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

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Running Head: CONSTRAINTS ON RUGBY PLACE KICKING PERFORMANCE

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

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Abstract

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

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

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

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

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

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

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

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

Method

Place kick performance outcome data were collected from publicly available television broadcasts of the 2015 Rugby World Cup (RWC), a 48-match tournament held in England and Wales. The performances of 51 place kickers (mean ± SD age: 26.7 ± 3.4 years; height: 1.82 ± 0.05 m; body mass: 90.5 ± 8.7 kg, descriptive statistics obtained from ESPN Scrum, http://stats.espnscrum.com/statsguru/rugby/stats/index.html) who attempted at least one place kick during the tournament were analysed. Before the start of the tournament, place kickers had prior international level experience (mean ± SD international caps: 33 ± 26; international points: 203 ± 272). The study was approved by the lead author's University's ethics committee (approval number: SMEC_2015-16_133).

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

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

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

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

Data on the resultant distance to goalposts (m) and angle to goalposts (°) for each kick were collected from Goalkickers (www.goalkickers.co.za), and used to map kicking success percentages across the pitch. Goalkickers use television broadcasts to manually plot kicks onto scaled co-ordinates of a pitch. The angle to goalposts was 0° if the kick was directly in front of the goalposts and increased as the kick position moved towards either the left or right touchline. The location of each kick was plotted onto a scaled pitch which was divided into scaled 10 × 10 m zones starting from each touchline and the try line (using Kinovea v.0.8.15, Kinovea open source project, www.kinovea.org). The mean kicking success percentages were then calculated for each zone to map the distribution of place kicking success across pitch area.

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

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

Results

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

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

<<<<<<<<<<<<<<<Insert Table I about here>>>>>>>>>>>>>>>

The mean distance of place kicks was 32 ± 12 m (mean ± SD) and the mean angle to the goalposts was 31 ± 18°. Figure 1 illustrates the distribution of mean kicking success percentages across the pitch area during the 2015 RWC.

<<<<<<<<<<<<<<<Insert Figure 1 about here>>>>>>>>>>>>>>>

A place kick from the mean distance (i.e. 32 m) directly in front of the goalposts (i.e. 0° angle) has an expected success percentage of 88%. Using the mean success percentage (75%) as the threshold, the threshold value of distance for kicks taken directly in front of the goalposts was 42 m (Figure 2). The threshold value for angle, using a 32 m kick, occurred at 39˚.

<<<<<<<<<<<<<<<Insert Figure 2 about here>>>>>>>>>>>>>>>

Of the 385 place kicks attempted by a place kicker when their previous place kick in the tournament was successful, 77% (95% CI 72% to 81%) were successful. There were 122 place kicks attempted by a kicker who had been unsuccessful with their previous kick, and 70% (95% CI 61% to 77%) of these were successful. The binomial logistic regression model revealed that the odds of an unsuccessful place kick are 1.431 times greater (95% CI = 0.853-2.398) when the kicker has missed their previous kick, compared to when the kicker has scored their previous kick (Table I).

Mean kicking success percentage was highest (83%; 95% CI 72% to 91%) in the tournament when scores were level and lowest when the kicker’s team were winning by 1-3 points (72%; 95% CI 58% to 82%). In the knockout stages, all six place kicks were successful when scores were level and 50% (95% CI 28% to 72%) were successful when the

kicker's team trailed by 3 points or fewer. Of the 48 matches in the tournament, three (6.3%) were decided (when scores were within 3 points and no further points were scored) by the success of a place kick; all three kicks were successful. Within each 10-minute time period throughout matches, the mean kicking success percentage was highest during the first 10 minutes (80%; 95% CI 68% to 88%) and lowest in the final 10 minutes before half-time (67%; 95% CI 56% to 76%) across the tournament (Figure 3).

<<<<<<<<<<<<<<<Insert Figure 3 about here>>>>>>>>>>>>>>>

Discussion

This study primarily aimed to analyse how specific contextual factors differed between successful and unsuccessful performance of a self-paced skill in elite Rugby Union players, using place kicks from the 2015 RWC as exemplar high performance data. A secondary aim of the study was to identify the location of threshold values of key task constraints at which performance levels dropped below mean tournament success percentages. The success of elite kickers dropped below the mean tournament success percentage (75%) when the distance to goalposts increased above 42 m, consistent with findings of Quarrie and Hopkins (2015). A threshold value of angle was located at 39˚ for an exemplar 32 m place kick, which aligns well with comparable evidence from previous research that has reported a 76% success for a 32 m place kick with a 34° angle (Quarrie & Hopkins, 2015).

Unlike other self-paced skills, such as basketball free throws and soccer penalties, place kicks in Rugby Union are executed from various locations. Distance to, and angle from the posts, are significant predictors of kick outcome and we have identified threshold values for performance outcomes that appear to be influenced by these key task constraints. Whilst

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

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

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

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

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

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

Researchers have previously indicated that prior performance can influence perception of task difficulty when kicking towards a target (Witt & Dorsch, 2009). Theoretically, suggestions of a relationship between preceding actions and perception of a current task are underpinned by Gibson's (1979) ecological approach to visual perception and the reciprocity of perception and action. Furthermore, various interacting constraints in a performance environment can offer an explanation for how perceptions, actions and thoughts shape emergent behaviours (Seifert & Davids, 2012). In a competitive performance environment, performers are required to satisfy task demands while performing under high emotional states induced by the context of competition. Previous research (Headrick et al., 2015) has identified how emotions can continuously interact with cognitions, perception and action to constrain performance. The outcome of place kicks could influence confidence, amongst other feelings, and alter the kicker's perception of task difficulty for future kicks. One consideration of our analysis of previous performance is that the final kick of a place kicker's previous game was coupled to the first kick of the following game. The effect of several previous kicks considered in a cluster, rather than just the one previous kick analysed in the present study, and the degree of error in a previous unsuccessful kick (the distance which the ball missed the goalposts by) could be explored in future place kicking research. Additionally, similar research on free kicks in other sports, like Association Football, could be conducted to understand whether factors like distance and angle to goal may influence decisions to shoot or pass the ball, as well as success percentages of performance outcomes (e.g., a goal scored or a shot on target). Further research is required to explore the effect that an unsuccessful final kick, particularly in losing situations, has on a place kicker's preparation and training for the next game. It is recommended that researchers explore the experiential knowledge of place kickers and their coaches (Renshaw & Gorman, 2015) to

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

Conclusions

Our data highlighted how subtle changes in task constraints and contextual factors can affect the emergence of performance outcomes in elite performers. We provided data from elite place kickers performing at the highest level of competition which highlighted fluctuations in place kicking success under specific contextual factors, suggesting that individual constraints such as perceptions, thoughts, emotions, and fatigue induced during competition can interact with perceptions and action to influence emergent behaviours. Future research could investigate the performance and training experiences of place kickers and coaches to explore how key task constraints and contextual factors may influence thoughts, perceptions and emotional states. Semi-structured interviews to explore the experiential knowledge of elite performers in place kicking situations can add further depth to the current quantitative analyses of task constraints and contextual factors on place kicking success. The findings of our study suggest how coaches, sport scientists and performance analysts could combine their expertise in order to design practice environments which 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	*p*	OR	95% CI
Time[a]			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[b]			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[c]			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	

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

[a]Time interval of 0-10 minutes was used as the reference category for time.

[b]Score margin of winning by 8+ was used as the reference category for score margin.

[c]Successful previous kick was used as the reference category for previous kick.

Figure Captions

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° for a 32 m kick) as indicated by the black x's.

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.

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

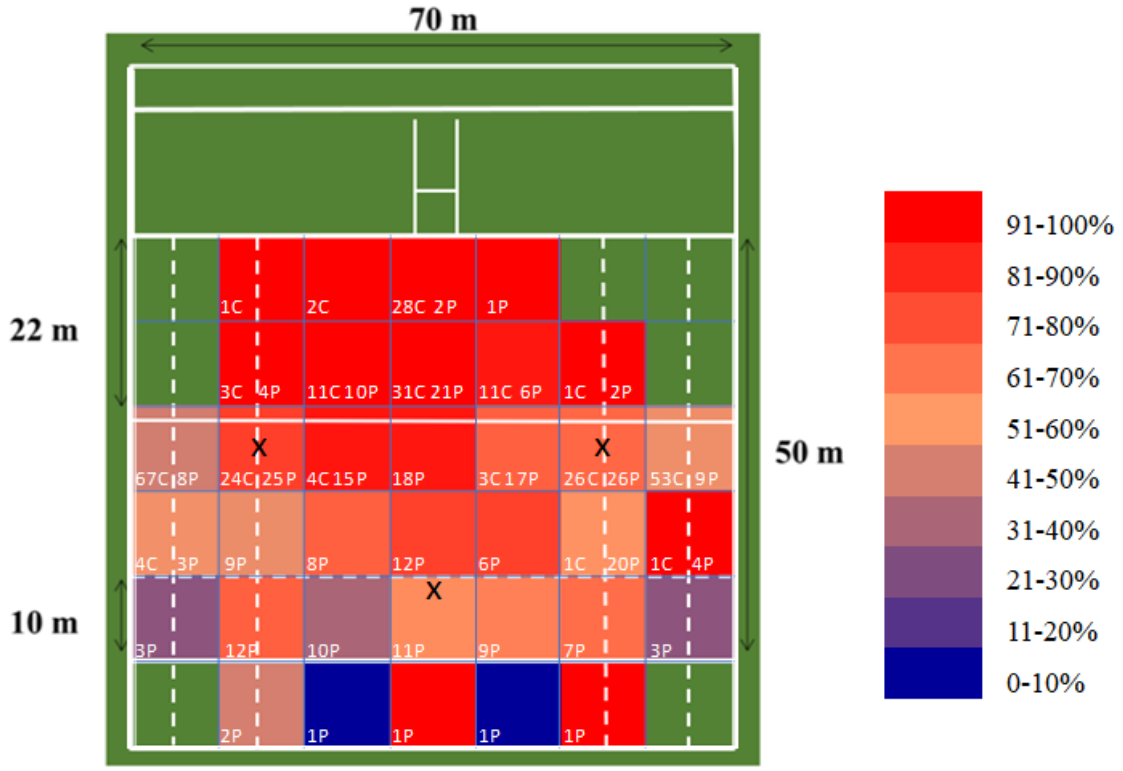

Figure 1. Distribution of mean kicking success percentages in the 2015 Rugby World Cup depending on the location of place kicks, including thresholds of distance (42 m) and angle (39° for a 32 m kick) as indicated by the black x's.

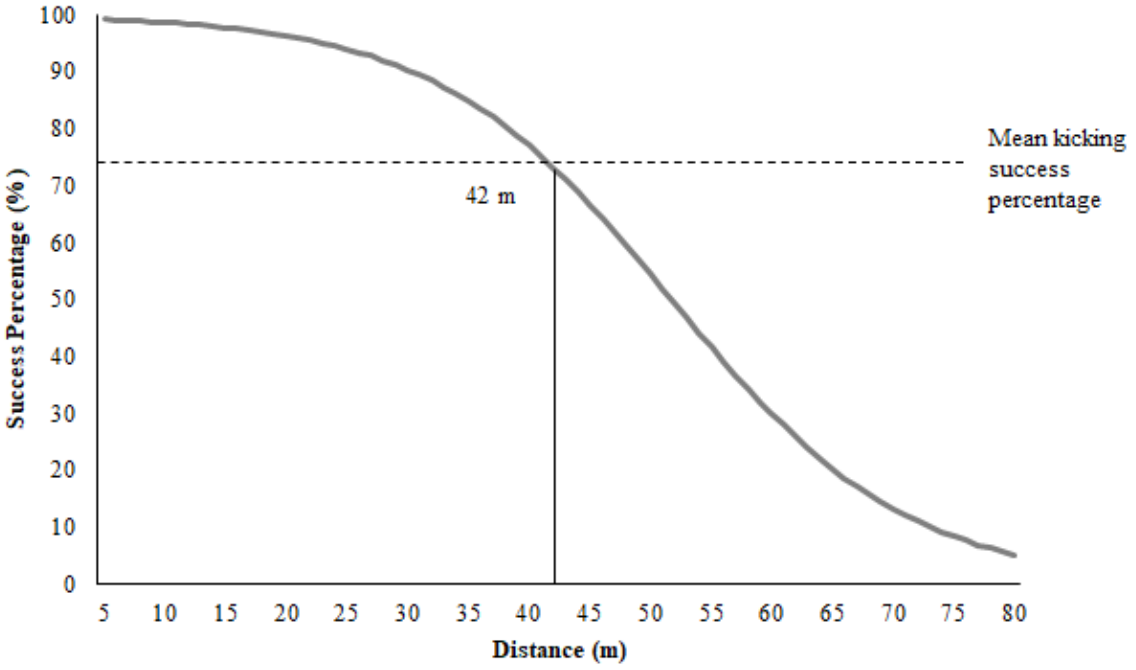

Figure 2. The odds of success at each independent metre to goalposts and the threshold for distance to goalposts, calculated using the odds ratio output from the binomial logistic regression model.

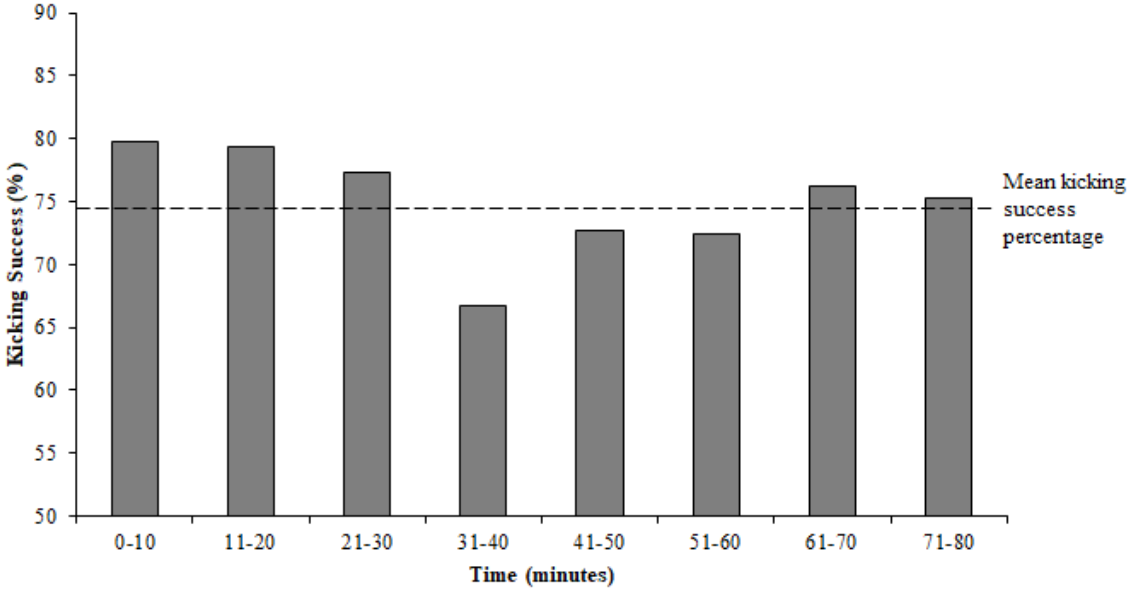

Figure 3. Mean kicking success percentages across 10-minute time intervals of matches in the 2015 Rugby World Cup.

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