicker's position. In contrast to the earlier claims that a goalkeeper may benefit by standing marginally to the left or right of the center of the goal, to influence the direction of the kicker's shot, the present study suggests that this is probably not a good strategy in elite football competitions.

Keywords: Soccer, penalty kick, line bisection, landmark task, Bayesian modelling

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A Laboratory Study and Analysis of Men's World Cup Shoot-Outs.

The work reported in this article concerns goal side selection of penalty shots in a soccer related experimental task and in men's FIFA World Cup matches between 1982 and 2018. Inspiration for the present work derives from studies of the so-called 'off-center' effect in penalty kick scenarios – the tendency for penalty kickers to place the ball to the goal side with the greater area to the side of the goalkeeper, when the goalkeeper stands marginally off-center (Masters, van der Kamp, & Jackson, 2007; Memmert, Noel, Machlitt, van der Kamp, & Weigelt, 2020; Noël, van der Kamp, & Memmert, 2015; Noël, van der Kamp, Weigelt, & Memmert, 2015; Noël, van der Kamp, Masters, & Memmert, 2016; Weigelt & Memmert, 2012; Weigelt, Memmert, & Shack, 2012). Here, an aim is to extend understanding of penalty kickers' goal side selection in soccer by further examination of the influence of the goalkeeper's position and by simultaneous examination of the initial starting, and hence viewing, position of the kicker. To date there is a dearth of research examining the influence of the goalkeeper's position and simultaneously initial viewing position of kicker, on the kicker's goal side selection of penalty kicks. Yet, most kickers approach the ball at an angle that may in turn determine, or at least play a role in, goal side selection. As a result, goal side selection of penalty kicks in soccer as potentially influenced by the goalkeeper's position may also depend on the initial starting position of the kicker.

Penalty kicks are used in soccer for two reasons: (1) to determine the winner when the score is tied after regulation playing time, (2) as a punishment against a team that falls foul of certain rules during the game. Successful penalty kicks are often decisive about which team wins the game (Bar-Eli, Azar, Ritov, Keidar-Levin, & Schein, 2007), and so provide a unique setting by which to examine human choice behavior under competitive conditions (Avugos,

Azar, Sher, Gavish, & Bar-Eli, 2020; Chiappori, Levitt, & Groseclose, 2002). In a penalty kick, the kicker shoots a stationary ball from a penalty mark, aligned central to the goalmouth and located 36 ft (10.97 m) away from the goal line. Until the ball is kicked, the goalkeeper must stay on the goal line between the left and right goal posts, and no other players are allowed to intervene (IFAB, 2019/20).

The standard goalmouth dimensions in association soccer are 24 ft (7.32 m) wide and 8 ft (2.44 m) high, so the goalmouth area is 192 ft^2 (17.84 m^2). After Masters et al (2007), the goalkeeper's position before the ball is kicked is expressed in terms of the difference between the left and right goalmouth areas either side of the goalkeeper's veridical midline as a percentage of the total goal mouth area, $(Left_{area} - Right_{area}) / Total_{area} \times 100$. Likewise, the kicker's position is expressed as the percentage difference in the left minus right goalmouth areas either side of the kicker's body midline, before taking their run-up to kick the ball. In this respect, a -1% displacement of the player is equivalent to the player standing 3.4 cm to the left of the veridical center of the goalmouth on a regulation adult sized soccer pitch. Throughout the present paper, interpretation of the signed ± displacement of the goalkeeper's position and kicker's position from central is always from the kicker's perspective, which is necessarily in opposition (inverse) to the goalkeeper's perspective (what is right from the kicker's perspective is left from goalkeeper's perspective and vice versa).

From an analysis of penalty-kicks taken in elite soccer competitions Masters, et al., (2007) found that for 96% of the penalty kicks the goalkeeper was positioned slightly off-center, and for 59% of the shots the kicker aimed the ball to the goal side with the greatest area. These observations led Masters et al., to suggest that goalkeepers may obtain a small advantage in penalty kick situations by standing marginally to the left or right of the center of the goalmouth, to influence the direction of penalty kicks to the goal side with the greatest area and then strategically dive to the goal side with the greater area.

Subsequently, Masters, et al., (2007) report three experimental studies examining the possibility that minor displacements of the goalkeeper from central can influence the goal side selection of kickers' penalty shots in soccer. In the first experiment, participants viewed a rectangular outline on a computer screen, representing the goalmouth, with a small filled block on the 'goal-line' representing the goalkeeper (the rectangle was scaled to 3% of normal goal size). Given small displacements of the filled block from central, participants judged the side of goal with the greatest area. In the second experiment, the block was replaced with an image of Oliver Khan (renowned former German goalkeeper), and the goal and goalkeeper were projected onto a screen scaled to 44% of normal size. In this case, participants kicked a ball from a penalty spot to the side with the greater area. In both experiments, participants were able to discriminate goal side differences in area as small as 0.5%, which remained constant regardless of the scaling of the images. In the third experiment, instructions were to take a penalty kick only when the goalkeeper (i.e., Kahn) was standing in the center of the goal. Nonetheless, participants kicked the ball regardless of small displacements of the goalkeeper, and kicked the ball to the goal side with the largest area at above chance levels for differences in areas between ±1.6% and ±3%. This off-center effect has subsequently been found for penalty kicks taken against photo realistic images of a soccer goal and goalkeeper, and in trials with regular soccer players on adult sized soccer pitches (Memmert, et al., 2020; Noël, et al., 2015a, 2015b, 2016; Weigelt & Memmert, 2012; Weigelt, et al., 2012). Consequently, the off-center effect appears to be a reasonably stable phenomenon that occurs both on and off the soccer pitch.

Goal side selection of penalty kicks in soccer is widely considered analogous to the neuropsychological task of horizontal line bisection task, especially the landmark task of selecting which, left or right, segment of a pre-bisected line is longer (Masters, et al., 2007; Noël, et al., 2015b; Weigelt & Memmert, 2012, Weigelt, et al., 2012). Experimentally

displacing a bisection mark along a horizontal line, in small units from left to right of central, monotonically increases the probability of a left-side longer judgement, describing a classic sigmoidal function (Gökaydin, Brugger, & Loetscher, 2017; McCourt, & Olafson, 1997; Märker, Learmonth, Thut, & Harvey, 2019; Toraldo, McIntosh, Dijkerman, & Milner, 2004). From this sigmoidal function, it is possible to estimate the location of the bisection mark that predictively gives rise to an equal (50%) proportion of left and right longer judgments (McCourt, & Olafson, 1997; Märker, et al., 2019; Toraldo, et al., 2004); termed, point of subjectively equality (PSE). In the Landmark Task, neurologically healthy participants tend to make marginally more left, as compared to right, line longer judgements (Jewel & McCourt, 2000; McCourt, & Olafson, 1997; Milner, Brechmann, & Pagliarini, 1992; Thomas, Castine, Loetscher, & Nicholls, 2015). Therefore, the PSE is typically located just to the left of the exact center of the line, indicative of a tendency for participants to over-estimate the length of the left- as compared to right-line segment. Likewise, when asked to bisect a horizontal line into two equal parts neurologically healthy participants tend to misbisect the line placing their midline mark marginally to the left of true center, a phenomenon Bowers and Heilman (1980) termed pseudoneglect.

Penalty kickers (soccer players and soccer novices alike) also err in judging the central position of a goalkeeper (Masters, et al., 2007; Memmert, et al., 2020; Noël, et al., 2015a, 2015b, Noël, et al., 2016; Weigelt & Memmert, 2012; Weigelt, et al., 2012). When asked to position a goalkeeper in the center of the goalmouth, from a viewing distance behind the penalty spot, participants have been found to place the goalkeeper just to the right of center on most (62%) trials, and in the true veridical center of the goal on very few trials (< 3%) or not all (Noël, et al., 2015a, 2015b). In other soccer related tasks, in which participants have selected the goal side with the greatest area, the proportion of kicks to the goal side with the greatest area has been found to increase monotonically as the area to the side of the

goalkeeper is increased (Masters, et al., 2007; Memmert, et al., 2020; Weigelt & Memmert, 2012; Weigelt, et al., 2012). Noël, et al., (2015b) found a small tendency for participant to select the left side goal, but other studies (Memmert, et al., 2020; Weigelt & Memmert, 2012; Weigelt, et al., 2012) have shown a small tendency for participants to make more kicks to the right, as compared to left, goal side area. This variability in participants' tendency to select the left or right goal side fits with of studies of line bisection, in which the magnitude and direction of line bisection errors are known to be susceptible to individual differences (Benwell, Thut, Learmonth, Harvey, 2013; McCourt, & Olafson, 1997), and can vary with changes in viewing distance (Longo, Trippier, & Vagnoni, 2015; McCourt, & Garlinghouse, 2000; Nicholls, Beckman, & Churches, 2016; Rinaldia, et al., 2018).

Systematic asymmetries in line bisection are also known to vary with experimental manipulation of the egocentric spatial location of lines (Rinaldia, et al., 2018; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; Zago, et al., 2017). In general, the further leftward a horizontal line is placed relative to participant's body midline, the more leftward the bisection error, but this overestimation of the length of left line segments can cross over to become rightward as lines are presented further rightward in space (Bultitude & Davies, 2006; McCourt & Jewell, 1999; Mennemeier, Rapcsak, Pierce, & Vezey, 2001; Rinaldia, et al., 2018). Consequently, kickers' goal side selection of penalty shots in soccer may not only be related to the (off-center) position of the goalkeeper but also by the starting, and hence viewing, position of the kicker. To date the joint influence of both the goalkeeper's position and kicker's position on the kicker's goal side selection has been largely ignored in studies of the off-center effect in soccer.

Study I

The present study follows naturally on from the work of Masters et al. (2007; Memmert, et al., 2020; Noël, et al., 2015a, 2015b, Noël, et al., 2016; Weigelt & Memmert,

2012; Weigelt, et al., 2012). It set out to examine the joint effect of manipulating both the goalkeeper's position and kicker's viewing position, on the kicker's goal side selection of penalty shots in a soccer related experimental task. In line with Weigelt and Memmert (2012; Weigelt, et al., 2012), participants were presented with photo realistic images of a goal and goalkeeper, here scaled to 2% of real size. The goalkeeper was presented at 7 different locations along the goal line from -5% left to +5% right in small units of about 1.65% (there are some small rounding errors of no concern). To mimic changes in the kicker's viewing position participants were aligned centrally to the computer monitor and the goalmouth was presented at 7 different displacements relative to the center of the computer monitor from -5% left to +5% right in units of 1.65%.

In line with real soccer matches, participants were instructed to choose the (left or right) goal side to best score a goal. This contrasts with studies of the off-center effect that have instructed participants to select the goal side with the greatest area (Masters et al., 2007; Memmert, et al., 2020; Weigelt & Memmert, 2012; Weigelt, et al., 2012), and with studies using the Landmark task in which participants are instructed to select the longer (or shorter) line segment (see Jewell & McCourt, 2000, for a review). Nonetheless, our prediction was that the proportion of left goal side selections would rise monotonically as the position of the goalkeeper was moved from left-to-right along the goal-line, and systematically depend on the joint position of both the goalkeeper and kicker. Regressing participants' binary goal side selections on the goalkeeper's position and kicker's position, relative to the veridical center of the goalmouth, will then reveal the precise extent to which both the goalkeeper's position and kicker's viewing position influence participants' goal side selection in this soccer related experimental task. It was also of interest to assess participants' response times (RTs). Using the Landmark task, McCourt and Olafson (1997) found close agreement between RT and binary response probability and, on the basis of earlier research (Patching, Englund, &

Hellström, 2012), RT expressed in terms of signed response speed (*SRS*) is hypothesized to show a close relationship to binary response probability, *P,* expressed in terms of logit *P*. Further empirical evidence of a close relationship between response probability and RT in the present soccer related task promises to provide increased credence for the view that both response probability and RT may be used in similar fashion to scale systematic patterns of asymmetries obtained with the Landmark task (McCourt & Olafson, 1997), and psychophysical method of paired stimulus comparison (Patching et al., 2012).

One approach employed in modelling psychometric functions is to fit individual curves to each participant's data and then perform statistical analysis on the extracted parameters (McCourt & Olafson, 1997; Patching et al., 2012; Toraldo, et al., 2004). An alternative to this two stage approach is to use Bayesian hierarchical modelling. Bayesian hierarchical modelling is advantageous to the classic two stage approach because it permits modelling all of the data and all of the parameters in one step rather than two (Moscatelli, Mezzetti, & Lacquaniti, 2012). After a hierarchical Bayesian model has been fitted the estimated parameters can be investigated in many ways. The estimated parameters for each participant can be examined or the parameters can be examined for the group of participants as a whole, depending on where interest lies. All parameter estimates provide for reliability measures in the form of credible intervals (CIs), here determined by the 95% highest probability density interval of each parameter estimate (after Kruschke, 2014; McElreath, 2020).

Methods

Participants. Forty participants recruited from Lund University's student population, 11 women and 29 men aged between 20 and 50 years ($M \pm SD = 26.6 \pm 5.9$ years), took part in the experiment. All participants claimed to be right-handed, and all participants reported normal or corrected to normal vision. All but 3 participants claimed to be right-footed. None of the participants played soccer on a regular basis.

Apparatus. A microcomputer (Fujitso Lifebook Series 5) running MATLAB (The MathWorks, Inc.) was used to run the experiment. Stimulus presentation and timing were controlled using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). The pixel resolution of the video monitor was 1366 x 768 with a refresh rate of 60 Hz. Participants responded using the two vertical arrow keys marked with red and green stickers, positioned at the bottom right of the microcomputer's standard QUERTY, keyboard. For goal side selection, participants used the index finger of their right hand to press the down arrow key, and the forefinger of their right hand to press the upper arrow key.

Stimuli. The stimuli consisted of 16 images each representing a unique condition characterized by different combinations of goalkeeper and goalmouth displacements. The goalkeeper was presented at 7 different locations relative to the center of the goal, from -3.40 mm (left) to 3.40 mm (right) in 6 steps of 1.13 mm. In addition, the goal mouth was presented at 7 different positions relative to the center of the computer monitor, from -3.40 mm (left) to 3.40 mm (right) in 6 steps of 1.13 mm. Each image was 185 x 156 mm in size. The goalmouth dimensions depicted in the images was 140 x 49 mm (0.0069 m^2), which is 0.04% of the total area of original sized goals used in association football [7.32 m x 2.44 m (17.86 m^2)]. The goalkeeper's height was 40 mm [approximately 2% of Manuel Neuer's real height (1.93m)], and the distance between the goal line and the penalty spot (were the ball was shown) was scaled to 0.3% (0.03m) of real playing distance (11m). Figure 1 shows 4 representative images.

Figure 1 about here

Design. Figure 2 illustrates the factorial combination of the goalkeeper's positions and goalmouth displacements used in the Experiment. After Hellström (1978; Patching et al.,

2012) the 7 goalkeeper positions and 7 goalmouth displacements were combined factorially about their mean position, and difference of position, to create 16 different stimuli in a diamond-shaped arrangement.

Figure 2 about here

The experiment consisted of 2 sections (practice and experimental), with no break between the 2 sections. The first 32 trials, in which each stimulus was presented twice in pseudorandom order, were deemed practice trials. Following the practice trials, participants completed a further 256 experimental trials in which all the stimuli were presented 16 times in pseudo randomized cycles of 64 trials. The stimuli were presented in new pseudorandom orders for each participant.

Twenty participants were instructed to indicate right goal side selection by pressing the up-arrow key with the forefinger of their right hand and left goal side selection by pressing the down-arrow key with the index finger of their right hand. The other 20 participants were instructed to indicate right goal side selection by pressing the down-arrow key with the index finger of their right hand and left goal side selection by pressing the upper-arrow key with the forefinger of their right hand. Participants were seated comfortably, aligned centrally to the computer monitor at arm's length (~57 cm). In this manner, the goalmouth displacements relative to the center of the computer monitor mirror changes in the participant's egocentric viewing position of the goalmouth.

Procedure. At the start of the experiment, participants were presented with written instructions on the computer monitor. From the kicker's perspective, participants were instructed to decide, as quickly as possible, the best side of the goal (left or right) to place the ball to score a goal. Participants were required to indicate that they had understood the

instructions by pressing one of the response keys to start the experimental session. On each trial, each image was presented until the participant made a goal side selection either by pressing the up-arrow key or down-arrow key. RT was measured from stimulus onset until the participant made a response. The inter-trial-interval was set at a random duration from 1000 to 3000 ms. On the average, participants took 30 minutes to complete the experiment.

The present experiment was carried out in accordance with the rules and regulations laid down by the Ethics Committee for the Swedish Research Council. All participants gave written informed consent in accordance with the Declaration of Helsinki.

Data analyses. On initial inspection of the data, one participant was removed from the dataset because they consistently chose the left goal side over all the experimental trials. Thereafter, all responses less than 100 ms were considered as anticipations, and all responses greater than 2000 ms were considered to be feinting responses. Feinting is said to occur in soccer when a penalty kicker delays taking the penalty shot after being signaled by the referee to proceed, in attempt to mislead the goalkeeper. 10.46% of responses were classified as feinting and 0.23% of responses classified as anticipations, and were removed from all further analysis.

To examine relations between binary goal side selection and the speed of participant's choice responses, participants' binary choices were expressed in terms of the log odds ratio of response probability (P) = logit $P = \log_e[P_{left} / (1 - P_{left})]$, separately for each of the 16 conditions, over all participants. On this basis, a negative effect indicates a greater proportion of right over left goal side selections, and a positive effect a greater proportion of left over right goal side selections. Then, following procedures described by Patching et al. (2012), RT was expressed in terms of signed response speed (*SRS*) calculated as 1/RT (in seconds) for a left goal side selection, and -1/RT for a right goal side selection. Subsequently, logit P was

regressed on *SRS*, by way of the following Bayesian linear model with reasonably weak priors,

Logit $P \sim \text{Normal}(\mu_i, \sigma)$	[likelihood]
$\mu_i = b_0 + b_1 SRS_i$	[linear model]
$(b_0, b_1) \sim \text{Normal}(0, 10)$	[constant and slope prior]
$\sigma \sim \text{Uniform}(0, 10)$	[sigma prior].

In line with earlier research (McCourt & Olafson, 1997; Patching et al., 2012), this analysis revealed a close relationship between logit *P* and *SRS*.

To examine the influence of changes in the goalkeeper's position and goalmouth displacements, participant's binary goal side selections, and separately *SRS,* were regressed linearly on the goalkeeper's positions, relative to the center of the goalmouth, and goalmouth location, relative to participant's body midline. The relative influence of the goalkeeper's position and kicker's position on each participant's binary goal side selection (GS_{01}) is captured by way of a simple linear equation in which the goalkeeper's position (*keeper*) and kicker's position (*kicker*) are multiplied by a weighting (b_1 and b_2), the products subtracted and a constant (b_0) added. Participants were entered with their own intercepts as well as by-participant slopes for the effects of the goalkeeper's position and kicker's position. This hierarchical linear model was formulated as follows,

$GS_{01} \sim \text{Bernoulli}(p)$	[likelihood]
$\text{logit}(p) = b_{0[\text{subj}[i]]} + b_{1[\text{subj}[i]]} Keeper_j - b_{2[\text{subj}[i]]} Kicker_j$	[linear model]
$(b_{0\text{subj}[i]}, b_{1\text{subj}[i]}, b_{2\text{subj}[i]}) \sim \text{Normal}(\mu, \sigma)$	[b_0, b_1, b_2, priors]
$(b_0\mu, b_1\mu, b_2\mu) \sim \text{Normal}(0, 1)$	[μ prior]

$(b_0\sigma, b_1\sigma, b_2\sigma) \sim \text{HalfCauchy}(0, 1)$ [σ prior]

Separately, the same hierarchical model was used to regress *SRS* on the goalkeeper's position and kicker's position, with the exception that *SRS* was assumed to follow a normal distribution with parameters μ and σ

$SRS \sim \text{Normal}(\mu, \sigma)$ [likelihood]

$\mu = b_{0[subj[i]]} + b_{1[subj[i]]}Keeper_i - b_{2[subj[i]]}Kicker_i$ [linear model]

$\sigma \sim \text{HalfCauchy}(0, 1)$ [σ prior].

This analysis revealed a similar pattern of results for both logit *P* and *SRS.* Overall, participants tended to make more and faster left as compared to right side goal selections. However, for both logit *P* and *SRS,* this overall tendency toward left as compared to right goal side selections is modulated by both the goalkeeper's position and kicker's position. Inclusion of the experimental variable 'response assignment' failed to improve model fit for logit *P* [WAIC = 9484.5 (SE = 88.93) vs. 9484.3 (88.89), respectively] or *SRS* [WAIC = 33641.4 (167.44) vs. 33641.3 (167.42), respectively], and so this variable is not included in any of the analysis reported in the present paper.

To examine the joint effect of changes in the goalkeeper's position and kicker's position, participants' binary goal side choices, and separately *SRS*, were regressed on the difference between the goalkeeper's position and kicker's position [$(Keeper_j - Kicker_j) / 2$] and on and the joint sum of their positions [$(Keeper_j + Kicker_j) / 2$]. Participants were entered with their own intercepts as well as by-participant slopes for each effect, by way of the following linear model for binary goal side selection,

$$GS_{01} \sim \text{Bernoulli}(p_i) \quad \text{[likelihood]}$$

$$\text{logit}\,(p_i) = b_{0[subj[i]]} + b_{1[subj[i]]}(Keeper_j - Kicker_j) / 2 + b_{2[subj[i]]}(Keeper_j + Kicker_j) / 2 \quad \text{[linear model]}$$

$$(b_{0subj[i]}, b_{1subj[i]}, b_{2subj[i]}) \sim \text{Normal}(\mu, \sigma) \quad [b_0, b_1, b_2, \text{priors}]$$

$$(b_0\mu, b_1\mu, b_2\mu) \sim \text{Normal}(0, 1) \quad [\mu \text{ hyper prior}]$$

$$(b_0\sigma, b_1\sigma, b_2\sigma) \sim \text{HalfCauchy}(0, 1) \quad [\sigma \text{ hyper prior}]$$

The same model was applied to examine the joint effects of changes in the goalkeeper's position and kicker's position on *SRS*, with the exception that *SRS* was assumed to follow a normal distribution with parameters μ and σ

$$SRS \sim \text{Normal}\,(\mu, \sigma) \quad \text{[likelihood]}$$

$$SRS = b_{0[subj[i]]} + b_{1[subj[i]]}(Keeper_j - Kicker_j) / 2 + b_{2[subj[i]]}(Keeper_j + Kicker_j) / 2 \quad \text{[linear model]}$$

$$\sigma \sim \text{HalfCauchy}(0, 1) \quad [\sigma \text{ prior}].$$

This analysis shows that participants' tendency to choose the left-goal side became increasingly rightward as the position of the goalkeeper shifted leftward and the position of the kicker rightward. Moreover, participants' increasingly selected the left goal side as the joint average position of the goalkeeper and kicker became more rightward. The indication is, therefore, that participants' binary goal side selections and speed of responses depends on the relative positioning of the 2 soccer players.

All data analyses were conducted using R (R Core Team, 2020) and Stan (Carpenter, et al., 2017, Stan Development Team, 2018), along with the 'rethinking' package (McElreath, 2020) and other utilities provided by the 'psych' package (Revelle, 2019). All posterior

distributions are based on 2000 warmup steps, and 3000 sampled steps, for each of 3 independent chains, which showed little autocorrelation. Good convergence obtained between the multiple chains as tested with the $\hat{R}$ statistic (Gelman, et al., 2013), which was found to be less than 1.01 in every case. The resulting Hamilton Monte Carlo samples are therefore highly representative of the underlying posterior distributions. Extensive sensitivity analysis using different priors made no difference to interpretation of the results obtained.

Results

Figure 3 shows the linear relationship between mean *SRS* and logit *P*, as fit by Bayesian regression over the 16 different stimulus conditions, b_0 = -0.02, b_1 = 1.46, 95% CIs [-0.07, 0.02] and [1.31, 1.59], respectively.

Figure 3 about here

For logistic regression of binary responses on the goalkeeper's position and kicker's position group level mean estimates of the coefficients are b_0 = 0.24, $b_{1\text{keeper}}$ = 0.24, $b_{2\text{kicker}}$ = 0.07, 95% CIs [-0.13, 0.60], [0.13, 0,36], and [-0.01, 0.14], respectively. For standard linear regression of *SRS* on the goalkeeper's position and kicker's mean group level estimates of the coefficients are b_0 = 0.10, $b_{1\text{keeper}}$ = 0.10, $b_{2\text{kicker}}$ = 0.04, 95% CIs [-0.01, 0.30], [0.06, 0.15], and [0.01, 0.07], respectively. Figure 4 shows so called counterfactual plots (after McElreath, 2020) of predicted group level estimates of the percentage of left goal side selections, and separately *SRS*, given changes in the goalkeeper's position, and given changes in the kickers' position, while holding the kicker's position at a constant central position (top 2 panels), and holding the goalkeeper's position central (bottom 2 panels). These plots are said to be counterfactual because they represent predictions from the repression equations based on, but not necessarily observed in, the experimental task.

Figure 4 about here

For logistic regression of binary responses on the relative joint positions of the goalkeeper and kicker, group level mean estimates of the coefficients are $b_0 = 0.24$, $b_{1(Keeper - Kicker) / 2} = 0.31$, $b_{2(Keeper + Kicker) / 2} = 0.18$, 95% CIs [-0.13, 0.61], [0.16, 0.46], and [0.06, 0.29], respectively. Separately, for *SRS* by way of standard linear regression $b_0 = 0.10$, $b_{1(Keeper - Kicker) / 2} = 0.15$, $b_{2(Keeper + Kicker) / 2} = 0.06$, 95% CIs [-0.10, 0.29], CI [0.08, 0.21], and CI [0.01, 0.11], respectively. Figure 5 shows counterfactual plots of predicted group level estimates of the percentage of left goal side selections, and separately *SRS*, given changes in the relative difference between the goalkeeper's position and kicker's position, and given changes in the average position of the goalkeeper's and kicker's position, holding their average position at a constant central position (top 2 panels), and holding their difference in position constant (bottom 2 panels).

Figure 5 about here

Discussion

The present study examined the binary goal side selection, and signed speed, of penalty shots in a soccer related experimental task given small changes in the lateral position of the goal keeper and egocentric viewing position of the kicker (i.e., participant) relative the veridical center of the goal mouth. To this end both the lateral position of the goalkeeper and position of the kicker were jointly manipulated in a semi-factorial design.

The data show a close relationship between binary goal side selection, expressed as logit *P,* and *SRS*. Therefore, it appears that both logit *P* and *SRS* are sensitive to changes in

the lateral positions of the goalkeeper and kicker and can be used, equivalently, to scale goal side selection as a function of the 2 players' positioning. This conforms to earlier research (Patching, et al., 2012) that has shown a close relationship between logit *P* and *SRS* in binary choice tasks, and suggests that *SRS* may be used as a supplementary measure to shed light on potential mechanisms of attention underlying systematic asymmetries in comparison of paired stimulus magnitudes.

Overall, participants' tended to choose the left over right goal side, but this did depend on the goalkeeper's lateral position and, to lesser extent, kicker's egocentric viewing position. Participants' tendency to choose the left over right goal side became increasingly rightward as the position of the goalkeeper shifted leftward and the position of the kicker rightward. Moreover, participants' increasingly selected the left goal side as the average position of the goalkeeper and kicker became more rightward. The indication is that participants' binary goal side selections and speed of goal side selections depended on the relative positioning of the 2 soccer players.

In line with studies of the Landmark task (Gökaydin, Brugger, & Loetscher, 2017; McCourt & Olafson, 1997; Märker, Learmonth, Thut, & Harvey, 2019; Toraldo, McIntosh, Dijkerman, & Milner, 2004), the probability of selecting the left goal side increased monotonically as the goalkeeper was moved from left to right along the goal-line, and by inference shows the PSE to be located just to the left of true center. On this basis, the present experimental study suggests that participants tended to overestimate the area to the left, as compared to right, of the goalkeeper's veridical midline. Consequently, in analogy with studies of line bisection, in which neurologically healthy participants typically overestimate the length of left as compared to right line lengths (Jewel & McCourt, 2000), the present findings suggest that small leftward, displacements of the goalkeeper from central may

actually put the goalkeeper at a disadvantage by increasing the likelihood of kickers equally, and randomly, choosing either goal side to shot the ball.

The findings of the present study are in line with results obtained in studies using the Landmark Task (e.g., McCourt & Olafson, 1997), but the precise extent to which insights from the present experimental work extend to penalty shots in elite soccer matches remains unclear. The present experimental work did not incorporate a team based competitive element which is a fundamental aspect of professional soccer matches, and none of the participants were experienced soccer players. On this basis, it is pertinent to analyze penalty kicks taken in men's FIFA World Cup matches in order to provide further insights about the goal side selection of penalty shots in soccer.

Study II

Beyond the work of Masters et al. (2007), who merely report the proportion of penalty shots to the goal side with the greatest area, detailed archival research has yet to be conducted examining the kicker's goal side placement of the ball in relation to the goalkeeper's position and in relation to the kicker's starting position in elite soccer competitions. On these grounds, Study II set-out to examine penalty shots made by professional soccer players under competitive conditions, and in particular goal side placement of the ball in relation to the position of the goalkeeper (relative to the center of the goal), and initial starting position of the kicker (relative to the center of the goal). Other descriptive aspects of the penalty shots are summarized for general interest.

The data. All analyses are based on video footage of 30 FIFA Men's World Cup penalty shoot outs (i.e., kicks from the penalty mark taken when one team must be awarded victory and the score is tied after regulation playing time) from 1982 to 2018, obtained freely from FIFA online video archives < www.fifa.com >. Video footage of the penalty shots used for the present analysis include, (1) those showing both the kicker and goalkeeper at their

respective starting positions, (2) images displaying the moment in which the ball crossed the goalmouth line, (3) whether the penalty shot resulted in a goal or not. Video footage shot from a perspective that did not allow for measurement of the goalkeeper's starting position and kicker's initial position was excluded from analysis. On this basis, one hundred penalty kicks were selected for analysis.

For measurement of the starting position of the goalkeeper's position and kicker's position, individual video frames were extracted at a rate of 60 per second using the free and open source VL media player (VideoLAN organization, France). Each image was scaled to a pixel resolution of 1250 x 927 on a Hewllet Packard 450 G5 Notebook PC (Hewlett Packard Enterprise, USA), with a 39.6 cm (15.6 in) diagonal screen with an active area of 344.2 x 193.5 mm. The pixel resolution of the video monitor was 1366 x 768, and so the viewable size of each image on the computer screen was 315 x 233.6 mm.

Measurement. All measurements were done manually by placing gridlines over each image using the ruler facilities provided by Microsoft PowerPoint (Microsoft Corporation, 2016). Measurements of interest were the goalkeeper's initial displacement relative the center of the goal (veridical center of the goalkeeper to the veridical center of the goalmouth), kicker's starting position relative to the center of the goal (veridical center of the kicker relative to the veridical center of the goalmouth), and for scaling purpose the goalmouth width represented in each image. All measurements were taken in millimeters, converted to centimeters and subsequently scaled to real size goal dimensions. Other aspects of interest were the foot used by the kicker to take the penalty shot, whether the goalkeeper dived to the left or right, and whether the penalty shot resulted in a goal or not.

Data analysis. Overall, 76% of the penalty shots resulted in a goal. The goalkeeper's starting position was to the right of the center of the goalmouth on 62% of the penalty shots and the goalkeeper's dived to the left on 54% of the penalty shots. The kicker's starting

position was to the left of the ball 77% of the time. The kickers directed the ball to the goal side with the greatest area to the side of the keeper on 51% of the penalty shots. On 76% of the penalty shots the kicker took the penalty shot with their right foot and only 1 occasion occurred in which the kicker took the penalty shot using the foot corresponding to their starting position – in this case the kicker started their run up to the ball standing to their left of the ball and used their left foot to kick the ball. On 55% of the penalty shots the kicker kicked the ball to the left side of the goal mouth, but the goalkeeper dived to the opposing side of the kicker's ball placement 47% of the time (i.e., the kicker kicked the ball to the right or left of the goalkeeper and the goalkeeper dived to left or right, respectively).

To examine relations between kickers' goal side selection, position of the goalkeeper (relative to the center of the goal), and starting position of the kicker (relative to the center of the goal), each left or right goal side placed penalty shot ($GS_{01;}$ coded 1 = left, 0 = right) was regressed linearly on the goalkeeper's position and kicker's position by way of the following linear model. In this case each kicker made only one penalty shoot and so a hierarchical modelling approach is ruled out, but otherwise this analysis follows the same procedures as described in Study I,

$$GS_{01} \sim \text{Bernoulli}(p) \qquad \text{[likelihood]}$$

$$\text{logit}\,(p) = b_0 + b_1 Keeper_{\text{j}} + b_2 Kicker_{\text{j}} \qquad \text{[linear model]}$$

$$(b_{0,}\, b_{1,}\, b_2) \sim \text{Normal}(0,\, 1) \qquad \text{[intercept and slope priors]}$$

This analysis shows a very small, and considerably variable, effect of the goalkeeper's position on the kicker's goal side ball placement. No relation was found between the kicker's initial starting position and their subsequent goal side placement of the ball.

Following the procedures detailed in Study I, joint effects of the goalkeeper's position and kicker's position on goal side selection were examined by regressing each goal side selection on the difference between the goalkeeper's position and kicker's position [($Keeper_j$ - $Kicker_j$) / 2] and on the joint sum of their positions [($Keeper_j$ + $Kicker_j$) / 2].

$$GS_{01} \sim \text{Bernoulli}(p) \qquad \text{[likelihood]}$$

$$\text{logit}(p) = b_0 + b_1 (Keeper_j - Kicker_j) / 2 + b_2 (Keeper_j + Kicker_j) / 2 \qquad \text{[linear model]}$$

$$(b_0, b_1, b_2) \sim \text{Normal}(0, 1) \qquad \text{[intercept and slope priors]}$$

This analysis shows a very small but increasing tendency for professional male footballers to shoot the ball to the left goal side as the goalkeeper stands further to the right of the veridical center of the goalmouth and the kicker initially stands at a position increasingly left of the ball. Moreover, the kickers' tended to kick the ball more often to the left of the veridical center of the goalmouth as the joint average position of both players became increasingly rightward. In line with Study 1, the indication is that the kickers' goal side selection is related to the relative positioning of the 2 soccer players. However, in analysis of these world cup penalty shots, the joint effects of the goalkeeper's position and kicker's position are very small and unreliable.

Exactly, the same procedures were used to fit the models in Study II as described in Study I. All HMC chains showed good convergence, and extensive sensitivity analysis using different priors made no difference to interpretation of the final results obtained.

Results

Figure 6 shows histograms of the frequency (out of 100) of the goalkeeper's position and kicker's position. On the mean average, the goalkeeper tended to stand to the right of the

center of the goalmouth ($M \pm SD = 1.49 \pm 4.1\%$), and the kicker's starting position was most often to the left of the ball, ($M \pm SD = -21.02 \pm 47.1\%$).

Figure 6 about here

For logistic regression of goal side placement on the goalkeeper's position and kicker's position mean group level estimates of the coefficients are $b_0 = 0.13$, $b_{1\text{Keeper}} = 0.02$, $b_{2\text{Kicker}} = 0.00$, 95% CIs [-0.32, 0.56], [-0.08, 0.11], and [-0.01, 0.01], respectively. Figure 7 shows counterfactual plots of predicted estimates of the percentage of left goal side shots, given changes in the goalkeeper's position, and given changes in the kickers' position, while holding the kicker's position at a constant central position (left panel), and holding the goalkeeper's position central (right panel).

Figure 7 about here

For logistic regression of binary responses on the relative joint positions of the goalkeeper and kicker group level mean estimates of the coefficients are $b_0 = 0.12$, $b_{1(Keeper - Kicker) / 2} = 0.02$, $b_{2(Keeper + Kicker) / 2} = 0.02$, 95% CIs [-0.33, 0.56], [-0.08, 0.12], and [-0.08, 0.11], respectively. Figure 8 shows counterfactual plots of the estimated percentage of left goal side shots, given changes in the relative difference between the goalkeeper's position and kicker's position, and given changes in the sum of the goalkeeper's and kicker's positions, holding joint average positions at a constant value $Keeper_j + Kicker_j = 0$ (left panel), and holding their difference in position constant $Keeper_j - Kicker_j = 0$ (right panel).

Figure 8 about here

Discussion

Study II examines kickers' goal side selection of penalty shoot-outs in FIFA World Cup soccer matches. In line with Study I the data shows a small tendency for kickers to shot the ball to the left goal side more often than the right goal side. This leftward tendency conforms to earlier analysis of elite football competitions in which kickers have similarly been found to direct their penalty shots more often to the left than right goal side (Bar-Eli & Azar, 2009; Price & Wolfers, 2014; Roskes, Sligte, Shalvi, & De Dreu, 2011). However, as mirrored in the wide credible intervals obtained in the present analysis, and as reported by others (e.g., Avugos et al., 2020), this tendency for kickers to shoot the ball to the left is highly variable and may crossover to become rightward.

Regarding the off-center effect in soccer, the present analysis shows that kickers tend to select the left, as compared to right, goal side increasingly more often as the goalkeeper is increasingly positioned to the right of the true center veridical center of the goalmouth. This fits with Study I, but in contrast to Study I the present analysis shows this off-center effect to be very small and highly variable, and no main effect of changes in the kicker's position obtained. Moreover, joint effects of changes in both the goalkeeper's and kicker's position, on the kicker's goal side selection where similarly found to be very small and highly variable. In all, the present study suggests that kickers' goal side selection of penalty shots in world cup matches, is barely influenced by small displacements of the goalkeeper from central, not influenced by the kicker's starting position, and only vaguely influenced by the joint position of both the goalkeeper and kicker. In the present analysis, all effects were found to be small and considerably variable, and strikingly smaller and more variable than those found under the controlled conditions of Study I with naive participants.

General discussion

The present study set out to investigate the off-center effect in soccer (after Masters et al., 2007), especially kickers' goal side selection of penalty shots given changes in the goalkeeper's position and kicker's initial starting position. In Study I participants selected the, left versus right, goal side by which to best score a goal, and both the position of the goalkeeper and kicker were systematically displaced from central in semi-factorial combination. Overall, the findings obtained in Study I conform to those obtained in studies of line bisection, especially the Landmark Task. In studies of line bisection neurological healthy participants typically show a small tendency to bisect lines to the left of center (Jewel & McCourt, 2000; Milner, et al., 1992), increasingly judge the left, as comparted to right, segment of bisected lines as longer as the transection mark is moved from left to right of central (Gökaydin, et al., 2017; McCourt & Olafson, 1997; Märker, et al., 2019; Toraldo, et al., 2004) and, with increasing displacement of lines from participant's body midline, increasingly bisect lines to the side corresponding to their egocentric viewing position (Bultitude & Davies, 2006; McCourt & Jewell, 1999; Mennemeier, et al., 2001; Reuter-Lorenz, et al., 1990; Rinaldia, et al., 2018; Zago, et al., 2017).

Study II builds on Study I by examining the influence of the goalkeeper's position and kicker's position on kicker's goal side selection in world cup shoot-outs. In line with earlier analysis (Bar-Eli & Azar, 2009; Price & Wolfers, 2014; Roskes, Sligte, Shalvi, & De Dreu, 2011), Study II revealed a tendency for kickers to start their run-up to the ball from their left and showed a slight tendency for kickers to shoot the ball the left goal side. In terms of the biomechanics of kicking, most soccer players find it easier to use the inside of their left or right dominant foot to kick the ball to their right or left, respectively (Chiappori, Levitt & Groseclose, 2002; Palacios-Huerta, 2003), but beyond the biomechanics of kicking, perceptual and cognitive factors may also play a role in the goal side selection of kickers. In contrast to the tendency to choose the left goal side as found in the present study, Noël, et al.,

(2015a; 2015b) found a tendency for participants to position the goalkeeper just to the right of central when instructed to position the goalkeeper centrally, and although Noël, et al., (2015a; 2015b) found a slight tendency for kicker's to aim the ball to the left goal side, others (Memmert, et al., 2020; Weigelt & Memmert, 2012; Weigelt, et al., 2012) have found a small tendency for participants to select the right goal side when taking penalty shots. Overall, this variability in goal side selection in studies of the off-center effect in soccer mirrors that found in studies of line bisection in which both the magnitude and direction of line bisection errors are known to be highly susceptible to individual differences and highly variable with manipulation of perceptual aspects of the lines, such as viewing distance and spatial location of the lines (Jewel & McCourt, 2000; McCourt & Olafson, 1997). Various accounts of systematic asymmetries in line bisection exist, mostly based on notions of attention and localization of function in the human brain (see Nicholls & Roberts, 2002; Bultitude & Davies, 2006; Zago, et al., 2017; for reviews), but precisely what perceptual / cognitive mechanisms underlie systematic asymmetries in line bisection remain poorly understood. Weighting analysis of line bisection errors (McIntosh, Schindler, Birchall, & Milner, 2005; McIntosh, Ietswaart, & Milner, 2017), and other weighting models developed in psychophysics to account for the over- or underestimation of one stimulus magnitude as compared to another, such as Hellström's Sensation Weighting Model (Hellström, 1979, 2000; see Hellström, Patching, & Rammansayer, 2020, for a recent review of this research), seemingly have potential to advance theoretical understanding in the area.

Regarding the off-center effect in soccer, the findings of Study I like earlier studies (Masters, et al., 2007; Memmert, et al., 2020; Noël, et al., 2015a, 2015b, Noël, et al., 2016; Weigelt & Memmert, 2012; Weigelt, et al., 2012) shows tendency for penalty kickers to place the ball to the goal side with the greater area when the goalkeeper stands marginally off-center, and goes further by showing an effect of the kicker's viewing position on participants'

goal side selection. On the basis that kickers tend to select the goal side with the greatest area, Masters et al. (2007; Memmert, et al., 2020; Noël, et al., 2015a, 2015b, Noël, et al., 2016; Weigelt & Memmert, 2012; Weigelt, et al., 2012) suggested that goalkeepers may gain an advantage in penalty kick situations by standing marginally off-center to influence the goal side selection of kickers. On the basis of the present work, however, and in analogy with studies of line bisection, a goalkeeper positioned marginally to the left or right of the center of the goalmouth may actually lead to kickers' more equally, and randomly, shooting the ball to the left or right goal side, and so reduce the predictability of kicker's goal side selection of penalty kicks in soccer.

Study II shows the off-center to be barely existent and highly variable in the world cup penalty shoots examined in the present study. Further research analyzing the behavior of goalkeepers and kickers in elite football competitions is required to corroborate the findings of the present study. But, on the basis of the results obtained, soccer related experimental tasks conducted under controlled conditions do not necessarily reflect the behavior of skilled players' in elite soccer matches. In elite soccer games the penalty kick pits the will of two highly skilled players against each other who both trying to outwit their each other, whereas neurological studies of line bisection typically lack any competitive element. So, while neuropsychological studies of line bisection seemingly have potential to inform about the behavior of soccer players, and while experimental studies of penalty kick scenarios seemingly have potential to inform studies of visual neglect, the two scenarios are very different and great care is required in extrapolating results from carefully controlled experimental studies to the heat of elite soccer competitions.

Conclusion

Under controlled conditions, the off-center effect in soccer appears to yield results comparable to those obtained in studies of line bisection, especially the Landmark Task.

However, the present study shows that results obtained in an experimental soccer related task do not extrapolate well to the behavior of highly skilled goalkeepers and kickers in men's world cup matches. Consequently, great care should be exercised when making bench side recommendations about to the behavior of skilled soccer players on the basis of controlled experimental tasks.

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Figure captions

Figure 1. Example of 4 penalty shootout scenarios used in the Experiment. In all conditions, a picture of German goalkeeper (Manuel Neuer) was positioned on the goal line and a football was placed in the penalty spot. (A) The goalkeeper is positioned centrally in the goal, and the goal mouth is offset -3.4 mm to the left of center, so from the egocentric viewpoint of the kicker (i.e., participant whose viewpoint was aligned with the center of the computer monitor), they are positioned 3.4 mm to the right of the ball. (B) The goalkeeper is positioned centrally in the goal, and the goalmouth is offset 3.4 mm to the right of center, so the egocentric viewpoint of the kicker is -3.4 mm to the left of the ball. (C) The goalkeeper is positioned -3.4 mm to the left of the center of the goal, and the egocentric viewpoint of the kicker is central in relation to the goalmouth. (D) The goalkeeper is positioned 3.4 mm to the right of the center of the goal, and the egocentric viewpoint of the kicker is central in relation to the goalmouth.

Figure 2. Semi-factorial combination of stimuli used in the Experiment. The black squares show the pairings of the goalkeeper's position (relative to the center of the goal) and goal mouth position relative to the center of the computer monitor. The lower left to upper right diagonal shows the mean position of the goalkeeper relative the center of the goal and goal mouth displacement relative to the center of the computer monitor. The opposing upper left to lower right diagonal shows the difference in the positions of the goalkeeper relative to the center of the goalmouth and goalmouth relative to the center of the computer monitor. Note, there are some minor rounding errors of no concern.

Figure 3. Linear relationship between mean *SRS* and logit *P* as computed for each stimulus condition over all participants. The unfilled circles show mean *SRS* versus logit *P* for each condition computed over all participants, the solid black line shows the linear prediction and the shaded region shows the 95% CI about the prediction.

Figure 4. Top 2 panels: Counterfactual plots of the probability (inverse logit *P*) of left goal side selection (left panel) and *SRS* (right panel) with changes in the goalkeeper's position relative to the center of the goal, when the kicker's egocentric viewing position is held at a constant position aligned central to the goalmouth. The unfilled circles show the probability of left goal side selection, and mean *SRS*, respectively, computed over all participants and marginalized over the kicker's position. Bottom 2 panels: Counterfactual plots of the probability left goal side selection (left panel) and *SRS* (right panel) with changes in the kicker's egocentric viewing position relative to the center of the goalmouth, when the goalkeeper is held at a constant position aligned central to the goalmouth. The unfilled circles show the probability of left side selection, and mean *SRS*, respectively, computed over all participants and marginalized over the goalkeeper's position. In each panel, the solid dark line shows the predicted group level estimate and the shaded area shows the 95% CI about the estimate.

Figure 5. Top 2 panels: Counterfactual plots of the probability of left goal side selection (left panel) and *SRS* (right panel) with changes in the difference between the goalkeeper's and kicker's position, when the joint sum of their positions is held constant. The unfilled circles show the probability of left side selection, and mean *SRS*, respectively, computed over all participants and marginalized over the sum of the goalkeeper's position and kicker's position. Bottom 2 panels: Counterfactual plots of the probability of left goal side selection (left panel)

and *SRS* (right panel) with changes in the sum of the goalkeeper's and kicker's position, when the difference in their positions is held constant. The unfilled circles show the probability of left side selection, and mean *SRS*, respectively, computed over all participants and marginalized over the difference of the goalkeeper's position and kicker's position. In each panel, the solid dark line shows the predicted group level estimate and the shaded area shows the 95% CI about the estimate.

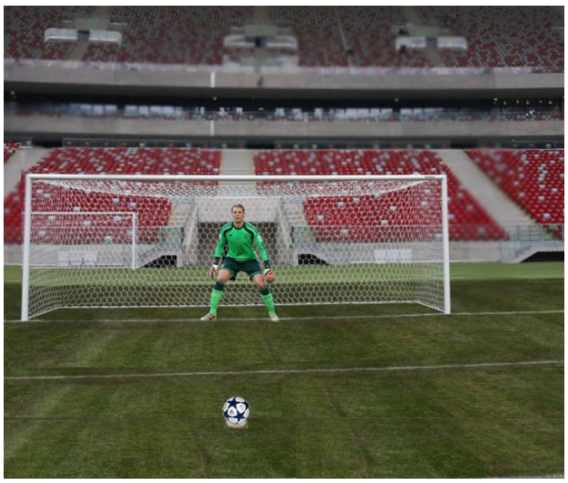
Figure 6. Frequency histograms showing the goalkeeper's position (left panel) and kicker's position (right panel) for each of the 100 penalty shots analyzed. Note, that on the rare occasion in which the kicker's position is greater than ±100%, the kicker's initial standing position, before making their run up to the ball, was beyond the extent of the vertical left or right goalpost.

Figure 7. Left panel: Counterfactual plot of the probability of left goal side ball placement with changes in the goalkeeper's position relative to the center of the goal, when the kicker's egocentric viewing position is held at a constant position aligned central to the goalmouth. The unfilled circles show the probability of left goal side placement, computed over all participants and marginalized over the kicker's position. Right panel: Counterfactual plot of the probability of left goal side ball placement with changes in the kicker's egocentric viewing position relative to the center of the goalmouth, when the goalkeeper is held at a constant position aligned central to the goalmouth. The unfilled circles show the probability of left goal side placement, computed over all participants and marginalized over the goalkeeper's position. In each panel, the solid dark line shows the predicted group level estimate and the shaded area shows the 95% CI about the estimate.

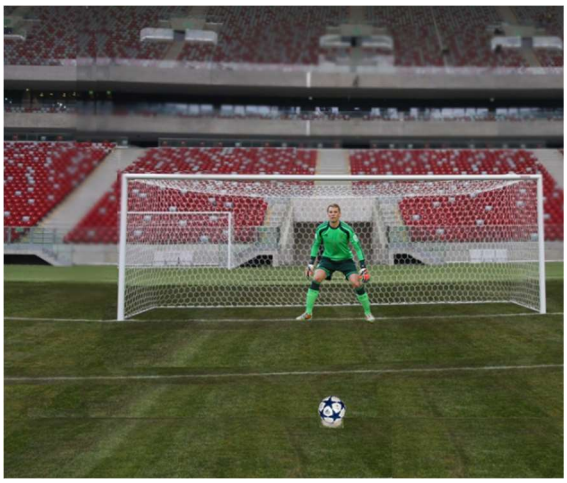
Figure 8. Left panel: Counterfactual plot of the probability of left goal side ball placement with changes in the difference between the goalkeeper's and kicker's position, when the joint sum of their positions is held constant. The unfilled circles show the probability of left goal side placement, computed over all participants and marginalized over the sum of the goalkeeper's position and kicker's position. Right panel: Counterfactual plot of the probability of left goal side ball placement with changes in the sum of the goalkeeper's and kicker's position, when the difference in their positions is held constant. The unfilled circles show the probability of left goal side placement, computed over all participants and marginalized over the difference of the goalkeeper's position and kicker's position. In each panel, the solid dark line shows the predicted group level estimate and the shaded area shows the 95% CI about the estimate.

Figure 1

(A)



(B)



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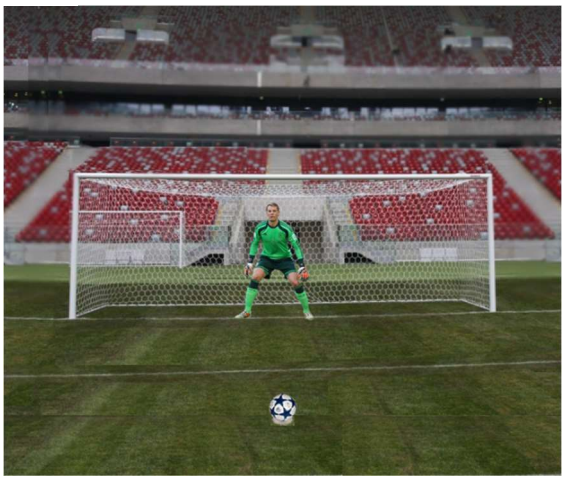

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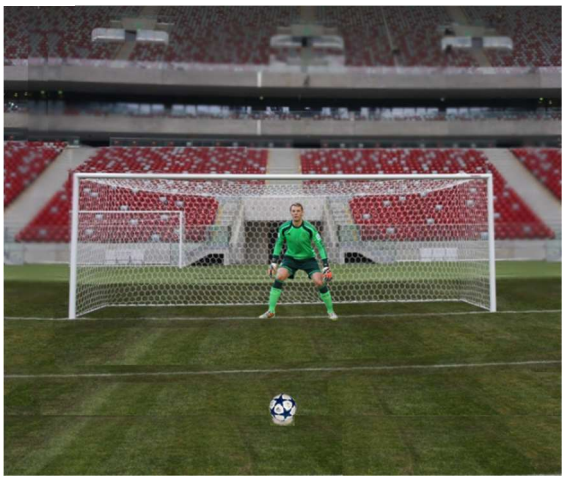


Figure 2

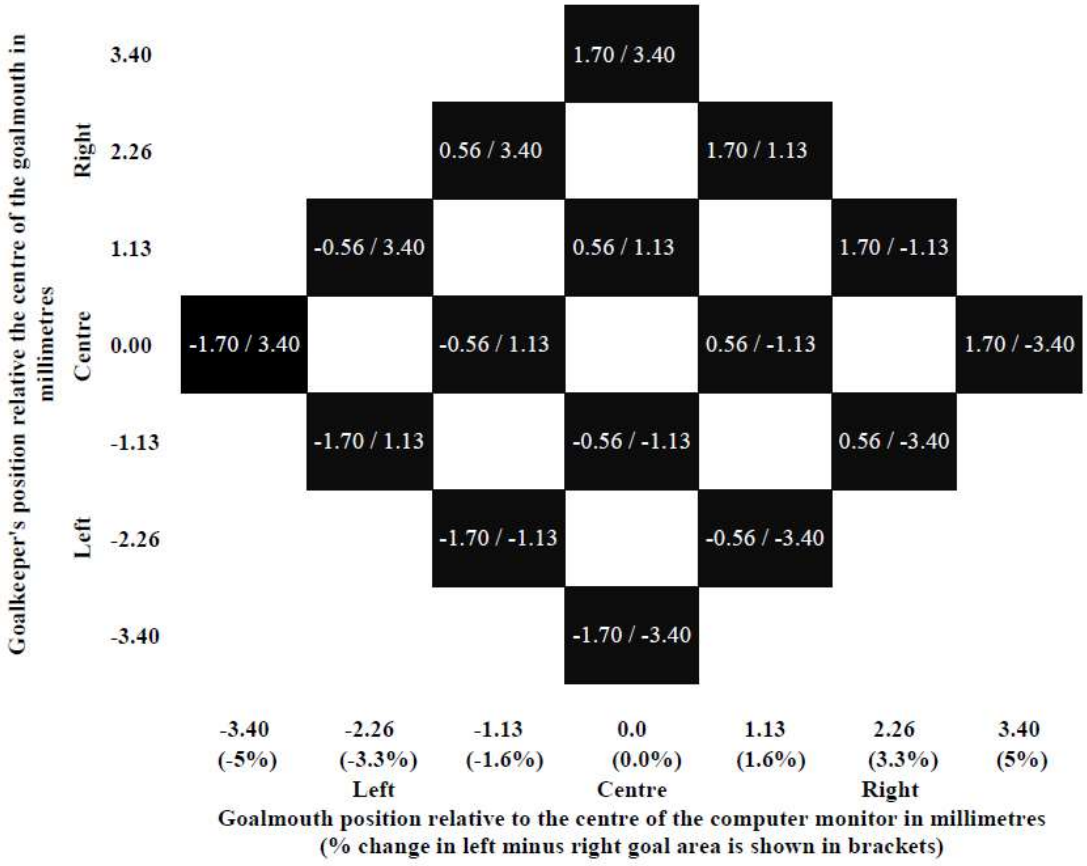

Goalkeeper's position relative the centre of the goalmouth in millimetres
Left
Centre
Right
3.40
2.26
1.13
0.00
-1.13
-2.26
-3.40
1.70 / 3.40
0.56 / 3.40
1.70 / 1.13
-0.56 / 3.40
0.56 / 1.13
1.70 / -1.13
-1.70 / 3.40
-0.56 / 1.13
0.56 / -1.13
1.70 / -3.40
-1.70 / 1.13
-0.56 / -1.13
0.56 / -3.40
-1.70 / -1.13
-0.56 / -3.40
-1.70 / -3.40
-3.40 (-5%)
-2.26 (-3.3%)
-1.13 (-1.6%)
0.0 (0.0%)
1.13 (1.6%)
2.26 (3.3%)
3.40 (5%)
Left
Centre
Right
Goalmouth position relative to the centre of the computer monitor in millimetres
(% change in left minus right goal area is shown in brackets)

Figure 3

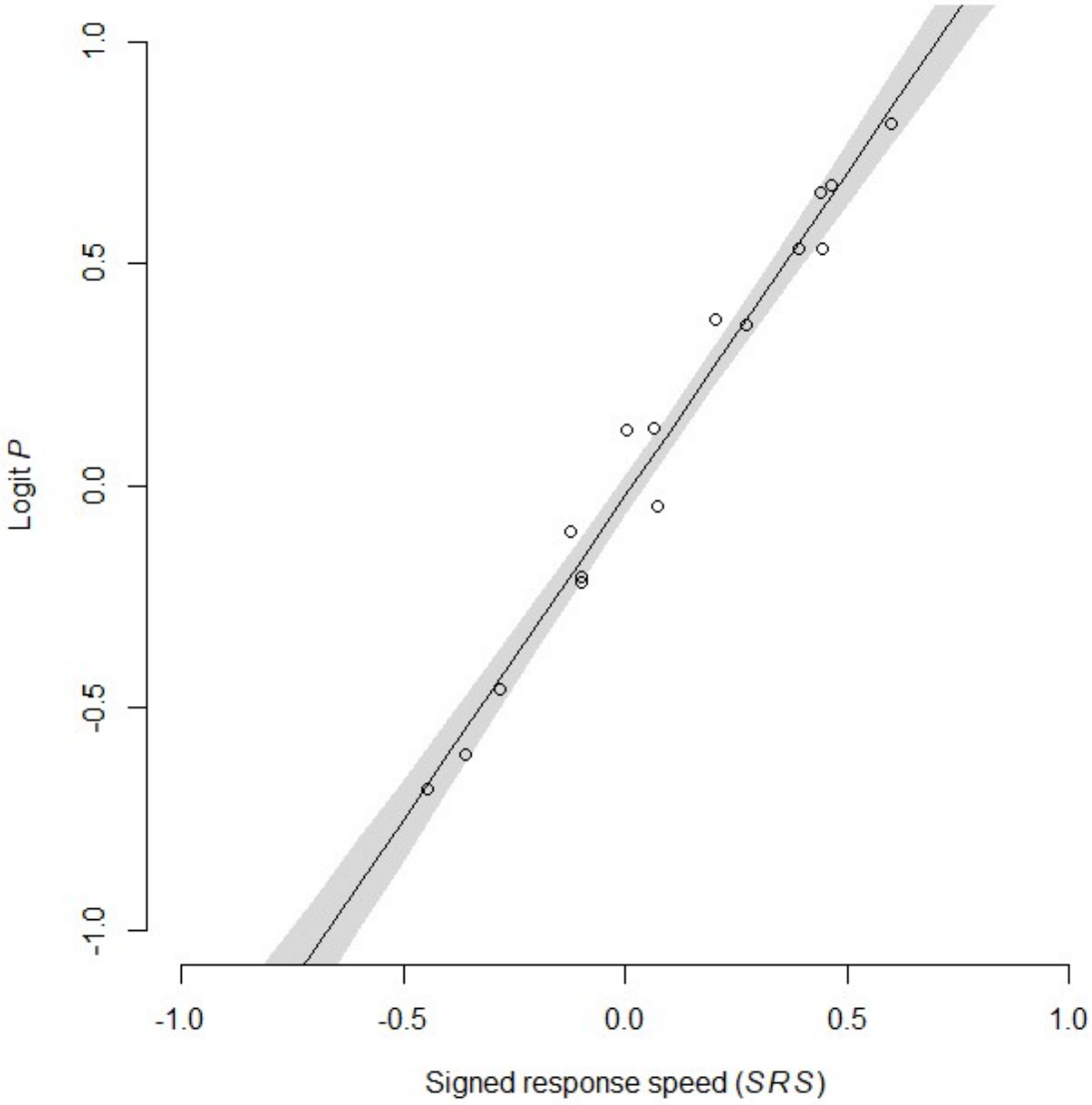


Figure 4

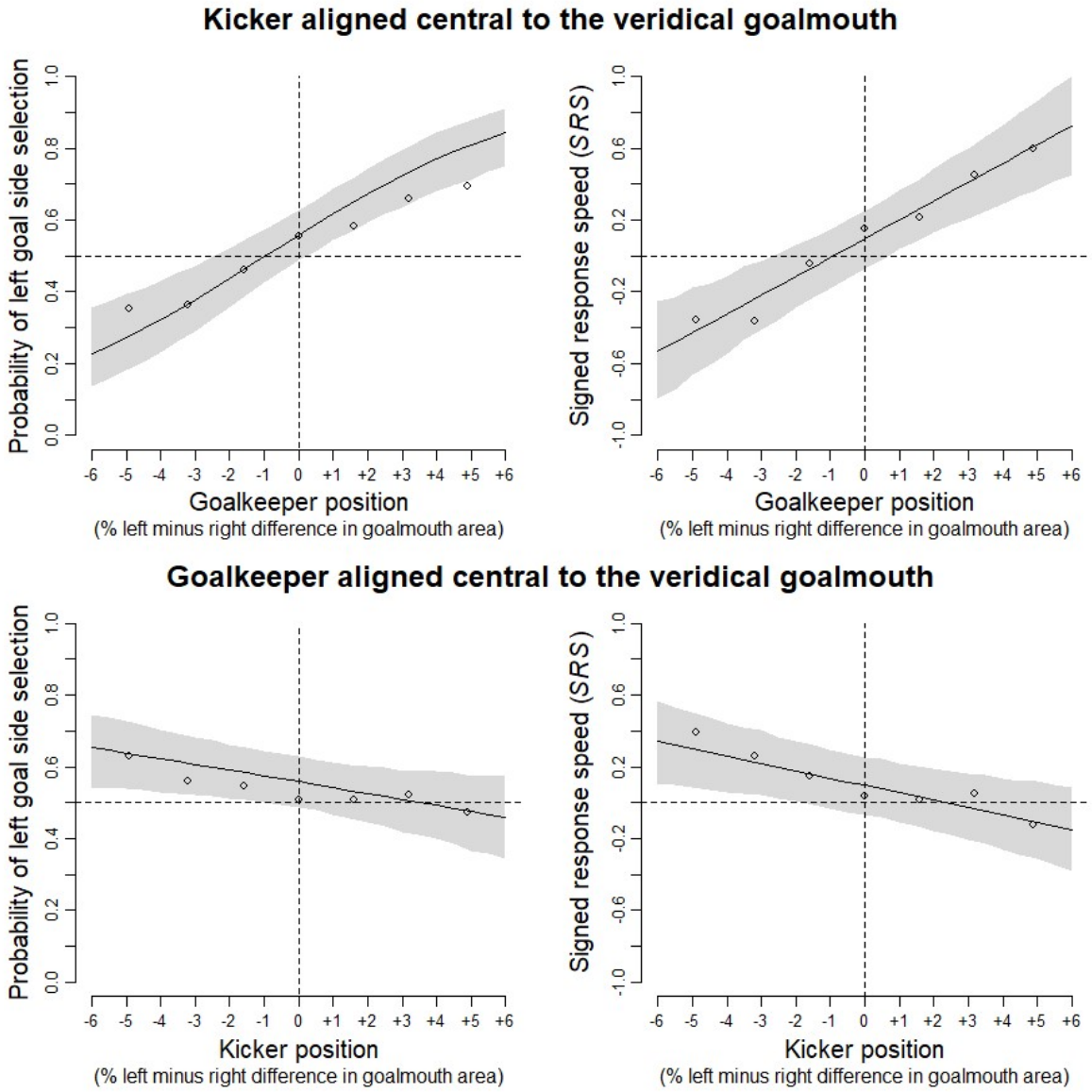

Kicker aligned central to the veridical goalmouth
Probability of left goal side selection
Signed response speed (SRS)
Goalkeeper position
(% left minus right difference in goalmouth area)
Goalkeeper aligned central to the veridical goalmouth
Kicker position
(% left minus right difference in goalmouth area)

Figure 5

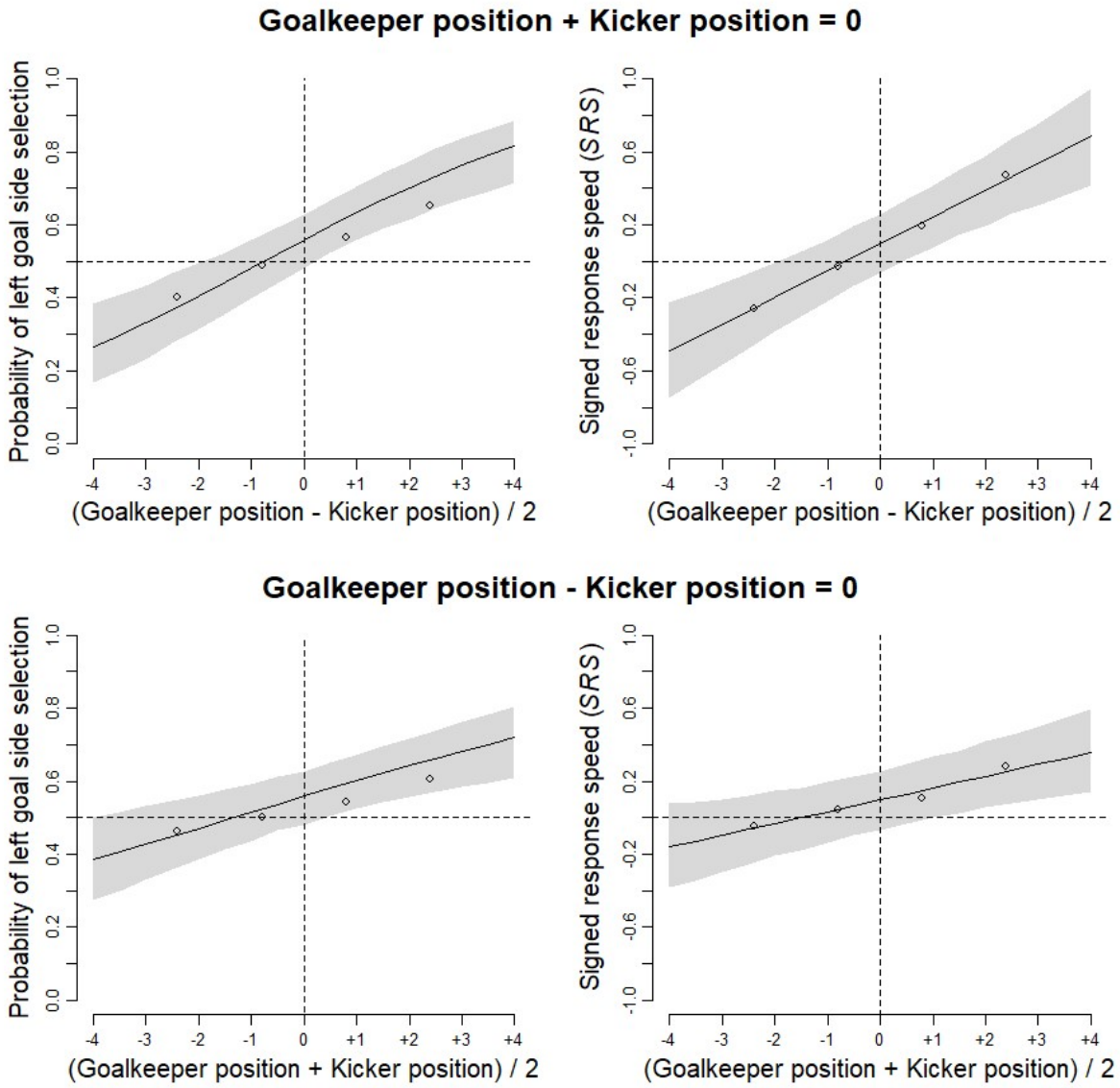

Goalkeeper position + Kicker position = 0
Probability of left goal side selection
Signed response speed (SRS)
(Goalkeeper position - Kicker position) / 2
(Goalkeeper position - Kicker position) / 2
Goalkeeper position - Kicker position = 0
Probability of left goal side selection
Signed response speed (SRS)
(Goalkeeper position + Kicker position) / 2
(Goalkeeper position + Kicker position) / 2

Figure 6

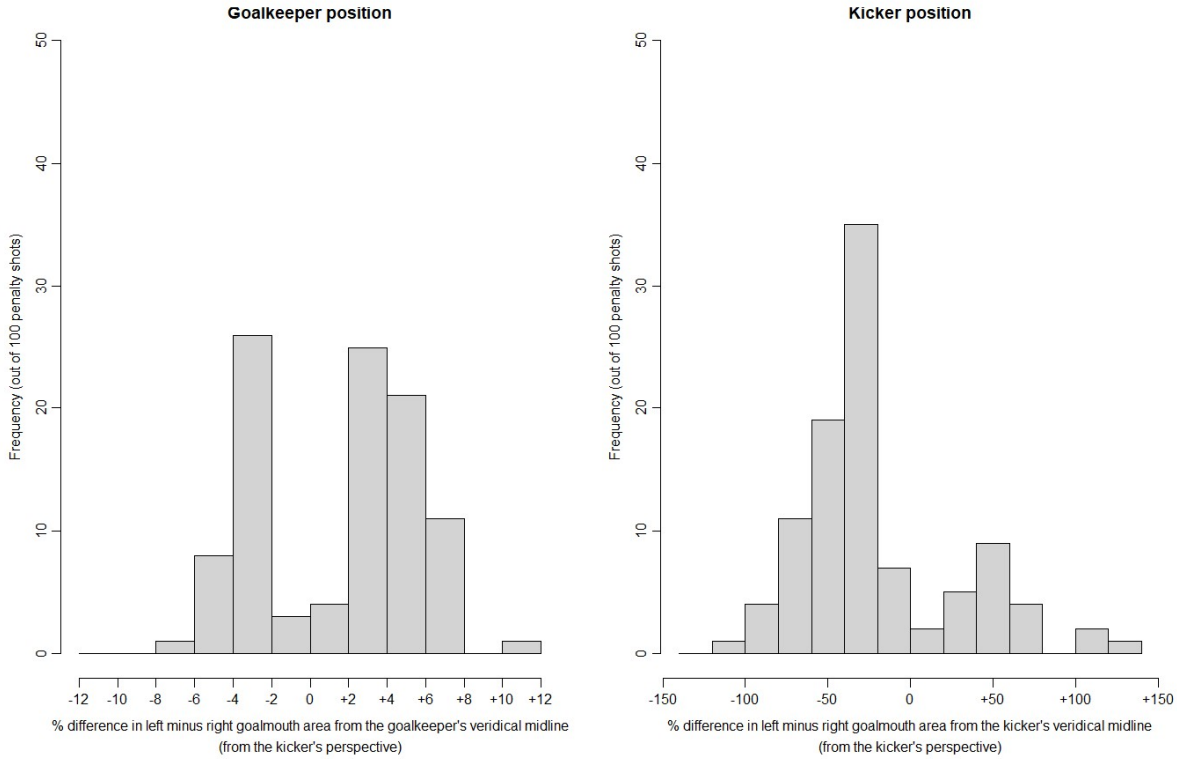

Goalkeeper position
Frequency (out of 100 penalty shots)
0
10
20
30
40
50
-12 -10 -8 -6 -4 -2 0 +2 +4 +6 +8 +10 +12
% difference in left minus right goalmouth area from the goalkeeper's veridical midline
(from the kicker's perspective)
Kicker position
Frequency (out of 100 penalty shots)
0
10
20
30
40
50
-150 -100 -50 0 +50 +100 +150
% difference in left minus right goalmouth area from the kicker's veridical midline
(from the kicker's perspective)

Figure 7

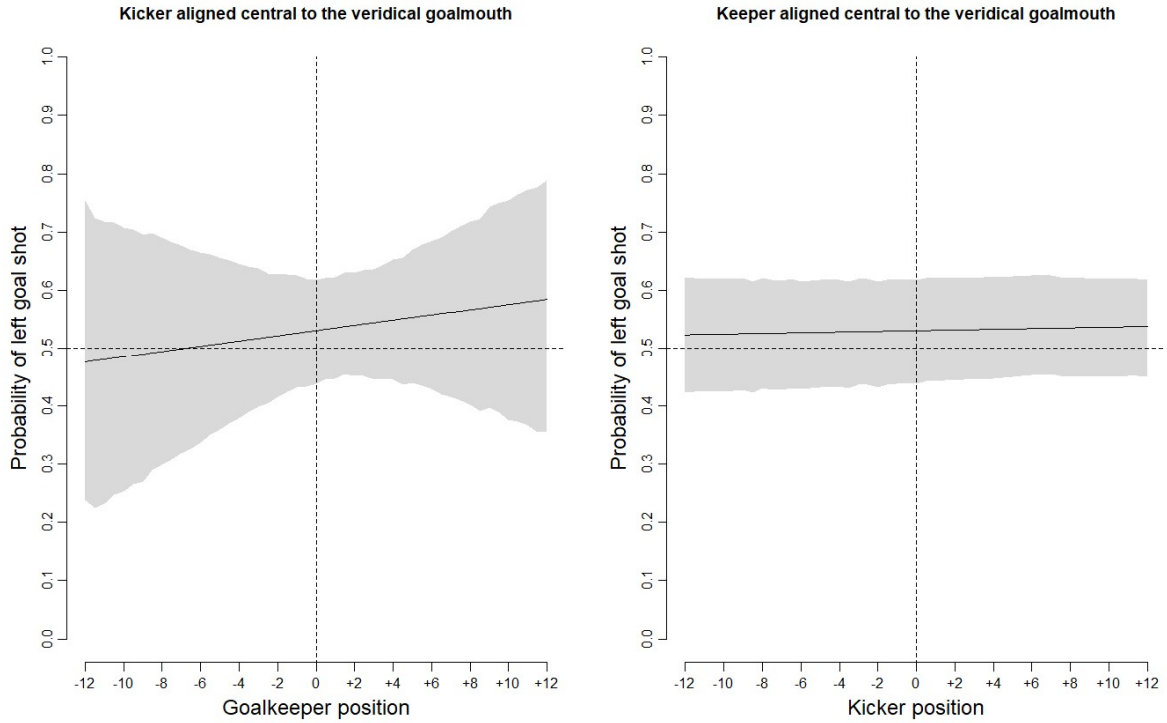
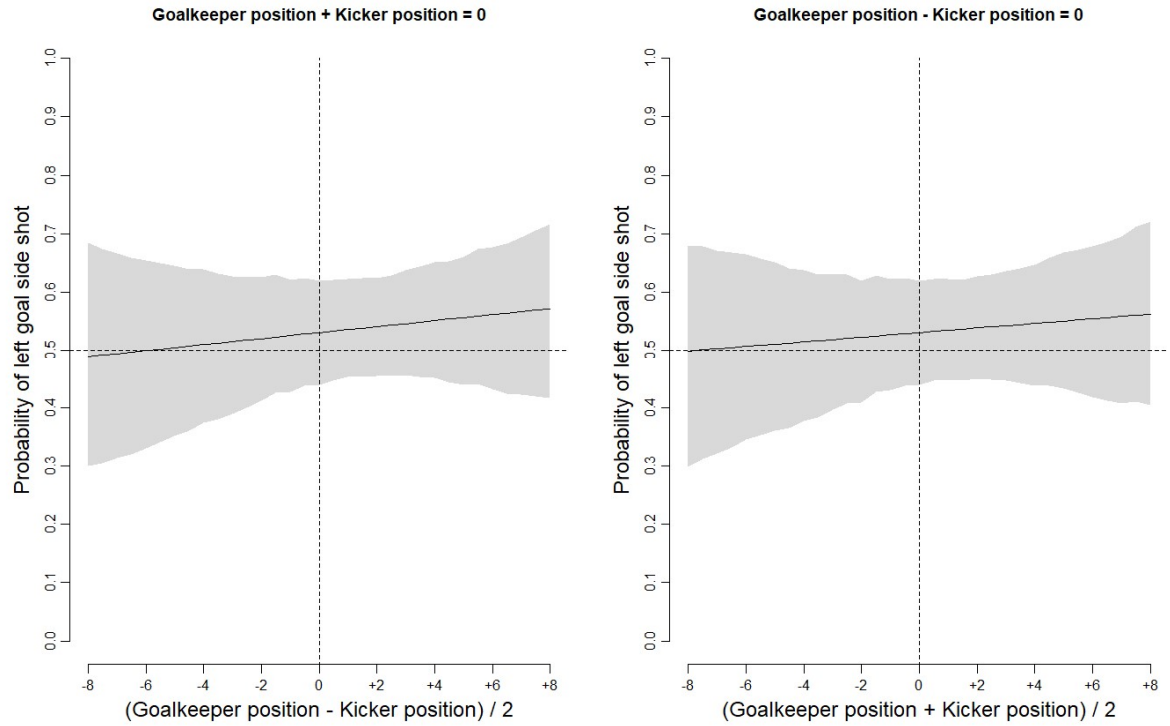

Kicker aligned central to the veridical goalmouth
Probability of left goal shot
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
-12 -10 -8 -6 -4 -2 0 +2 +4 +6 +8 +10 +12
Goalkeeper position
Keeper aligned central to the veridical goalmouth
Probability of left goal shot
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
-12 -10 -8 -6 -4 -2 0 +2 +4 +6 +8 +10 +12
Kicker position

Figure 8


Goalkeeper position + Kicker position = 0
Probability of left goal side shot
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
-8
-6
-4
-2
0
+2
+4
+6
+8
(Goalkeeper position - Kicker position) / 2
Goalkeeper position - Kicker position = 0
Probability of left goal side shot
(Goalkeeper position + Kicker position) / 2