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An observational analysis of kicker–goalkeeper interaction in penalties between national football teams in international competitions

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ABSTRACT

An observation instrument was designed to analyse the interaction between the kicker and goalkeeper in a penalty kick, which allows to obtain relevant information in order to predict the direction of the kick. To fulfil this aim, an analysis was carried out of the interaction between kickers and goalkeepers in penalties taken in the following international team competitions: European Football Championship, Africa Cup of Nations, Copa América, AFC Asian Cup and Concacaf Gold Cup. Intra and inter-observer reliability was guaranteed using Cohen's Kappa coefficient. Evidence was produced of generalisation accuracy in the observation sample and of the validity of the observation instrument. The results obtained provide relevant information regarding the zone –or sector– of the goal towards which the kick is aimed, from the information contained: in the contextual dimensions "competition", "match time", "match score" and "match result"; and in the dimensions that make up the diachronic structure of the observation instrument –"start of kicker's run-up in relation to the ball", "goalkeeper actions prior to the kick", "movements in kicker's run-up", "length of kicker's run-up", "speed of kicker's run-up", "direction of kicker's supporting foot", "position of opposite arm to kicker's kicking foot" and "contact surface".

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Football; penalty; interaction; observational methodology; synchronic and diachronic analysis

1. Introduction

A penalty involves the interaction between two participants – player and goalkeeper – with different aims (Furley et al., 2017; Lopes et al., 2012). In this interaction, the player will try to mislead the goalkeeper so that he will not guess where the kick will be aimed; whilst the goalkeeper will try to generate uncertainty and doubt in the kicker so that he will kick with less precision and attempt to guess which side the shot will be aimed at (Van der Kamp & Masters, 2008). The ball takes between 408 and 620 ms to reach the goal (Sánchez et al., 2005), while the goalkeeper may need between 700 and 1000 ms to reach the ball, depending on the placement of the kick (Dicks et al., 2010). If the goalkeeper does not anticipate the movement, this considerably reduces the probability of stopping the shot (Savelsbergh et al., 2002).

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Penalty kick efficiency in the World Cup, the European Championship and the Copa América were set between 73.2% (Noël et al., 2021) and 78.9% (Jordet et al., 2007). If a penalty is awarded during a match, there is a great possibility of it altering the score and being relevant to the result. Effectiveness in penalty shootouts is reduced to 70% (López-Botella & Palao, 2007) and even to 64.3% from the sixth kick to the ninth (Jordet et al., 2007), which is explained by the fact that not all players are specialist penalty kickers and that the more important the penalty, the higher the degree of anxiety produced in the player (McGarry & Franks, 2000).

The context and importance of the penalty modify the kicker's emotional state (Jordet & Elferink-Gemser, 2012); the competition itself (Palao et al., 2010) and the point in the match when the penalty occurs are both relevant. In the European Championship and World Cup, twice the number of penalties is awarded in the second half of the match than in the first, and more penalties are given in the last 30 min than in the first 60 (Dalton et al., 2015).

Studies have been carried out which analyse the kicker's movements and posture and the relationship with the goal zone the kick is aimed at the supporting foot tends to point in the direction that the ball is aimed (Lees & Owens, 2011); the distance from the supporting foot to the ball when the kick is taken influences the height of the shot in that the further away from the ball the supporting foot is, the higher the shot (Lees et al., 2010); faster speed when approaching the ball implies less accuracy (Lees & Nolan, 2002); if accuracy is desired, then the kick is taken with the interior side of the foot, and if greater speed is the objective, then the instep is used (Hunter et al., 2018); a right-footed kicker with the supporting foot pointing left and the left arm at an upper abduction angle greater than 90° has a higher possibility of shooting towards the left (Buscà et al., 2022).

The goalkeeper's behaviour prior to the kick has also been studied at the beginning of the kicker's run-up, goalkeepers tend to focus on the upper parts of the body – head, chest and arms – but, as the moment of contact approaches, they focus their attention on the lower part of the body (Navia et al., 2013); expert goalkeepers need around 250 ms to receive the latest information from the kicker, beginning to move about 50 ms before the player kicks the ball (Dicks et al., 2010); inaction – not diving in a penalty that ends in a goal – produces in goalkeepers a greater feeling of not having done everything possible to stop the penalty than if they had dived, despite the fact that if the goalkeeper remains in the middle and the ball goes to the middle he has more possibilities of stopping the ball than if he chooses one side and the ball goes to that side (Bar-Ely et al., 2007); if the goalkeeper places himself between six and ten centimetres to one side at the moment the ball is kicked, this increases the probability that the kicker will aim at the side he perceives to be more open by 10% (Masters et al., 2007); if the goalkeeper flaps his arms up and down, this makes the kicker perceives the goal in a different way, and produces lower shots that are also closer to the goalposts (Van der Kamp & Masters, 2008).

A team that aspires to go far in international competitions with national squads will, in all probability, be faced with a penalty – in favour or against – at some point on their way to the final. Since the first edition of the European Championship was held in 1960, there have been 88 penalties in 440 matches, an

average of 0.20 penalties per match (https://es.uefa.com). Furthermore, there is a good possibility that, during such a competition, a team will be faced with a penalty shootout, given that they occur in 21.8% of the qualifying matches of the World Cup, European Championship and Copa América (Jordet et al., 2007). In the last European Championship´21, Italy won the championship after two penalty shootouts. In the Copa América´21 and Asian Cup´19, the champions Argentina and runners-up Algeria also won a penalty shootout in the qualifying rounds in order to get to the final. Even in the last World Cup – Qatar 22 – Argentina won the quarterfinals and the final on penalties.

This work had two aims. The first was to design an observation instrument to analyse the kicker–goalkeeper interaction in a penalty kick, allowing the goalkeeper and coaching team to obtain relevant information for predicting the direction of the kick. This aim was fulfilled through a second aim focussing on the analysis of kicker–goalkeeper interaction in penalties taken in the following international team competitions held between 2019 and 2021: European Championship, Copa América, Africa Cup of Nations, AFC Asian Cup and Concacaf Gold Cup.

2. Method

This work has been developed at the core of observational methodology (Anguera, 1979). Observational methodology, being justifiably considered as *mixed method* in itself (Anguera et al., 2017), has developed its own *quantitizing* pathway from the option "*connecting*" (Creswell & Plano Clark, 2017) that allows the alternation of QUAL-QUAN-QUAL stages and is being widely applied in different fields, including sports.

In line with (Anguera et al., 2011), the proposed observational design was as follows: nomothetic, in analysing the performance of 149 kickers and 66 goalkeepers; of follow-up that is both inter-session (penalties taken in different competitions) and intra-session (behaviours occurring in each of the penalties that make up the observational sample); and multidimensional, with proxemic and gestural type dimensions.

3. Participants

The observational sample was made up of all the penalties taken ($n = 185$) in the following international competitions between national football teams: European Championship´21 ($n = 55$; order number: 1–55), Copa América´21, ($n = 36$; 56–91), Asian Cup´19 ($n = 35$; 92–126), Africa Cup of Nations´19 ($n = 48$; 127–174), and Concacaf Gold Cup´21 ($n = 11$; 175–185).

Film footage of all the penalties is openly available in the official YouTube channels of the UEFA (@uefa), CONCACAF (@concacaf), CONMEBOL (@conmebol), CAN (@caftvafricanfootball) and AFC @afcasiancup). This research work has been approved by the Research Ethics Committee of the University of La Rioja (file Nº 43_2023).

Table 1. Observation instrument: dimensions, category systems and codes.

Nº	DIMENSION	CATEGORY SYSTEMS AND CODES
1	Competition	European Championship (CEC), Copa América (CCAM), Africa Cup of Nations (CCAF), AFC Asian Cup (CCAS), Concacaf Gold Cup (CCO)
2	Match Time	0–30´ (TI), 31–60´ (TM), 61–90+ (TE), Extra time (TET), Penalty shootout (TPS)
3	Match Score	Winning (MSW), Drawing (MSD), Losing (MSL)
4	Match Result	Won (MRG), Drawn (MRD), Lost (MRL), Penalty shootout (MRPS)
5	Start of kicker's run-up in relation to the ball	Right (SRR), Middle (SRM), Left (SRI)
6	Goalkeeper's actions prior to the kick	No movement (GNM), Lateral movements (GML), Arm movements (GAM), Jumps (GJ), Crouches (GC), Moves forward (GMF)
7	Movements in the kicker's run-up	Skipping (MKS), Sudden stop (MSS), Change of pace (MCP)
8	Speed of kicker's run-up	Fast – with flight phase (SF), Slow – without flight phase (SS)
9	Length of kicker's run-up	Up to 3 steps (LKS), More than 3 steps (LKL), From outside the area (LKOA)
10	Direction of kicker's supporting foot	To the left of the goalkeeper (DSFL), To the middle (DSLM), To the right of the goalkeeper (DSFR)
11	Position of opposite arm to kicker's kicking foot	Arm outstretched and open (OAO), Arm close to body (OAC), Arm open with elbow bent (OAEF), Arm half-open (OAHO)
12	Kicker's kicking foot	Left (FL), Right (FR)
13	Kicker's contact surface	Interior (CSI), Exterior (CSE), Instep (CSIN)
14	Goalkeeper's position when kick taken	Defeated to the left (GPL), Defeated to the right (GPR), In the middle (GPM)
15	Shot trajectory	Rectilinear (STR), Parabolic (STP)
16	End zone-sector of kick	Z1 and Z4, left sector; Z2 and Z5, middle sector; Z3 and Z6, right sector *Z1 Z2 Z3* *Z4 Z5 Z6*
17	Result of kick	Goal (RG), Goalkeeper blocks (RGB), Crossbar or post (RP), Miss (RM)

4. Observation instrument

For this work, an *ad hoc* observation instrument was designed (see Table 1) that is a combination of field format and category systems, from an exhaustive theoretical review. In terms of their relevance, it is worth highlighting the works of Nolan (2001), Savelsbergh et al. (2002), Williams and Griffiths (2002), Dicks et al. (2010), Lees and Owens (2011), Li et al. (2015), Furley et al. (2017), Nadal et al. (2018), Prieto Lage et al. (2020) and G. S. Pinheiro et al. (2021).

The observation instrument, based on Anguera et al. (2007), was developed from a dynamic process of dimensions proposal and an initial formulation of tentative category systems for each one, subsequently modified in accordance with an empirical-inductive strategy, and then again, according to a theoretical-deductive strategy. After recording 22 penalties that do not form part of the observational sample of this research (penalty shootout in the final of the Europa League´21 -Villarreal vs. Manchester United) without detecting new behaviours in any of the criteria, the precautionary test was passed, with catalogue type lists being assumed as repertory type lists (Anguera & Izquierdo, 2006), counting on the presumption of exhaustivity.

5. Recording and coding

Recording and coding of the penalties was done via the LINCE software, version 1.4 (Gabín et al., 2012). The recording centres on four key moments or *critical frames* (Lindeman et al., 2000) are as follows: Critical frame 1) is recorded at the moment the kicker begins his approach to the ball (criteria recorded from 1 to 5); critical frame 2) is

recorded when the kicker places his non-dominant supporting leg – in terms of the kick – on the ground (criteria recorded 1–4, 6, 8–11); critical frame 3) is recorded when the foot hits the ball (criteria recorded 1–4, 12–14); critical frame 4) is recorded when the goalkeeper stops the ball, the ball touches the net, goes over the goal line or touches one of the posts (criteria recorded 1–4, 15–17). Furthermore, during the approach run-up – between critical frame 1 and critical frame 2 – other frames are recorded that are not considered key (Garzón et al., 2011), but which capture the interaction between the kicker and goalkeeper (criteria recorded 1–4, 6 and 7).

The obtained data, in accordance with Bakeman's classical typology (1978) for observational data, are type IV, concurrent and time-based. Similarly, in accordance with Bakeman and Quera (1995), the data type is multi-event, due to the fact that the observational design is multidimensional.

6. Data reliability

Two observers were given the task of recording the data that underpins this research work. The observers' training was carried out in three phases, in line with the proposal of Arana et al. (2016), p. 1) theoretical training in the observation instrument; 2) theoretical-practical training in the recording procedure in relation to feeding the observation instrument into the LINCE software; 3) practical training: observers' autonomous recording of an observation session outside the sample – penalty shootout in the final of the UEFA Champions League´16, Real Madrid vs. Atlético de Madrid. The training process was considered complete once a high level of concordance – Cohen's Kappa (1960) greater than 0.80 – between the observers had been obtained in the nine penalties that make up the sample.

The first observer recorded the whole of the observational sample. Subsequently, in order to provide evidence of intra- and inter-observer concordance, both observers went on to record 11.35% of the total number of penalties – the second observer on two occasions –, with the following distribution by competition: European Championship (10.90%), Copa América (11.11%), Asian Cup (11.42%), Africa Cup of Nations (10.41%) and Gold Cup (16.66%). There was a period of 1 week between the first and second observations of both observers. Table 2 shows the percentage of agreement and the Kappa coefficient by competition. The values of Cohen's Kappa coefficient (1960) obtained guarantee an *almost perfect* agreement (Landis & Koch, 1977, p. 165).

6.1. Generalizability of the results

This section was developed at the heart of the Generalisability Theory (Cronbach et al., 1972). The sum of squares necessary for the generalisability design was obtained via SPSS, version 25, at the heart of the General Linear Model (GLM). The data was subsequently fed into Ysewijn's *Generalisability Theory (GT) Software* (1996). Table 3 presents the results that correspond to the generalisability design: [Competition] [Category] [Penalty]. Variance components estimation was carried out for an infinite population for all the facets. The design reveals that variability is associated with the category facet and its interaction with the penalty and competition facets, being null for the penalty and competition facets. The elevated value of the determination coefficient obtained ($r^2 = 1$) indicates that, with the

Table 2. Reliability evidence. Intra- and inter-observer concordance.

	1st observer intra-observer concordance		2nd observer intra-observer concordance		Inter-observer concordance	
	Kappa	% Agreement	Kappa	% Agreement	Kappa	% Agreement
European C.	0.93	94 %	0.93	94 %	0.87	87 %
Copa América	0.88	89 %	0.81	82 %	0.83	83 %
Asian Cup	0.95	96 %	0.81	82 %	0.86	87 %
Gold Cup	1	100 %	1	100 %	0.87	89 %
Africa Cup	0.96	96 %	0.92	92 %	0.87	87 %

Table 3. Generalisability analysis results corresponding to the observation plan [competition] [category] [penalties].

Source	Sum of squares	gl	Root mean square	% Variance
Corrected model	18545.637	11654	1.591	
Intersection	2062.973	1	2062.973	
Competition	.114	4	.028	
Penalties	16.680	54	.309	
Categories	4310.828	62	69.529	23%
Competition*Penalties	41.205	126	.327	
Competition*Categories	3548.974	248	14.310	28%
Penalties*Categories	3118.726	3348	.932	13%
Competition*Penalties*Categories	4625.390	7812	.592	38%
Error	.000	0		
Total	21775.000	11655		
Corrected Total	18545.637	11654		

combination of the aforementioned facets, we can explain with guarantees the variability they provide in their development of data packs that make up the observational sample. The analysis of the generalisability coefficients of the measurement plan that positions the penalties facet as an instrumentation facet, [Competition] [Category]/[Penalty], determines that the analysed penalties obtain a reliability generalisation accuracy of 0.956 – the same value of relative (e^2) and absolute generalisability coefficient (Φ).

The validity of the observation instrument is addressed by placing the category facet in the instrumentation facet, [Competition] [Penalty]/[Category], in line with Blanco-Villaseñor et al. (2010). Within the methodological framework of the Generalisability Theory, an instrument is considered valid when variability corresponding to the category facet is very high and guarantees, therefore, the observational instrument's capacity for discrimination, which translates to a generalisability coefficient equal or near to 0, as is the case with this research work (coefficient G relative and absolute = 0.00).

6.2. Data analysis

Two types of data analysis were carried out: one synchronic (Cramer's V and adjusted residuals) and the other diachronic, with detection of regular behavioural structures in the recordings that make up the observational sample (T-pattern detection).

With the synchronic statistical analysis, carried out using the statistical package IBM-SPSS-26, our aim was to specify the existing relationship between the "goal sector" (Z1 and Z4, left sector; Z2 and Z5, middle sector; Z3 and Z6, right sector) and the criteria in the four *critical frames*, taking into account the leg – right or

left – with which the kicker takes the kick. To this end, Cramer's V was used, which, in addition to analysing the existence of an association between category dimensions, enables us to measure the intensity of this relationship. The value of this coefficient goes from 0 (minimal association or perfect independence between dimensions) to 1 (maximum association or perfect association between dimensions). According to Crewson (2006) intensity is as follows: high when the value of the coefficient is greater than 0.50; moderate if the value is between 0.30 and 0.50; low if the value is between 0.10 and 0.30; and there is no association with values lower than 0.10.

Once the significance and intensity of the relationship between two given criteria had been determined, a specific analysis was done of the relationship established between the categories that make up the criteria, through an analysis of adjusted residuals (Haberman, 1973). This test involves dividing the residual of each cell (difference between observed and expected frequency) by the square root of the variance of the residual. The values obtained with this transformation follow a normal distribution. Therefore, for a significance level of 0.05, all those residuals typified higher than 1.96 are statistically significant – a positive relationship is inferred between the categories, and they report cells with more cases in that cell than there should have been if the analysed variables had been independent. Meanwhile, from the residuals lower than −1.96 an association of statistically significant inhibition is inferred, indicating that in the cell fewer cases were recorded than there should have been under the independence hypothesis. With a view to avoiding redundancy in the results section, only adjusted residuals with a plus sign will be mentioned.

In terms of diachronic analysis, a search was carried out of regular behavioural structures hidden in the record via the software THEME6.Edu, which uses an algorithm developed by Magnusson (1996, 2000) as its base, thus enabling the detection of T-patterns – a "statistical construction" detected from a combination of events that occur in the same order, with time distances between them that stay relatively invariant in relation to the null analysis that each recorded behaviour code is independent and randomly distributed in time. Although the main contribution of the THEME software is the detection of temporal patterns, it also offers the possibility of detecting sequential structures under the order parameter (Lapresa, Anguera, et al., 2013; Lapresa, Arana, et al., 2013; Terroba et al., 2021). In this work, we have resorted to this analysis possibility that THEME allows, via the assignation to each occurrence of a duration equal to 1.

In line with Amatria et al. (2017) quantitative and qualitative filters were used in the process of T-pattern detection and selection. In terms of quantitative filters, the following search parameters were selected (see reference manual: PatternVision Ltd, & Noldus Information Technology bv, 2004): a) a fixed minimum frequency of 2; b) a significance level of 0.005, by which the percentage probability of accepting a critical interval due to chance is of 0.5%; c) a redundancy reduction fixed at 90, so that, if more than 90% of the occurrences of a new detected pattern started and finished almost at the same time as the patterns already detected, the new pattern was discarded. In terms of qualitative filters, we selected – for their relevance in fulfilling the pre-set aim – those T-patterns that reflect critical frames 3 and 4, in addition to critical frame 2 or other non-key frames.

7. Results

7.1. From the statistical analysis

Below we present the results that confirm a significant association between "goal sector" (Z1 and Z4, left sector; Z2 and Z5, middle sector; Z3 and Z6, right sector) and the criteria that integrate the four critical frames, bearing in mind the leg – right or left – that the kicker uses to take the kick (see Table 4).

In right-footed kickers, we found a high intensity in the association with the criterion "direction of kicker's supporting foot" (Cramer's V = 0.790; $p < 0.001$). In the residuals analysis, a positive relationship can be observed: between the category "kicker's supporting foot pointing to the left of the goalkeeper" and the kick being aimed at the "right sector" (z = 9.221); between the category "kicker's supporting foot pointing to the middle of the goalkeeper" and the kick being aimed at the "middle sector" (z = 9.766); and between the category "kicker's supporting foot pointing to the right of the goalkeeper" and the shot being aimed at the "left sector" (z = 8.933).

In terms of the criterion "kicker's contact surface" the intensity was moderate (Cramer's V = 0.431; $p < 0.001$). In the local analysis, a positive relationship can be seen between the "interior" contact surface category and the shot going towards the "right sector" (z = 5.155), and between the "instep" contact surface category and the shot being aimed at the "left sector" (z = 3.815).

The association intensity is low with the criteria: "position of opposite arm to kicker's kicking foot" (Cramer's V = 0.283; $p < 0.001$), "speed of kicker's run-up" (Cramer's V = 0.222; $p = 0.031$), and "start of kicker's run-up in relation to the ball" (Cramer's V = 0.234; $p = 0.005$). The results of the adjusted residuals analysis indicate a positive association between the categories: "position arm outstretched and open opposite to kicker's kicking foot" and the shot going towards the "left sector" (z = 3.735); "position arm close to body opposite to kicker's kicking foot" and the shot being sent to the "right sector" (z = 4.400); "kicker's fast run-up speed" and a shot to the "middle sector" (z = 2.592); "start of kicker's run-up to the middle of the ball" and a shot to the "middle sector" (z = 3.290)

As far as left-footed kickers are concerned, a high intensity was demonstrated in the association with the "direction of the kicker's supporting foot" (Cramer's V = 0.718; $p < 0.001$). In the residuals analysis, a positive relationship was shown: between

Table 4. Significant results of the global analysis of the relationship intensity (Cramer's V) between the criterion "End sector of kick" and the rest of the criteria in the observation instrument, depending on the foot used to take the kick.

	End sector of kick	
Criteria	Right-footed kickers	Left-footed kickers
Direction of kicker's supporting foot	.790**	.718**
Kicker's contact surface	.431**	.468*
Position of opposite arm to kicker's kicking foot	.283**	
Start of kicker's run-up in relation to the ball	.222*	
Speed of kicker's run-up	.234**	
Match result		.460*
Match score at the moment of the penalty		.365*

** $p<.001$; *$p<.05$

Table 5. Local analysis of adjusted residuals depending on the foot used to take the shot and the goal sector the shot is aimed at. The value of the significantly adjusted residual is shown in brackets.

Left Sector		Middle Sector	Right Sector
Right Foot	Direction of supporting foot: right (8.933) Contact surface: instep (3.815)Arm outstretched and open (3.735)	Direction of supporting foot: middle (9.766) Start of run-up: middle (3.290) Speed of run-up: fast (2.592)	Direction of supporting foot: left (9.221) Contact surface: interior (5.155) Arm close to body (4.400)
Left Foot	Direction of supporting foot: right (4.066) Contact surface: interior (2.966) Match result: drawn (2.498) Match score: winning (2.307)	Direction of supporting foot: middle (4.992) Match result: lost (2.966) Match score: losing (2.438)	Direction of supporting foot: left (4.432)

the category "kicker's supporting foot pointing to the left of the goalkeeper" and the shot being aimed at the "right sector" (z = 4.432); between the category "kicker's supporting foot pointing to the middle of goalkeeper" and the shot going to the "middle sector" (z = 4.992); and between the category "kicker's supporting foot pointing to the right of the goalkeeper" and the shot being aimed at the "left sector" (z = 4.066).

Furthermore, a moderate relationship was obtained with the criterion "kicker's contact surface" (Cramer's V = 0.468; $p = 0.014$); with the "match result" (Cramer's V = 0.460; $p = 0.005$); and with the "match score at the moment of the penalty" (Cramer's V = 0.365; $p = 0.024$). The results of the adjusted residuals analysis indicate a positive relationship between the categories: contact surface "interior" and the shot going towards the "left sector" (z = 2.966); "match result drawn" and a shot towards the "left sector" (z = 2.498); "match result lost" and the shot being aimed at the "middle sector" (z = 2.948); "match score winning" and a shot to the "left sector" (z = 2.307); "match score losing" and a shot to the "middle sector" (z = 2.438). Table 5 shows information relative to the adjusted residuals analysis.

7.2. T-patterns detected

Table 6 shows the T-patterns detected, by competition, with the search parameters and pre-set qualitative filters (Amatria et al., 2017) ordered according to the criteria that had high or medium intensity (Cramer's V) in the association with the goal sector the shot is aimed at. It contains information relating to the zone the shot is directed at, the constituent T-pattern multi-events, the penalties in which it occurs and the mean of the internal intervals between multi-events: if the mean is equal to 1, the behaviours reflected in the T-pattern multi-events are consecutive, and therefore there are no interspersed behaviours; if it is equal to 2, there is an interspersed behaviour; etc. Furthermore, Figure 1 presents a graphical representation of each one of the T-patterns contained in Table 6.

Table 6. T-patterns detected with the search parameters and pre-set qualitative filters.

N	Significant Criteria	Competition	Zone	T-pattern	Penalties	Mean Internal Intervals
1	Direction of supporting foot- Position of opposite arm to kicker's kicking foot- Speed of run-up- Start of run-up in relation to the ball	European Champ.	6	(((cec,tps,msd,mrps,sri cec,tps, msd,mrps,gc,sf,lkl,dsfl,oao) cec, tps,msd,mrps,rf,csi,gpl) cec,tps, msd,mrps,str,z6,rgb)	30–48	2-1-1
2	Direction of supporting foot- Position of opposite arm to kicker's kicking foot- Speed of run-up	Copa América	6	(((ccam,tps,msd,mrps,sri ccam, tps,msd,mrps,mks) ccam,tps, msd,mrps,gc,ss, lkl,dsfl,oac) (ccam,tps,msd,mrps,rf,csi, gplccam,tps,msd,mrps,str,z6, rgb))	85–87	1-2-1-1
3				((ccam,tps,msd,mrps,appl ccam, tps,msd,mrpsgc,ss, lkl,dsfl,oac) (ccam,tps,msd,mrps,rf,csi,gpl ccam,tps,msd,mrps,str,z6,rgb))	85–90	1-1-1
4				((ccam,tpn,re,rfpn,gc,ss, lkl,dsfl, oac ccam,tpn,re,rfpn,rf,csi,gpl) ccam,tpn,re,rfpn,str,z6,rgb)	85-87-90	1–1
5	Contact surface- Ball trajectory	European Champ.	1	((cec,tps,msd,mrps,sri cec,tps, msd,mrps,gam)(cec,tps,msd, mrps,rf,csin,gpl cec,tps,msd, mrps,str,z1,rg))	16–27	1.5-2.5-1
6	Contact surface- Ball trajectory.	European Champ.	4	((cec,tps,msd,mrps,gml cec,tps, msd,mrps,rf,csi,gpr) cec,tps, msd,mrps,str,z4,rgb)	29-31-36	2.67–1
7		Asian Cup	4	((ccas,tps,msd,mrps,sri ccas,tps, msd,mrps,gc)(ccas,tps,msd, mrps,rf,csi,gpl ccas,tps,msd, mrps,str,z4,rg))	106–110	1-2.5-1
8		Copa América	6	((ccam,tps,msd,mrps,sri (ccam, tps,msd,mrps,gc ccam,tps,msd, mrps,rf,csi,gpl)) ccam,tps,msd, mrps,str,z6,rg)	76–77	1.5-2.5-1

8. Discussion

What follows is a discussion of the results obtained from the data analyses (synchronic: Cramer's V and adjusted residuals; and diachronic: T-pattern detection), done following the pre-set order in the record structure. The record structure, in addition to integrating contextual aspects ("competition", "match time", "match score" and "match result") respects the diachrony present in a penalty kick: "start of the run-up in relation to the ball", "goalkeeper's actions prior to the kick", "movements in the kicker's run-up", "length of kicker's run-up", "speed of kicker's run-up", "direction of kicker's supporting foot" and the "position of the opposite arm to kicker's kicking". The information provided by these dimensions can be considered effective since it is within the decision-making margin that the goalkeeper has, allowing him to cover the goal with conviction depending on the direction of the penalty (Dicks et al., 2010; Savelsbergh et al., 2002); by the time the "contact surface" arrives it will be too late for the goalkeeper to anticipate where the ball will go (Hunter et al., 2022).

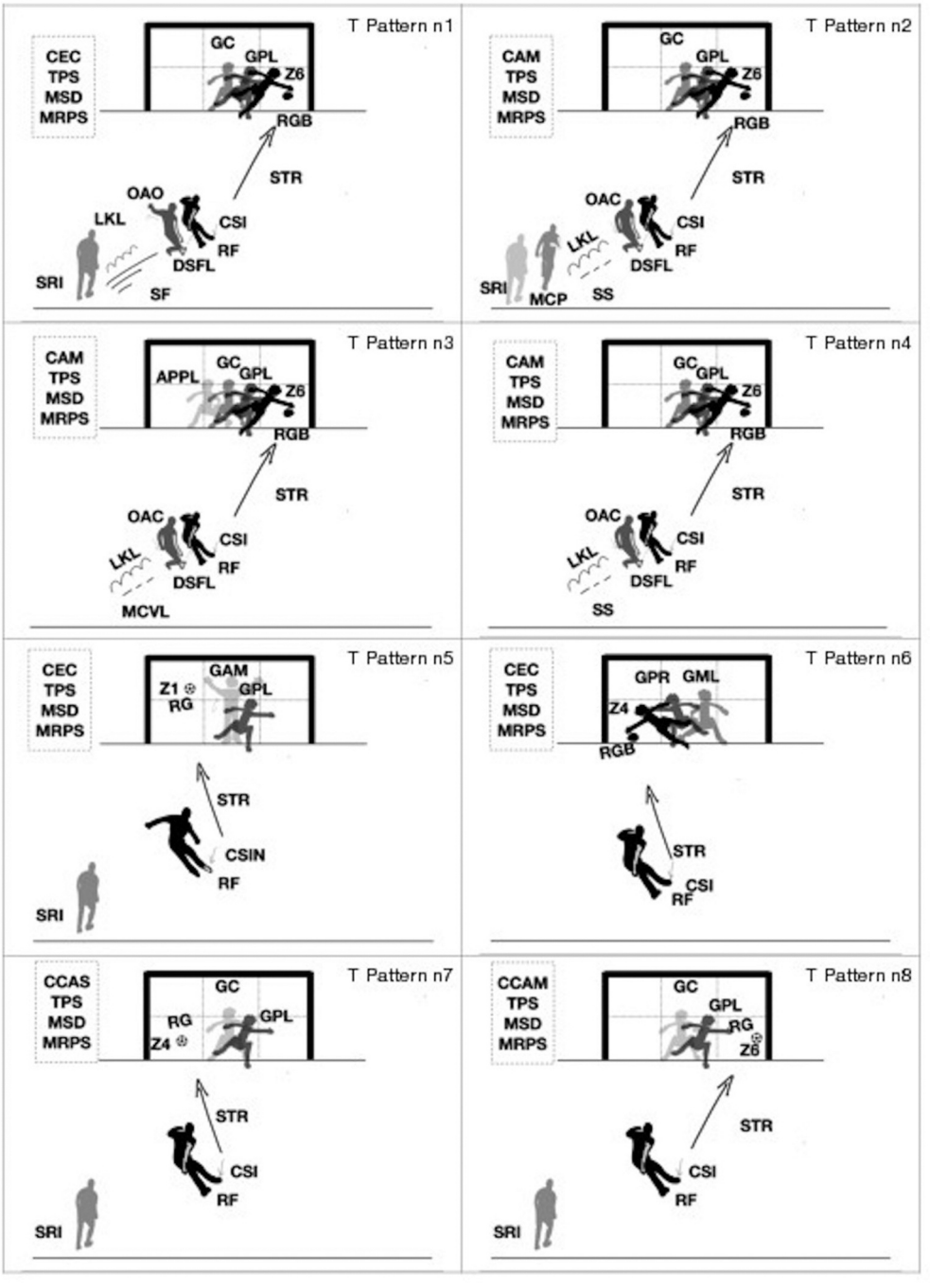

Figure 1. Graphical representation of the information contained in the multi-events that make up the detected T-patterns from the diachronic structure of the record. Contextual criteria are shown inside a rectangle.

With regard to contextual aspects, in left-footed players, a medium intensity association relationship was detected between the finishing sector of the kick and the "match score" at the moment the penalty is taken: when the kicker's team is "winning" the association is with the "left sector"; whilst, if the team is "losing", it is with the "middle sector". This aspect was not found in any existing scientific literature, and so we consider it to be a discovery of this study. In penalty shootouts, the analysis of adjusted residuals shows activation in that the players – right and left-footed – kick the ball towards their natural side, in line with the results of Palao et al. (2010). For biomechanical reasons, the natural aiming side for players with a right-side dominance is the "left sector", and that of players with a left-side dominance is the "right sector" (Navia & Ruiz, 2014).

In terms of the kickers' behaviours that can provide relevant information for anticipating the goal sector the shot is aimed at, we found that, in right-footed kickers, from the first kicker behaviour reflected in the observation instrument's record structure (criterion "start of run-up in relation to the ball"), relevant information is being generated that the goalkeeper can use to anticipate where the shot will be aimed. An associated relationship of low intensity was detected between the finishing sector of the kick and the "start of run-up in relation to the ball". Williams and Griffiths (2002) confirmed that when directing a penalty kick towards the goal side corresponding to the dominant foot, the participants tended to approach the ball from a wider angle than when kicking with their non-dominant side. In this current research, we found an activation relationship between the start of the kicker's run-up in relation to the ball "middle" and the finishing sector "middle", and between the start of the kicker's run-up in relation to the ball "left" and finishing sector "right". Furthermore, regular behavioural structures were detected in the European Championship (T-Pattern with order number 1) and in Copa América (T-Patterns with order numbers 2, 3, 4 and 8) that reflect a start of the kicker's run-up in relation to the ball "left" in penalties kicked towards the "right sector".

Continuing with the diachronic structure of penalty kicks reflected in the observation instrument, we found that with right-footed kickers there is an activation relationship between the speed of the kicker's run-up "fast" and finishing in the "middle sector", which in left-footed kickers corresponds to a shot towards the "right sector". In left-footed players, there is activation between the speed of the kicker's run-up "slow" and the shot being aimed towards the "left sector". The T-patterns with order numbers 2, 3 and 4 detected in penalties taken in Copa América reflect the kicker's approach with a run-up speed "slow" and the kick with contact surface "interior" in penalties aimed towards the "left sector".

Experienced goalkeepers start to move about 50 ms before the kicker makes contact with the ball (Dicks et al., 2010), a fact that supports the importance of the information provided by the dimension "direction of kicker's supporting foot", that is found within the time margin the goalkeeper has to anticipate his movement and increase his success rate (Savelsbergh et al., 2002). In this criterion there is a high-intensity association relationship with the finishing sector, both in left- and right-footed kickers. The analysis of adjusted residuals specifies the association between direction of the kicker's supporting foot "right" with a shot towards the "left sector"; direction of the kicker's supporting foot "middle" with a shot towards the "middle sector"; and direction of the kicker's supporting foot "left" with a shot towards the "right sector". Furthermore, in the T-pattern with order number 1 (corresponding to the European Championship) and in the T-Patterns

with order numbers 2, 3 and 4 (corresponding to the Copa América) the "direction of kicker's supporting foot" coincides with the finishing sector of the penalty. This result is in line with those of Li et al. (2015) and Nadal et al. (2018) who found a significant association relationship between the direction of the shot and the direction towards which the kicker's supporting foot was pointing.

In this same time interval, corresponding to critical frame 2, another important reference is the "position of opposite arm to kicker's kicking foot". In right-footed players, a low-intensity association relationship was detected with the goal sector the kick is aimed at. From the local analysis of adjusted residuals, an activation emanates between the category "arm outstretched and open" and the finishing "left sector", and of "arm close to body" with finishing "right sector". Furthermore, in T-patterns with order numbers 2, 3 and 4 (Copa América) it can be seen how kickers who kick the ball with their "arm close to the body" aim the ball towards "zone 6", corresponding to the finishing "right sector". These results are consistent with those of Nadal et al. (2018) – a player who kicks the ball with his arm outstretched and in abduction tends to aim towards the sector that corresponds to that arm – and Buscà et al. (2022) – the probability that a right-footed player aims the ball towards the "left sector" increases when the non-dominant arm is outstretched and in abduction; and, by contrast, if the arm is close to the body there is an increased probability of the shot being aimed towards the right sector.

In the final moment of the diachronic structure of the record, we detected a medium intensity association relationship between the finishing sector of the shot and the "contact surface" used by both right- and left-footed kickers. This is the last reference that the goalkeeper will have to be able to predict where the shot will be aimed, if the ball is not travelling very fast and is not very accurate. To be more exact, penalty kicks tend to be weaker and more imprecise (Van der Kamp, 2006, 2011) when the goalkeeper is facing a kicker who uses a strategy dependent on the goalkeeper, i.e. assessing the goalkeeper's behaviour before deciding where to aim the kick – a strategy adopted by 27.34% of the kickers (Noël et al., 2021). In terms of the adjusted residuals, the association is specified in that the players – whether they be right or left-footed – use the inside of their foot to direct the shot towards their natural side: when taking a penalty with the inside of their foot, left-footed kickers aim towards the "left sector," while players with a dominant right-side aim towards the "right sector". The above information is complemented by that provided by the constituent T-pattern multi-events with order number 1 (European Championship) and of the T-patterns with order numbers 2, 3, 4 and 8 (Copa América), in which the kicker uses the contact surface "interior" in shots aimed towards "zone 6" – finishing "right sector". An association relationship has also been found in right-footed players who use their "instep" as the contact surface, with the shot being directed towards the "left sector"; this information is complemented by that provided by the T-pattern with order number 5 (European Championship) in which right-footed players kick with their instep in shots aimed towards "zone 4", corresponding to the "left sector".

9. Conclusion

Two aims have been fulfilled in this research work. Firstly, an observation instrument was designed – for which evidence of reliability, validity and generalisability has been provided – to analyse the interaction between the kicker and the goalkeeper in a penalty kick, allowing the goalkeeper and coaching technicians to extract relevant information for predicting the direction of the kick. Secondly, as proof of the operability of the observation instrument, an observational analysis was carried out of the interaction between kickers and goalkeepers in the penalties taken in international team competitions held between 2019 and 2021. The high vertebration of the observation instrument means that the records achieved are a reliable register of the interaction between the kicker and the goalkeeper, but the consequential variability of each event (record row) limits the possibility of detecting T-patterns per competition. In this sense, our intention was to address in future works the specificity of shots taken in penalty shootouts regardless of the competition in which they occur. These findings provide relevant information about the zone – or sector – of the goal that the shot is aimed at from information contained in contextual dimensions and in which they configure the diachronic structure of the observation instrument. Thus, technicians and goalkeepers will be able to address the decision-making process by focusing on certain dimensions that this study deems relevant: "match time", "match score", "start of kicker's run-up in relation to the ball", "speed of kicker's run-up", "direction of kicker's supporting foot", "position of opposite arm to kicker's kicking foot", and "kicker's contact surface"

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Amatria, M., Lapresa, D., Arana, J., Anguera, M. T., & Jonsson, G. K. (2017). Detection and Selection of Behavioral Patterns Using Theme: A Concrete Example in Grassroots Soccer. *Sports*, *5*(1), 20. https://doi.org/10.3390/sports5010020

Anguera, M. T. (1979). Observational Typology. *Quality & Quantity European-American Journal of Methodology*, *13*(6), 449–484. https://doi.org/10.1007/BF00222999

Anguera, M. T., Blanco-Villaseñor, A., Hernández-Mendo, A., & Losada, J. L. (2011). Diseños observacionales: ajuste y aplicación en psicología del deporte [Observational designs: their suitability and application in sports psychology]. *Cuadernos de Psicología del Deporte*, *11*(2), 63–76.

Anguera, M. T., Camerino, O., Castañer, M., Sánchez-Algarra, P., & Onwuegbuzie, A. J. (2017). The specificity of observational studies in physical activity and sports sciences: Moving forward in mixed methods research and proposals for achieving quantitative and qualitative symmetry. *Frontiers in Psychology*, *8*, 2196. https://doi.org/10.3389/fpsyg.2017.02196

Anguera, M. T., & Izquierdo, C. (2006). Methodological approaches in human communication: From complexity of perceived situation to data analysis. In G. Riva, M. T. Anguera, B. K. Wiederhold, & F. Mantovani, (Coord.). *From Communication to Presence. Cognition, Emotions and Culture towards the Ultimate Communicative Experience* (pp. 203–222). IOS Press.

Anguera, M. T., Magnusson, M. S., & Jonsson, G. K. (2007). Instrumentos no estándar [Nonstandard instruments]. *Avances en Medición*, *5*(1), 63–82.

Arana, J., Lapresa, D., Anguera, M. T., & Garzón, B. (2016). *Ad hoc* procedure for optimising agreement between observational records. *Anales de Psicología*, *32*(2), 589–595. https://doi.org/10.6018/analesps.32.2.213551

Bakeman, R., & Quera, V. (1995). *Analyzing interaction: Sequential analysis with SDIS and GSEQ*. Cambridge University Press.

Bar-Ely, M., Azar, O. H., Ritov, I., Keidar Levin, Y., & Schein, G. (2007). Action bias among elite soccer goalkeepers: The case of penalty kicks. *Journal of Economic Psychology*, *28*(5), 606–621. https://doi.org/10.1016/j.joep.2006.12.001

Blanco-Villaseñor, A., Sastre, S., & Escolano, E. (2010). Desarrollo ejecutivo temprano y teoría de la generalizabilidad: bebes típicos y prematuros [Executive function in early childhood and Generalizability Theory: Typical babies and preterm babies]. *Psicothema*, *22*(2), 221–226.

Buscà, B., Hileno, R., Nadal, B., & Serna, J. (2022). Prediction of the penalty kick direction in men's soccer. *International Journal of Performance Analysis in Sport*, *22*(4), 571–582. https://doi.org/10.1080/24748668.2022.2097834

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, *20*(1), 37–46. https://doi.org/10.1177/001316446002000104

Creswell, J. W., & Plano Clark, V. L. (2017 2011). *Designing and conducting Mixed Methods Research*. 2nd Sage.

Crewson, P. (2006). *Applied statistics handbook*. AcaStat Software.

Cronbach, L. J., Gleser, G. C., Nanda, H., & Rajaratnam, N. (1972). *The dependability of behavioral measurements: Theory of generalizability for scores and profiles*. Wiley.

Dalton, K., Guillon, M., & Naroo, S. A. (2015). An analysis of penalty kicks in elite football post 1997. *International Journal of Sports Science & Coaching*, *10*(5), 815–827. https://doi.org/10.1260/1747-9541.10.5.815

Dicks, M., Davids, K., & Button, C. (2010). Individual differences in the visual control of intercepting a penalty kick in association football. *Human Movement Science*, *29*(3), 401–411. https://doi.org/10.1016/j.humov.2010.02.008

Furley, P., Noël, B., & Memmert, D. (2017). Attention towards the goalkeeper and distraction during penalty shootouts in association football: A retrospective analysis of penalty shootouts from 1984-2012. *Journal of Sports Sciences*, *35*(9), 873–879. https://doi.org/10.1080/02640414.2016.1195912

Gabín, B., Camerino, O., Anguera, M. T., & Castañer, M. (2012). Lince: Multiplatform sport analysis software. *Procedia, Social and Behavioral Sciences*, *46*, 4692–4694. https://doi.org/10.1016/j.sbspro.2012.06.320

Garzón, B., Lapresa, D., Anguera, M. T., & Arana, J. (2011). Análisis observacional del lanzamiento de tiro libre en jugadores de baloncesto base [Observational analysis of the free throw shot made by grassroots basketball players]. *Psicothema*, *23*(4), 851–857.

Haberman, S. J. (1973). The analysis of residuals in cross-classified tables. *Biometrics*, *29*(1), 205–220. https://doi.org/10.2307/2529686

Hunter, A. H., Angilletta, M. J., & Wilson, R. S. (2018). Behaviors of shooter and goalkeeper interact to determine the outcome of soccer penalties. *Scandinavian Journal of Medicine & Science in Sports*, *28*(12), 2751–2759. https://doi.org/10.1111/sms.13276

Hunter, A. H., Pavlic, T. P., Angilletta, M. J., & Wilson, R. S. (2022). Identifying the best strategy for soccer penalty success: A predictive model for optimising behavioural and biomechanical trade-offs. *Journal of Biomechanics*, *141*, 111208. https://doi.org/10.1016/j.jbiomech.2022.111208

Jordet, G., & Elferink-Gemser, M. T. (2012). Stress, coping, and emotions on the world stage: The experience of participating in a major soccer tournament penalty shootout. *Journal of Applied Sport Psychology*, *24*(1), 73–91. https://doi.org/10.1080/10413200.2011.619000

Jordet, G., Hartman, E., Visscher, C., & Lemmink, K. A. (2007). Kicks from the penalty mark in soccer: The roles of stress, skill, and fatigue for kick outcomes. *Journal of Sports Sciences*, *25*(2), 121–129. https://doi.org/10.1080/02640410600624020

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Lapresa, D., Anguera, M. T., Alsasua, R., Arana, J., & Garzón, B. (2013). Comparative analysis of T-patterns using real time data and simulated data by assignment of conventional durations: The construction of efficacy in children's basketball. *International Journal of Performance Analysis in Sport*, *13*(2), 321–339. https://doi.org/10.1080/24748668.2013.11868651

Lapresa, D., Arana, J., Anguera, M. T., & Garzón, B. (2013). Comparative analysis of the sequentiality using SDIS-GSEQ and THEME: A concrete example in soccer. *Journal of Sports Sciences*, *31*(15), 1687–1695. https://doi.org/10.1080/02640414.2013.796061

Lees, A., Asai, T., Andersen, T. B., Nunome, H., & Sterzing, T. (2010). The biomechanics of kicking in soccer: A review. *Journal of Sports Sciences*, *28*(8), 805–817. https://doi.org/10.1080/02640414.2010.481305

Lees, A., & Nolan, L. (2002). Three-dimensional kinematic analysis of the instep kick under speed and accuracy conditions. In W. Spinks, T. Reilly, & A. Murphy (Eds.), *Science and football IV* (pp. 16–21). Routledge.

Lees, A., & Owens, L. (2011). Early visual cues associated with a directional place kick in soccer. *Sports Biomechanics*, *10*(2), 125–134. https://doi.org/10.1080/14763141.2011.569565

Li, Y., Alexander, M., Glazebrook, C., & Leiter, J. (2015). Prediction of Kick direction from kinematics during the soccer penalty kick. *International Journal of Kinesiology and Sports Science*, *3*(4), 1–7. https://doi.org/10.7575/aiac.ijkss.v.3n.4p.1

Lindeman, B., Libkuman, T., King, D., & Kruse, B. (2000). Development of an instrument to assess jump-shooting form in basketball. *Journal of Sport Behavior*, *23*(4), 335–348.

Lopes, J. E., Araújo, D., Duarte, R., Davids, K., & Fernandes, O. (2012). Instructional constraints on movement and performance of players in the penalty kick. *International Journal of Performance Analysis in Sport*, *12*(2), 331–345. https://doi.org/10.1080/24748668.2012.11868602

López-Botella, M., & Palao, J. M. (2007). Relationship between laterality of foot strike and shot zone on penalty efficacy in specialist penalty takers. *International Journal of Performance Analysis in Sport*, *7*(3), 26–36. https://doi.org/10.1080/24748668.2007.11868407

Magnusson, M. S. (1996). Hidden real-time patterns in intra- and inter-individual behavior. *European Journal of Psychological Assessment*, *12*(2), 112–123. https://doi.org/10.1027/1015-5759.12.2.112

Masters, R., Van der Kamp, J., & Jackson, R. (2007). Imperceptibly off-center goalkeepers influence penalty-kick direction soccer. *Psychological Science*, *18*(3), 222–223. https://doi.org/10.1111/j.1467-9280.2007.01878.x

McGarry, T., & Franks, I. M. (2000). On winning the penalty shoot-out in soccer. *Journal of Sports Sciences*, *18*(6), 401–409. https://doi.org/10.1080/02640410050074331

Nadal, C. G., Serna, J., Nuviala, R., & Falcón, D. (2018). Diseño de un instrumento observacional para la valoración del penalti en fútbol y análisis de los resultados obtenidos [Design of an observational instrument for the assessment of the penalty kicks in football and analysis of the obtained results]. *Revista De Psicología Del Deporte*, *27*(2), 189–199.

Navia, J., & Ruiz, L. (2014). Análisis de la complejidad perceptivo-motriz y psicológica del penalti en el fútbol [Analysis of the perceptual-motor and psychological complexity of the soccer penalty kick]. *Revista internacional de ciencias del deporte*, *10*(37), 264–280. https://doi.org/10.5232/ricyde2014.03706

Navia, J., Ruiz, L., Graupera, J., Van der Kamp, J., & Avilés, C. (2013). La mirada de los porteros de fútbol-sala ante diferentes tipos de respuesta motriz [Futsal goalkeepers' gaze behavior with different type of motor response]. *Revista internacional de ciencias del deporte*, *9*(33), 269–281. https://doi.org/10.5232/ricyde2013.03305

Noël, B., van der Kamp, J., & Klatt, S. (2021). The interplay of goalkeepers and penalty takers affects their chances of success. *Frontiers in Psychology*, *12*, 12. https://doi.org/10.3389/fpsyg.2021.645312

Palao, J. M., López-Montero, M., & López-Botella, M. (2010). Relación Entre eficacia, lateralidad y zona de lanzamiento del penalti en función del nivel de competición en fútbol [Relationship between efficacy, laterality of foot strike, and shot zone of the penalty in relation to competition level in soccer.Of the penalty in relation to competition level in soccer]. *Revista internacional de ciencias del deporte*, *6*(19), 154–165. https://doi.org/10.5232/ricyde2010.01905

PatternVision Ltd, & Noldus Information Technology bv. (2004). *Theme, powerful tool for detection and analysis of hidden patterns in behaviour*. Noldus Information Technology bv. Reference manual, version 5.0.

Pinheiro, G. S., Nascimento, V. B., Dicks, M., Costa, V. T., & Lames, M. (2021). Design and validation of an observational system for penalty kick analysis in football (OSPAF). *Frontiers in Psychology*, *12*, 661179. https://doi.org/10.3389/fpsyg.2021.661179

Prieto Lage, I., Artigues-Ribas, L., & Gutiérrez-Santiago, A. (2020). Patrones técnico-tácticos del lanzador y el portero en los penales de la liga española de fútbol durante la temporada 2016-17 mediante T-patterns y coordenadas polares [technical-tactical patterns of the attacker and the goalkeeper in the penalty shootouts within the Spanish football league during the 2016-17 Season through T-patterns and Polar Coordinates]. *Cuadernos de Psicología del Deporte*, *20*(1), 166–180.

Sánchez, F. J. N., Sicilia, A. O., Guerrero, A. B., & Pugnaire, A. R. (2005). Anticipation in soccer goalkeepers during penalty kicking. *International Journal of Sport Psychology*, *36*(4), 284–298.

Savelsbergh, G. J. P., Williams, A. M., Van Der Kamp, J., & Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences*, *20*(3), 279–287. https://doi.org/10.1080/026404102317284826

Terroba, M., Ribera, J. M., Lapresa, D., & Anguera, M. T. (2021). Education intervention using a ground robot with programmed directional controls: Observational analysis of the development of computational thinking in early childhood education. *Revista de Psicodidáctica*, *26*(2), 143–151. https://doi.org/10.1016/j.psicod.2021.03.001

Van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alterations of kick direction increase errors and reduce accuracy. *Journal of Sports Sciences*, *24*(5), 467–477. https://doi.org/10.1080/02640410500190841

Van der Kamp, J. (2011). Exploring the merits of perceptual anticipation in the soccer penalty kick. *Motor Control*, *15*(3), 342–358. https://doi.org/10.1123/mcj.15.3.342

Van der Kamp, J., & Masters, R. (2008). The human Müller-Lyer illusion in goalkeeping. *Perception*, *37*(6), 951–954. https://doi.org/10.1068/p6010

Williams, A. M., & Griffiths, I. (2002). A kinematic analysis of the prevalence of pre- impact cues in the football penalty kick. *Journal of Sports Sciences*, *20*(1), 74.

Ysewijn, P. (1996). *About Software for Generalizability Studies (GT)*. Mimeograph.