

**Hot hands, cold feet? Investigating effects of interacting constraints on place kicking performance at the 2015 Rugby Union World Cup**

POCOCK, Chris <<http://orcid.org/0000-0001-5929-7273>>, BEZODIS, Neil E. <<http://orcid.org/0000-0003-2229-3310>>, DAVIDS, Keith <<http://orcid.org/0000-0003-1398-6123>> and NORTH, Jamie S. <<http://orcid.org/0000-0003-2429-4552>>

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1 Running Head: CONSTRAINTS ON RUGBY PLACE KICKING PERFORMANCE

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3 Hot hands, cold feet?: Investigating effects of interacting constraints on place kicking  
4 performance at the 2015 Rugby Union World Cup

5 Chris Pocock<sup>a</sup>

6 St Mary's University, Twickenham

7 Neil E. Bezodis<sup>b</sup>

8 Swansea University

9 Keith Davids<sup>c</sup>

10 Sheffield Hallam University

11 Jamie S. North<sup>a</sup>

12 St Mary's University, Twickenham

13  
14 <sup>a</sup>Expert Performance and Skill Acquisition research group, School of Sport, Health and  
15 Applied Science, St Mary's University, Twickenham, U.K.

16 <sup>b</sup>Applied Sports, Technology, Exercise and Medicine Research Centre, Swansea University,  
17 U.K.

18 <sup>c</sup>Centre for Sports Engineering Research, Sheffield Hallam University, U.K.

19  
20 Correspondence concerning this article should be addressed to Chris Pocock, School of Sport,  
21 Health and Applied Science, St Mary's University, Twickenham, TW1 4SX. Tel: 020 8240  
22 8243; Email: [chris.pocock@stmarys.ac.uk](mailto:chris.pocock@stmarys.ac.uk)

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25 Abstract

26 Place kicks in Rugby Union present valuable opportunities to score points outside the  
27 spatiotemporal dynamics of open play but are executed under varying performance  
28 constraints. We analysed effects of specific task constraints and relevant contextual factors on  
29 place kick performance in the 2015 Rugby Union World Cup. Data were collected from  
30 television broadcasts for each place kick. In addition to kick outcomes, contextual factors,  
31 including time of the kick in the match, score margin at the time of the kick, and outcome of  
32 the kicker's previous kick, were recorded. Effects of spatial task constraints were analysed  
33 for each kick, using distance (m) and angle ( $^{\circ}$ ) of the kick to the goalposts. A binomial  
34 logistic regression model revealed that distance from, and angle to, the goalposts were  
35 significant predictors of place kick outcome. Furthermore, the success percentage of kickers  
36 who missed their previous kick was 7% lower than those who scored their previous kick.  
37 Place kick success percentage in the 10 minutes before half-time was 8% lower than the  
38 mean tournament success percentage, which was 75% (95% CI 71% to 78%). The highest  
39 kick success percentage was recorded when scores were level (83%; 95% CI 72% to 91%).  
40 Our data highlighted how subtle changes in task constraints and contextual factors can  
41 influence performance outcomes in elite performers in international competition. Fluctuations  
42 in place kick success suggested that individual constraints, such as thoughts, emotions, and  
43 fatigue, induced during competition, could interact with perceptions to influence emergent  
44 performance behaviours.

45

46 **Keywords:** Context, place kick, Rugby Union, self-paced skills, task constraints.

47           Hot hands, cold feet?: Investigating effects of interacting constraints on place kicking  
48                           performance at the 2015 Rugby Union World Cup

49           Place kicks (penalties and conversions) contributed 45% of all points scored in 582  
50 international Rugby Union matches between 2002 and 2011 (Quarrie & Hopkins, 2015), and  
51 thus provide valuable opportunities to score points without the spatiotemporal dynamics of  
52 open play directly affecting the outcome. In performing such self-paced interceptive actions,  
53 in sports like Rugby Union, Australian Rules Football, Rugby League and Association  
54 Football, performers need to successfully adapt to numerous fluctuating constraints and  
55 contextual factors (e.g. score margin and time remaining) (Nel, 2013; Quarrie & Hopkins,  
56 2015) within competitive performance environments.

57           Place kicks in competitive matches are typically executed under varying  
58 environmental (e.g., weather and pitch conditions), task (e.g., location on the pitch), and  
59 individual (e.g., emotions, fatigue) constraints (Newell, 1986), and in fluctuating contexts  
60 (differentiated by variations in score margin, time remaining in the match, and previous  
61 performance of the place kicker). Theoretical frameworks like ecological dynamics  
62 conceptualise the adaptive nature of performance needed to satisfy the multiple interacting  
63 constraints existing at specific moments during competition (Davids, Araújo, Vilar, Renshaw,  
64 & Pinder, 2013). This theoretical rationale provides an appropriate lens through which to  
65 investigate how multiple interacting constraints and contextual factors may shape place  
66 kicking performance. Researchers have highlighted the need to investigate how contextual  
67 information may regulate perception and action in competitive performance (Headrick,  
68 Renshaw, Davids, Pinder, & Araújo, 2015). However, there have been limited attempts to  
69 understand how specific contextual factors may influence place kick performance outcomes  
70 in Rugby Union (see Nel, 2013; Quarrie & Hopkins, 2015 for exceptions). The aim in the

71 present study was to further existing research by analysing a broader range of contextual  
72 factors, underpinned by the theoretical framework of ecological dynamics, to provide novel  
73 insights into elite place kicking performance.

74 Previous analyses of place kicking in Rugby Union have typically recorded a  
75 particular observation in isolation without considering the dependence of a single observation  
76 on previous states (termed 'conditioned coupling', van Geert, 1994). Considering whether  
77 previous performance attempts may influence current performance (perhaps leading to  
78 variations in perceptions, thoughts and emotions), may enrich performance analysis and  
79 understanding of elite place kicking. The effects of a performer's previous performance have  
80 been considered in other sports, with terms such as "hot hands" used to capture the anecdotal  
81 view that basketball shooters have a greater chance of making a shot if their previous attempt  
82 was successful, compared with a previous unsuccessful attempt (Gilovich, Vallone, &  
83 Tversky, 1985). Although some research challenges the notion of "hot hands" (see Bar-Eli,  
84 Avugos, & Raab, 2006, for a review), evidence exists in golf for the reverse phenomenon in  
85 which poor performance can result in an increased likelihood of poor performance on a  
86 subsequent set of (3, 6, 9 or 18) holes (Arkes, 2016). There have been some suggestions that  
87 previous performance may shape a kicker's perceptions during current performance. For  
88 example, in American Football, novice kickers perceived the posts to be narrower, following  
89 missed field goal kicks, but wider and lower after successful kicks (Witt & Dorsch, 2009).  
90 Moreover, researchers have considered the locations of previous successful and unsuccessful  
91 American Football field goal attempts to estimate the probability of success on a future  
92 attempt (Berry & Berry, 1985). The suggestions that a performer's perception, and  
93 performance, of a task appears to be affected by preceding actions highlights the ongoing  
94 reciprocal relationship between cognitions, perception and action (Gibson, 1979). This

95 perspective advocates that, rather than viewing emerging performance behaviours of place  
96 kickers as being functionally independent, their effects on states (e.g., emotional, physical  
97 and psychological) of the place kicker (i.e. conditioned coupling, van Geert, 1994) should be  
98 considered when analysing place kicking performance.

99         Whilst researchers have demonstrated that a performer's perception of task difficulty  
100 can be dependent on previous performance outcomes (Witt & Dorsch, 2009), the difficulty of  
101 a place kick can also change due to the varying pitch locations from which penalties and  
102 conversions will be awarded. The interaction of two key task constraints: distance to the  
103 goalposts and the angle relative to a straight kick from directly in front of the goalposts, may  
104 influence performance of place kicks, because each reduces the margin for error in the initial  
105 ball launch. Although researchers have highlighted that distance and angle to goalposts can  
106 affect kick success (Nel, 2013), and success percentages across specific pitch zones have  
107 been recorded (Quarrie & Hopkins, 2015), the calculation of specific distance and angle  
108 thresholds where performance drops below mean kicking success would provide valuable  
109 additional information for coaches. Identifying threshold values in distance and angle for  
110 place kicking success, and contextual factors which differ between successful and  
111 unsuccessful performance, can inform the design of representative learning environments in  
112 practice (Pinder, Davids, Renshaw, & Araújo, 2011). Therefore, in this study our first aim  
113 was to analyse how specific contextual factors differed between successful and unsuccessful  
114 performance of a self-paced skill in elite Rugby Union players, using place kicks from the  
115 2015 Rugby Union World Cup as exemplar high performance data. Our second aim was to  
116 identify the location of threshold values of key task constraints, defined by distance from, and  
117 lateral angle to, the goalposts, at which performance levels drop below the mean tournament  
118 success percentage.

119 Method

120 Place kick performance outcome data were collected from publicly available  
121 television broadcasts of the 2015 Rugby World Cup (RWC), a 48-match tournament held in  
122 England and Wales. The performances of 51 place kickers (mean  $\pm$  SD age:  $26.7 \pm 3.4$  years;  
123 height:  $1.82 \pm 0.05$  m; body mass:  $90.5 \pm 8.7$  kg, descriptive statistics obtained from ESPN  
124 Scrum, <http://stats.espnscrum.com/statsguru/rugby/stats/index.html>) who attempted at least  
125 one place kick during the tournament were analysed. Before the start of the tournament, place  
126 kickers had prior international level experience (mean  $\pm$  SD international caps:  $33 \pm 26$ ;  
127 international points:  $203 \pm 272$ ). The study was approved by the lead author's University's  
128 ethics committee (approval number: SMEC\_2015-16\_133).

129 All 558 place kicks (287 penalties and 271 conversions) taken in the 2015 RWC were  
130 analysed. Selected match details, including local time of kick-off, date, venue and stage of the  
131 tournament, were collected from Rugby World Cup Match Centre  
132 ([www.rugbyworldcup.com](http://www.rugbyworldcup.com)). Further data were collected from televised match footage for  
133 each kick, including whether the kick was successful or not, the time in the match and the  
134 current score margin.

135 The outcome of the kicker's previous kick was associated with the success of the  
136 current kick. This was applied across the tournament (i.e. the final kick attempted by the  
137 kicker in the first match was used for the first kick attempted by the same kicker in the  
138 second match). For this measure, each kicker's first kick of the tournament was not analysed  
139 as the analysis focused specifically on the effect of previous performance *during* the 2015  
140 RWC. The time of each kick in the match was recorded when the kicker made ball contact

141 and was categorised using 10-minute time periods (kicks in the final play in each half were  
142 included in the 31-40 and 71-80-minute time periods, respectively).

143           Score margin at the time of the kick was recorded and categorised into: (i) level  
144 scores, (ii) kicker's team winning by 1-3, 4-7 and 8+ points, and (iii), kicker's team losing by  
145 1-3, 4-7 and 8+ points. Categories of score margin were chosen to reflect the probability of  
146 the kick changing the match status for the kicker's team: a team trailing by 3 points could  
147 level the scores with a successful penalty kick, a team trailing by 7 points could level the  
148 scores with a converted try and a team trailing by 8+ points would need to score more than  
149 once to level the scores.

150           Data on the resultant distance to goalposts (m) and angle to goalposts ( $^{\circ}$ ) for each kick  
151 were collected from Goalkickers ([www.goalkickers.co.za](http://www.goalkickers.co.za)), and used to map kicking success  
152 percentages across the pitch. Goalkickers use television broadcasts to manually plot kicks  
153 onto scaled co-ordinates of a pitch. The angle to goalposts was  $0^{\circ}$  if the kick was directly in  
154 front of the goalposts and increased as the kick position moved towards either the left or right  
155 touchline. The location of each kick was plotted onto a scaled pitch which was divided into  
156 scaled  $10 \times 10$  m zones starting from each touchline and the try line (using Kinovea v.0.8.15,  
157 Kinovea open source project, [www.kinovea.org](http://www.kinovea.org)). The mean kicking success percentages were  
158 then calculated for each zone to map the distribution of place kicking success across pitch  
159 area.

160           Binomial logistic regression analysis was performed to estimate the probabilities of  
161 place kick outcome (dependent variable) according to different sets of independent variables  
162 (SPSS Statistics version 21, IBM, USA). The regression model included time of kick, score  
163 margin, success of previous kick, distance to goalposts and angle to goalposts as independent



164 variables, but did not account for repeated measures of place kickers who kicked in multiple  
165 games in the tournament. The quality of the model was described by: i) the ability of the  
166 model to predict place kick outcome, based on the set of independent variables; ii) the odds-  
167 ratio value of each independent variable. For the scale variables of distance and angle, one  
168 unit represented 1 m and 1°, respectively. The regression model outputs were used to predict  
169 the odds of success at each independently increasing metre and degree, and threshold values  
170 of distance and angle were identified where success percentage first dropped below mean  
171 success percentage. The level of statistical significance was set at  $p \leq 0.05$ . Confidence  
172 intervals for success percentages were calculated using Wilson's method (Wilson, 1927) and  
173 were not derived from the model.

## 174 Results

175         Of the 558 place kicks attempted in the 2015 RWC, 418 were successful, yielding a  
176 mean kicking success percentage of 75% (95% CI 71% to 78%) in the tournament. The mean  
177 kicking success percentage of the 460 place kicks in pool matches was 74% (95% CI 70% to  
178 78%) and the mean kicking success percentage of the 98 place kicks attempted in the  
179 knockout stages was 80% (95% CI 71% to 86%).

180         The binomial logistic regression model was statistically significant in predicting the  
181 outcome of a place kick ( $\chi^2(17) = 118, p < 0.001$ ), compared to a model with no independent  
182 variables. The model explained 28% (Nagelkerke  $R^2$ ) of the variance in place kick outcome  
183 and correctly classified 76% of cases. The positive predictive value of the model (predicting a  
184 successful kick) was 79% and the negative predictive value (predicting an unsuccessful kick)  
185 was 54%. Of the five independent variables, two were statistically significant in predicting  
186 the outcome of a place kick: distance and angle (Table I).





232 there were some zones that displayed high success percentages past the threshold value for  
233 distance, these zones contained one kick respectively (Figure 1). It is suggested using our  
234 model (Table 1) that a greater sample size across multiple tournaments might display a  
235 decreased success percentage in place kicks over the threshold value of 50 m. Whilst it must  
236 be recognised that the distance and angle of each place kick were manually plotted from  
237 television broadcasts, these findings regarding effects of task constraints on place kick  
238 outcomes could be used to inform in-game decision making for penalty options, when teams  
239 are deciding whether to kick at goal or to kick to the touchline for a lineout.

240 Our data highlighted the fluctuations in place kick performance, shaped by specific  
241 contextual factors, such as time remaining and score margin. The mean kicking success  
242 percentage in the 2015 RWC tournament was 75%, which is broadly in line with data from a  
243 previous analysis (Quarrie & Hopkins, 2015) of international place kicking (72%). Kicking  
244 success was highest when scores were level, but success percentage was lower when the  
245 kicker's team was winning by fewer than three points in the tournament, or when the kicker's  
246 team was losing by fewer than three points in the knockout stages. Score margin appears to  
247 be an influential contextual factor when scores are within two points in other self-paced  
248 skills, such as a free throw in basketball, with observed decrements (6.3-8.8%) in  
249 performance relative to mean success percentage (Cao, Price, & Stone, 2011). However, in  
250 line with our findings, no observed decrements were found when attempting free throws  
251 whilst scores were level (Cao et al., 2011). These findings could be linked to the perceived  
252 pressure of successful performance when scores are close, specifically when losing by a close  
253 margin, which may induce feelings of fear or anxiety. When scores are level, this may reduce  
254 perceived pressure as an unsuccessful kick does not directly affect match outcome as the  
255 opposing team still need to score further points to win, although a successful kick could put

256 the place kicker's team into a leading position. These speculations are informed by previous  
257 findings in soccer penalty shootouts, in which elite players described the current score and  
258 prospect of missing a penalty as major sources of stress and anxiety (Jordet & Elferink-  
259 Gemser, 2012). Furthermore, soccer penalty success on negative valence shots (where the  
260 player had to score to avoid defeat) has been reported as 30% lower than positive valence  
261 shots (where the player has the opportunity to win the overall shootout). These findings  
262 support suggestions that performing a skill when trailing in score margin can influence  
263 performance (Jordet & Hartman, 2008). Further research is needed to investigate these  
264 suggestions in Rugby Union place kicking due to the relatively small number (98) of place  
265 kicks in the knockout stages in our sample. In a previous analysis of place kicking, Quarrie  
266 and Hopkins (2015) reported a lower success percentage (61%, compared to 72% mean  
267 success) in instances when the match outcome hinged on the success of a single place kick  
268 for a team trailing by one or two points, after which no further points were scored.  
269 Researchers should seek to further these observations and explore the emotions and  
270 perceptions of place kickers performing in contexts with closely matched scores to inform  
271 practice task designs that can prepare place kickers for such situations.

272         Our data may be useful for informing the design of practice tasks which faithfully  
273 represent key constraints and contextual factors present in performance environments. As  
274 proposed by Pinder et al. (2011), learning design needs to be representative of competitive  
275 environments when aiming to enhance transfer between practice and competition. In Rugby  
276 Union, coaches could design learning environments which allow place kickers to base their  
277 actions on relevant contextual factors and key constraints identified in analyses of  
278 performance. For example, fatigue accumulated during Rugby Union match-play can  
279 influence the distance covered by elite players; of all eight 10-minute time intervals in a

280 match, players cover the least distance in the 10 minutes before half-time (Roberts,  
281 Trewartha, Higgitt, El Abd, & Stokes, 2008). We also highlighted fluctuations in  
282 performance across time intervals in matches, with the lowest mean kicking success  
283 occurring in the 10 minutes prior to half-time, which may be related to the accumulated  
284 effects of physical and mental fatigue caused by events in the previous 30 minutes of a  
285 match. Whilst we analysed place kicking success percentages across 10-minute time  
286 intervals, future research could seek to analyse the effects of the characteristics of the phase  
287 of play *directly before* a place kick to analyse the potential influence of acute fatigue on place  
288 kickers. These types of insights can be valuable to coaches when simulating the relevant  
289 demands of competitive performance within practice environments. For example, coaches  
290 could introduce place kicking practice after 30 minutes of gameplay in training to simulate  
291 effects of an intense or less intense period of a match. Moreover, coaches can design game-  
292 related vignettes for place kickers which incorporate score margin and time remaining (e.g.  
293 "there are two minutes remaining and the team is trailing by one point") to simulate relevant  
294 contexts experienced in competitive environments (Headrick et al., 2015).

295         Our results provide evidence that the odds of an unsuccessful place kick are greater  
296 when the kicker has missed their previous kick, compared to when the kicker has scored their  
297 previous kick. Whilst larger sample sizes are required to confirm the size and direction of the  
298 effect, and these estimates are biased towards the players that attempted the most place kicks  
299 within the tournament due to the repeated measures structure of the data (Quarrie & Hopkins,  
300 2015), this finding has potentially valuable applied implications. Further research can explore  
301 the influence of task difficulty of previous performance on emerging behaviours, analysing if  
302 there could potentially be a larger effect if place kickers are unsuccessful with a perceived  
303 "easier" or "more important" previous kick.

304           Researchers have previously indicated that prior performance can influence perception  
305 of task difficulty when kicking towards a target (Witt & Dorsch, 2009). Theoretically,  
306 suggestions of a relationship between preceding actions and perception of a current task are  
307 underpinned by Gibson's (1979) ecological approach to visual perception and the reciprocity  
308 of perception and action. Furthermore, various interacting constraints in a performance  
309 environment can offer an explanation for how perceptions, actions and thoughts shape  
310 emergent behaviours (Seifert & Davids, 2012). In a competitive performance environment,  
311 performers are required to satisfy task demands while performing under high emotional states  
312 induced by the context of competition. Previous research (Headrick et al., 2015) has  
313 identified how emotions can continuously interact with cognitions, perception and action to  
314 constrain performance. The outcome of place kicks could influence confidence, amongst  
315 other feelings, and alter the kicker's perception of task difficulty for future kicks. One  
316 consideration of our analysis of previous performance is that the final kick of a place kicker's  
317 previous game was coupled to the first kick of the following game. The effect of several  
318 previous kicks considered in a cluster, rather than just the one previous kick analysed in the  
319 present study, and the degree of error in a previous unsuccessful kick (the distance which the  
320 ball missed the goalposts by) could be explored in future place kicking research.

321 Additionally, similar research on free kicks in other sports, like Association Football, could  
322 be conducted to understand whether factors like distance and angle to goal may influence  
323 decisions to shoot or pass the ball, as well as success percentages of performance outcomes  
324 (e.g., a goal scored or a shot on target). Further research is required to explore the effect that  
325 an unsuccessful final kick, particularly in losing situations, has on a place kicker's  
326 preparation and training for the next game. It is recommended that researchers explore the  
327 experiential knowledge of place kickers and their coaches (Renshaw & Gorman, 2015) to

328 understand the influence of previous performance on future place kicks, either within games  
329 or between games. This type research can also access thoughts, emotions and states of mind  
330 based on experiences of successful and unsuccessful place kicks in competitive  
331 environments.

### 332 Conclusions

333 Our data highlighted how subtle changes in task constraints and contextual factors can  
334 affect the emergence of performance outcomes in elite performers. We provided data from  
335 elite place kickers performing at the highest level of competition which highlighted  
336 fluctuations in place kicking success under specific contextual factors, suggesting that  
337 individual constraints such as perceptions, thoughts, emotions, and fatigue induced during  
338 competition can interact with perceptions and action to influence emergent behaviours.  
339 Future research could investigate the performance and training experiences of place kickers  
340 and coaches to explore how key task constraints and contextual factors may influence  
341 thoughts, perceptions and emotional states. Semi-structured interviews to explore the  
342 experiential knowledge of elite performers in place kicking situations can add further depth to  
343 the current quantitative analyses of task constraints and contextual factors on place kicking  
344 success. The findings of our study suggest how coaches, sport scientists and performance  
345 analysts could combine their expertise in order to design practice environments which  
346 successfully simulate the relevant constraints of competitive performance environments.

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415 Tables

416 Table I. Results of the binary logistic regression to predict the likelihood of place kick  
 417 outcome based on time of the kick, score margin, success of previous kick, distance to  
 418 goalposts and angle to goalposts.

	B	SE	Wald	<i>p</i>	OR	95% CI
Time <sup>a</sup>			2.277	0.943		
Time (11-20)	-0.007	0.490	0.000	0.989	0.993	[0.380, 2.597]
Time (21-30)	-0.149	0.523	0.081	0.775	0.861	[0.309, 2.401]
Time (31-40)	-0.479	0.492	0.947	0.331	0.620	[0.236, 1.625]
Time (41-50)	-0.353	0.546	0.417	0.518	0.703	[0.241, 2.050]
Time (51-60)	-0.242	0.522	0.215	0.643	0.785	[0.282, 2.185]
Time (61-70)	-0.275	0.549	0.250	0.617	0.760	[0.259, 2.228]
Time (71-80)	-0.028	0.516	0.003	0.957	0.973	[0.354, 2.674]
Score Margin <sup>b</sup>			3.571	0.735		
Score Margin (W4-7)	0.158	0.385	0.169	0.681	1.171	[0.551, 2.491]
Score Margin (W1-3)	-0.131	0.407	0.103	0.749	0.878	[0.395, 1.949]
Score Margin (Level)	0.535	0.515	1.077	0.299	1.707	[0.622, 4.683]
Score Margin (L1-3)	0.311	0.412	0.571	0.450	1.365	[0.609, 3.060]
Score Margin (L4-7)	-0.263	0.419	0.393	0.530	0.769	[0.338, 1.749]
Score Margin (L8+)	0.336	0.361	0.864	0.353	1.399	[0.689, 2.840]
Previous Kick <sup>c</sup>			4.234	0.120		
Previous Kick (Missed)	-0.358	0.264	1.843	0.175	0.699	[0.417, 1.172]
Previous Kick (First Kick)	-0.727	0.418	3.025	0.082	0.483	[0.213, 1.097]
Angle	-0.023	0.008	9.058	0.003	0.977	[0.963, 0.992]
Distance	-0.103	0.014	56.558	0.000	0.902	[0.878, 0.926]
Constant	5.779	0.784	54.277	0.000	323.515	

419 B: parameter estimate; SE: standard error of the parameter estimated; OR: odds ratio; CI:  
420 confidence interval for odds ratio.

421 <sup>a</sup>Time interval of 0-10 minutes was used as the reference category for time.

422 <sup>b</sup>Score margin of winning by 8+ was used as the reference category for score margin.

423 <sup>c</sup>Successful previous kick was used as the reference category for previous kick.

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439 Figure Captions

440 Figure 1. Distribution of mean kicking success percentages in the 2015 Rugby World Cup  
441 depending on the location of place kicks, including thresholds of distance (42 m) and angle  
442 ( $39^\circ$  for a 32 m kick) as indicated by the black x's.

443 Figure 2. The odds of success at each independent metre to goalposts and the threshold for  
444 distance to goalposts, calculated using the odds ratio output from the binomial logistic  
445 regression model.

446 Figure 3. Mean kicking success percentages across 10-minute time intervals of matches in the  
447 2015 Rugby World Cup.

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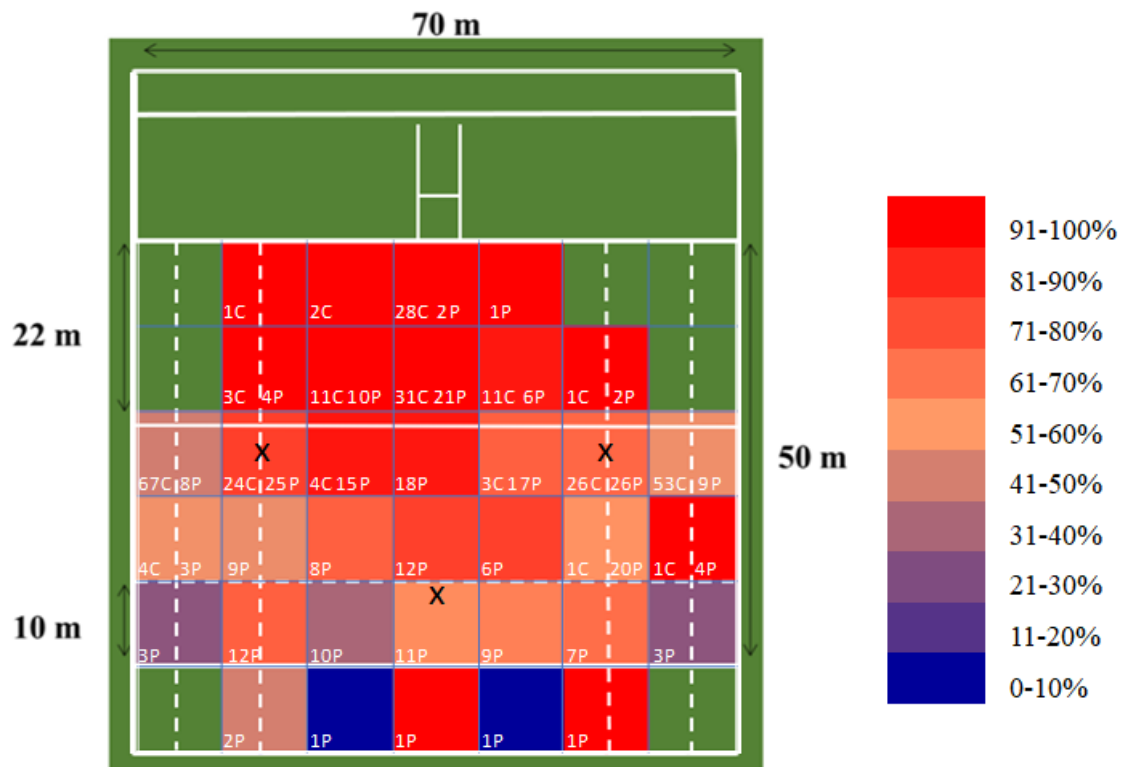


Figure 1. Distribution of mean kicking success percentages in the 2015 Rugby World Cup depending on the location of place kicks, including thresholds of distance (42 m) and angle ( $39^\circ$  for a 32 m kick) as indicated by the black x's.

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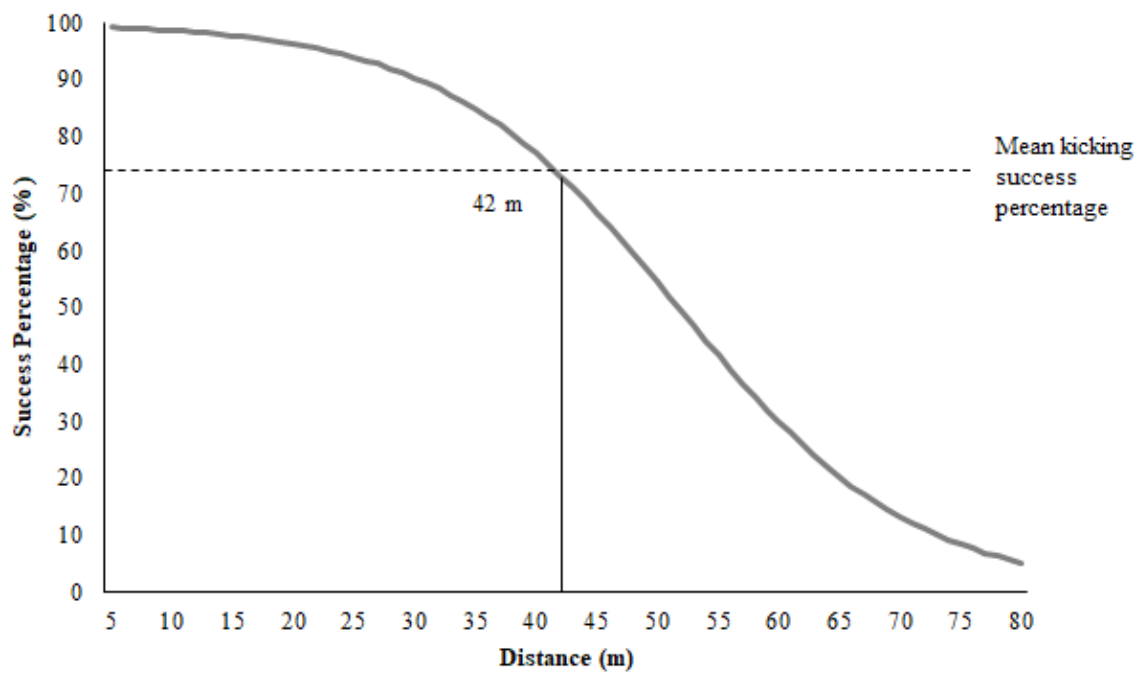


Figure 2. The odds of success at each independent metre to goalposts and the threshold for distance to goalposts, calculated using the odds ratio output from the binomial logistic regression model.

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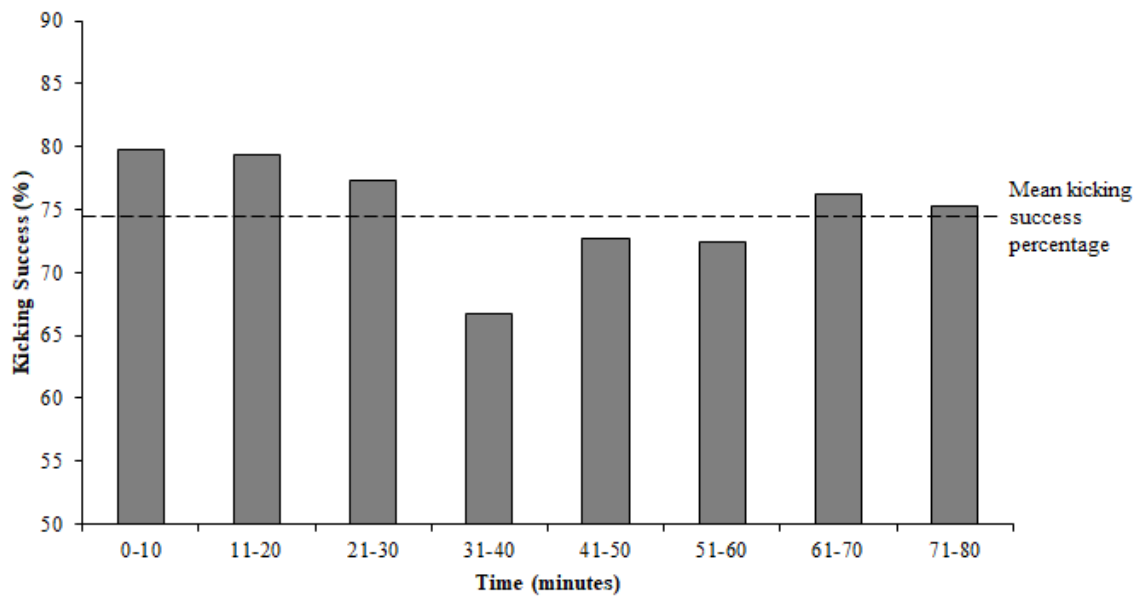


Figure 3. Mean kicking success percentages across 10-minute time intervals of matches in the 2015 Rugby World Cup.