Ger J Exerc Sport Res
https://doi.org/10.1007/s12662-019-00579-0
Received: 4 June 2018
Accepted: 20 February 2019

Silvan Steiner[1] · Stephan Rauh[1] · Martin Rumo[2] · Karin Sonderegger[2] · Roland Seiler[1]

[1] Institute of Sport Science, University of Bern, Bern, Switzerland

[2] Swiss Federal Institute of Sport, Magglingen (SFISM), Magglingen, Switzerland

Outplaying opponents—a differential perspective on passes using position data

Introduction

Passes are a performance-relevant parameter in football (e.g., Evangelos, Aristotelis, Ioannis, Stergios, & Foteini, 2014; Reed, 2004). They have received substantial research attention since Reep and Benjamin's (1968) classic publication. Until some years ago, studies on passes often involved notational analyses (see Rein & Memmert, 2016). The relation between the length of passing sequences, or the percentage of successful passes and goals are example foci of such studies (e.g., Hughes & Franks, 2004; Redwood-Brown, 2008). In recent years, the availability of new tracking technologies has largely improved the possibilities to research team sports within their natural settings and initiated a currently rising field of team sports research (Rein & Memmert, 2016). Among other things, these technologies have also enabled new perspectives on the passes played; one such perspective includes defining the number of opponents outplayed by a pass (Memmert & Raabe, 2017). In Germany, this measure came to prominence among a broader public during the UEFA (Union of European Football Associations) European Championship of 2016. Essentially, position data are used to locate opposing players between the ball carrier and target goal when a pass is played and when it is received. Calculating the difference in opponents at the two timepoints yields the number of opponents outplayed by that pass (Rein, Raabe, & Memmert, 2017).

Given the game's main goal of scoring higher than the opposing team, football teams' primary offensive tasks involve outplaying opponents to destabilize their defensive organization and create opportunities to score (Clemente, Martins, Couceiro, Mendes, & Figueiredo, 2014). Various studies have reported how the effectiveness of scoring opportunities increases when the number of opponents between the ball and target goal decreases (Ensum, Pollard, & Taylor, 2003; Gonzalez-Rodenas, Lopez-Bondia, Calabuig, James, & Aranda, 2015; Lago-Ballesteros, Lago-Peñas, & Rey, 2012). Concerning passes, it has been shown that winning teams outplay more opponents than losing teams do when initiating offensive moves via passes (Memmert & Raabe, 2017). Furthermore, the number of passes that outplay at least one opponent has been found to correlate positively with the number of goal scoring opportunities (Tenga, Holme, Ronglan, & Bahr, 2010; see also Liu, Gómez, Gonçalves, & Sampaio, 2016). Such findings substantiate that the number of opponents outplayed by a pass qualifies as one aspect of the offensive quality of this pass (see also Chawla, Estephan, Gudmundsson, & Horton, 2017). In this article, we adopt a differential perspective on passes that differ from each other concerning the number of outplayed opponents (NOO). Our perspective focuses on two essential aspects for the completion of any pass; these aspects are athletes' decisions to play a specific pass and the behavioral contributions of the pass receivers to completing the pass.

In terms of the passing decisions, there seems to be latent consensus that passes with a high NOO indicate clever passing decisions. To the best of our knowledge, no studies analyzing these decisions have yet been published. In this article, we deploy an ecological approach to analyzing passing decisions within naturally occurring game situations. The approach assumes that passing decisions are expressed by playing a pass, allowing for these decisions to be determined objectively (Turvey & Shaw, 1995). Furthermore, the decision to play to one specific team member can be put into relation to the options of passing the ball to any other team member present in that same situation. Using tracking data, all options (team members) can be described by their position-related features relative to the ball carrier's perspective (Steiner, 2018). Comparing the features of the chosen passing option with those of the discarded options is an ecologically grounded way to understand how the game context relates to the decisions to play specific passes (Araújo, Davids, & Hristovsky, 2006).

A recent study taking such an ecological approach reported that open passing lanes to team members, team members' spatial proximity to the ball carrier, and loose defense by opposing players are contextual features that increase team members' chances to receive a pass (Steiner, Rauh, Rumo, Sonderegger, & Seiler, 2018). However, this study did not differentiate passes according to qualita-

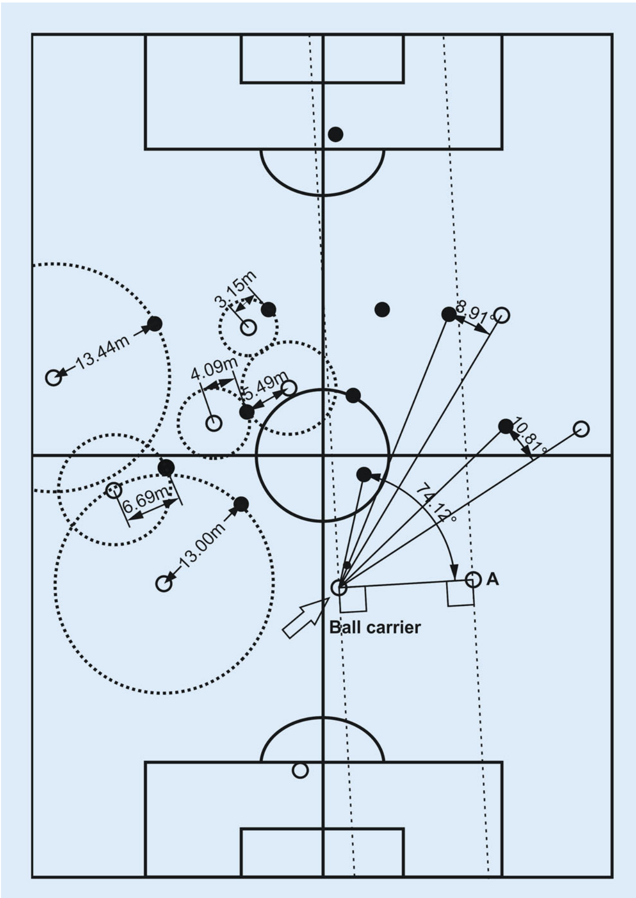

Fig. 1 ◄ Illustration of the operationalization of the predictor variables defensive coverage (*left side*) and openness of passing lanes (*right side*). When defining the openness of a passing lane, only opponents located in the area bounded by the length of the passing lane were considered. The *dashed lines* on the *right side* of the figure illustrate this area for the passing lane from the ball carrier to team member A

tive criteria. In the context of our differential perspective, we explore whether the effects of the contextual features on passing decisions differ between passes with a different NOO. If recurring patterns between certain contextual features and the decisions to play high NOO passes are found, then this could indicate the benefits of deploying attentional strategies with a special focus on these features (Steiner, 2018). Thus, our first research question is whether decisions to play high NOO passes differ from decisions to play low NOO passes with regard to how contextually embedded passing options are prioritized.

While passes with a high NOO may indeed indicate clever passing decisions, we assume that getting on the end of a high NOO pass on the part of the receiving athletes also represents a special contribution. Our assumption is based on the naive observation that completion of passes with a high NOO often requires anticipative capabilities and high physical effort. However, we could not find any publication to confirm this observation based on empirical data. Thus, our second research question refers to whether differences in the behavioral contributions of pass receivers to completing passes with a different NOO can be found. In exploring potential differences, we consider covered distances and running speed.

Methods

Data collection and data preparation

Position data collected during five halftimes of championship matches between some of Switzerland's best U18 football teams were analyzed. The data were collected in the context of a study run by the Swiss Federal Institute of Sport Magglingen (SFISM). The study was approved by an independent Institutional Review Board from the SFISM.

The athletes' positions were tracked by a local position measurement system (LPMS) at a rate of 1000 Hz divided by the number of 22 players. The LPMS tracks position data via 10 base stations located around the playing field. The base stations communicate with transponders attached to the athletes and estimate the athletes' distances. The players' positions are calculated via triangulation (Inmotiotec GmbH, Regau, Austria). Although the LPMS reliably tracks athletes' positions (Frencken, Lemmink, & Delleman, 2010; see also Ogris et al., 2012; Siegle, Stevens, & Lames, 2013; Stevens et al., 2014), the ball tracking works less reliably. The ball does not carry a transponder and is tracked by 12 cameras. Hence, when clear sight on the ball is prevented (e. g., during infights or when the ball is off field), the system may generate ball position artefacts (Memmert & Raabe, 2017). To obtain reliable ball position data, we manually corrected the ball positions with the SFISM's *balltrackgenerator*. Match videos were considered to define the appropriate ball positions. We then generated a pass list using Inmotiotec's pass detection algorithm. Simply put, the algorithm codes a pass when individual ball possession (see Link & Hoernig, 2017) changes within members of the same team and ball movement parameters indicate that the ball has been kicked (internal document, Inmotiotec GmbH). Comparing random samples of the derived pass list to the video recordings of the matches indicated that the algorithm did not reliably detect all passes. For example, it occurred that the algorithm assigned opponent players standing in the vicinity of the actual pass receivers as pass receivers, resulting in erroneous list entries for ball losses instead of entries for completed passes. Therefore, we double-checked each entry of the entire pass list by consulting the corresponding scene in the match videos. The corrected list included a total of 1778 completed passes. During correction of the pass list, we assigned codes for special pass events to allow for more control over the kinds of passes to be included in the data analysis. We coded passes that resulted directly from set plays (free kicks and corners), kickoffs, goal kicks, and throw-ins. These passes were excluded from our analyses because the circumstances under which they are played do not correspond to those of passes played from open play. Passes that were completed (e.g., touched once by a team member) but could not be brought under control (Aquino, Puggina, Alves, & Garganta, 2017) were also excluded, resulting in a final number of 1379 passes. Furthermore, we coded long balls and clearances as we expected both types of passes to be associated with high NOOs. This coding enabled tests of how inclusion/exclusion of these passes affects the statistical parameters to be estimated. A half-time sample coded by two independent raters yielded an interrater agreement for the special pass events of Cohen's $\kappa = 0.94$ (Cohen, 1960).

For every passing situation, the positions and running speeds of all 22 players at the moments of the pass and pass reception were exported to a data file. The NOO for each pass was calculated using MATLAB (The MathWorks, Inc., Natick, MA, United States). The number of opponent players located closer to the goal than the ball carrier at the time of the pass and farther away from the goal than the ball receiver at the time of pass reception defined the passes' NOO. The middle of the goal line was the reference point for calculating the distances to the goal (see Memmert & Raabe, 2017).

A static measure was used to operationalize the openness of the passing lane to a team member. We defined the passing lane (the straight) from the ball carrier to that team member. Cones originating from the ball carrier and fitting between the passing lane and any opponent located in the area bounded by the length of the passing lane were defined. The angle of the cone with the smallest angle defined the openness of the passing lane to this team member (the operationalization of this variable is illustrated in **Fig. 1**, right side). Each team member's Euclidean distance to the ball carrier was calculated. A team member's defensive coverage was operationalized by the Euclidean distance of the opponent closest to this team member (**Fig. 1**, left side). To retain information about the situation-specific distributions of all variables, and to eliminate potential outliers, we standardized the variables to values

Abstract · Zusammenfassung

Ger J Exerc Sport Res https://doi.org/10.1007/s12662-019-00579-0

S. Steiner · S. Rauh · M. Rumo · K. Sonderegger · R. Seiler

Outplaying opponents—a differential perspective on passes using position data

Abstract

In recent years, the availability of new tracking technologies has enabled new perspectives on passes played in football. One such perspective includes measuring the number of opponents that are outplayed by a pass (NOO). Various studies substantiate that this measure qualifies as one aspect of the passes' offensive quality. Given the latent consensus that high-NOO passes indicate clever passing decisions, one aim of this study was to analyze how athletes prioritize contextually embedded passing options when playing passes that differ with regard to their NOO. Another aim was to determine the contributions of pass receivers to completing passes with different NOOs. To this end, position- and speed-related features of 12,411 passing options from 1,379 passing situations tracked during championship matches were analyzed. Overall, the findings indicate that decisions to play high NOO passes differ from decisions to play low NOO passes with regard to how contextually embedded passing options are prioritized. The passes' NOOs increased as the decision-makers' tendency to pass to loosely defended team members with open passing lanes and positions near the ball carrier decreased. Furthermore, higher physical contributions on the part of the pass receivers were observed when pass receivers completed passes with higher NOOs. Based on the findings, passes with a high NOO could be considered risky passes. The presented approach could be adopted to further analyze the circumstances that allow athletes to play such passes compared with those that absolutely do not, which could represent an important step concerning educational programs in football.

Keywords

Decision-making · Packing · Soccer · Contextual information · Environment

Gegner aus dem Spiel nehmen – eine differenzielle Betrachtung von Pässen mittels Positionsdaten

Zusammenfassung

Das Aufkommen neuer Tracking-Technologien hat in den letzten Jahren neue Perspektiven auf Passspiele im Fußball eröffnet. Eine dieser Perspektiven beinhaltet das Bestimmen der Anzahl von Gegnern, die mit einem Pass überspielt werden („number of outplayed opponents“ [NOO]). Gemäß verschiedenen Studien kann dieses Maß als eine Kennzahl der offensiven Qualität eines Passes betrachtet werden und es existiert latenter Konsens, dass Pässen mit hoher NOO clevere Passentscheidungen zugrunde liegen. Vor diesem Hintergrund war ein Ziel dieser Studie, zu analysieren, wie Athleten kontextuell eingebettete Passoptionen bei Zuspielen mit unterschiedlicher NOO priorisieren. Ein weiteres Ziel war, die Beiträge von Passempfängern zur gelingenden Komplettierung von Pässen mit unterschiedlicher NOO zu bestimmen. Zu diesem Zweck wurden positions- und geschwindigkeitsbezogene Merkmale von 12.411 Passoptionen aus 1379 während Meisterschaftsspielen aufgezeichneten Passsituationen analysiert. Die Ergebnisse deuten darauf hin, dass kontextuell eingebettete Passoptionen bei Pässen mit hoher bzw. tiefer NOO unterschiedlich priorisiert werden. Mit abnehmender Tendenz der Passspieler, Pässe zu nahe positionierten, lose verteidigten Mitspielern mit offenen Passwegen zu spielen, erhöhte sich die Anzahl überspielter Gegner. Zudem zeigte sich, dass Ballempfänger für die Komplettierung von Pässen mit hoher NOO größere physische Beiträge leisteten als bei der Komplettierung von Pässen mit tiefer NOO. Basierend auf diesen Ergebnissen können Pässe mit hoher NOO als riskante Pässe interpretiert werden. In weiterführenden Untersuchungen könnten mit dem dargestellten methodischen Zugang diejenigen situativen Umstände bestimmt werden, unter welchen das Spielen riskanter Pässe eine Option sein könnte bzw. eher unterlassen werden sollte. Entsprechende Befunde wären im Hinblick auf fußballspezifische Ausbildungsprogramme interessant.

Schlüsselwörter

Entscheidung · Packing · Fußball · Kontextuelle Information · Umwelt

of 0–10 in each passing situation. The variables were then z-standardized. No standardized values larger than 3.29 indicated the absence of outliers. The data were arranged in a long data file (Heck, Thomas, & Tabata, 2014). Every passing situation was represented by nine cases, each representing one of the nine field players of the team with ball possession that were available as passing options to the ball carrier.[1] A variable coded the passing decisions: the pass receiver (1), and non-receivers (0).

As indicators of the ball receivers' behaviors, we considered the running speed at the time of ball reception, as well as the covered distances and changes in running speed from the moment the pass was played until the moment of ball reception.

Statistical analyses

We calculated binary logistic regression models to estimate the effects of the contextual features on passing decisions (SPSS Version 24). Each team member was described by the openness of the passing lane leading to him, by his spatial proximity to the decision-maker, by how tightly he was defended by opposing players, and by his current speed (predictor variables). The passing decisions' binary code for pass receivers (1) vs. non-receivers (0) was used as the dependent variable. Thus, to regress our model estimates, we analyzed to which 1379 out of the 12,411 passing options the passes were played. A significant coefficient estimate for a predictor variable would indicate that pass receivers set themselves apart from the other team members by their value in this specific variable. Running the regression model separately for passing situations that result in passes with different NOOs enables exploration of whether decision-makers prioritize contextually embedded passing options differently depending on the kind of pass played.

Binary logistic regressions assume linear relationships between predictor variables and the logit transform of the dependent variable. We tested this assumption separately for the pass categories NOO = 0, 1, 2, 3, 4, and ≥5 using the Box–Tidwell approach (Hosmer & Lemeshow, 2000).[2] The assumption of a linear relationship between the distance and logit of the passing decisions was violated in three pass categories (NOO = 1, 3, and ≥5). Furthermore, no linearity in the logit was found for the openness of the passing lane variable for passes with no, or one outplayed opponent. Predictors with no linearity in the logit must not be included as continuous predictor variables in logistic regression analysis (Tabachnick & Fidell, 2014). Both variables were area transformed to obtain five categories with an equal number of cases (Lienert & Raatz, 1998). The cutoffs for the passing lane were 0.319, 1.193, 2.741, and 6.175; those for distance were 1.168, 3.311, 5.323, and 7.976. The quintile transformation resulted in a linear relationship between the five-stage openness of the passing lane variable and its natural logarithm for all pass categories. However, no consistent linearity in the logit was found for the five-stage distance variable (NOO = 1 and 3). The variable was treated as a categorical variable. For all the regression models specified, the link logit function was used.

Concerning the contribution of the pass receivers to completing a pass, we exported the running speed at the time of ball reception, covered distances, and changes in running speed from the moment the pass was played until the moment of ball reception separately for each pass category. A Shapiro–Wilk test indicated that the values of these behavioral variables were not normally distributed. In addition, numerous outliers were detected. Accounting for these data specifics, the pass receivers' contributions to the different pass categories were compared using the nonparametric Kruskal–Wallis test. Being based on ranks, the test is not affected by extreme values and yields robust results even when data are not normally distributed and outliers are present (Eid, Gollwitzer, & Schmitt, 2015).

Results

Fig. 2 shows descriptive statistics of the analyzed passes categorized according to the passes' NOO, the zones from which they were played or received, and the roles of the players playing/receiving the passes. Among other things, it can be seen that the majority of the passes were played/received in the middle third of the playfield, and that more passes were played/received by defenders and midfielders as opposed to forwards.

Because of the demonstrably high NOOs of long balls ($N = 37$, $Mdn_{\mathrm{NOO}} = 4.12$) and clearances ($N = 13$, $Mdn_{\mathrm{NOO}} = 2.75$), we tested to what degree the inclusion/exclusion of these passes would affect the results of our statistical analyses. Regarding the results to our first research question (section "Effects of contextual features on passing decisions"), we found that exclusion resulted in a negligible median change in odds ratio (OR) = 0.01, with all estimates remaining at their respective level of significance ($p = 0.001$, 0.01, 0.05, or >0.05). Regarding the results to our second research question (section "Contributions of ball receivers to completing passes"), exclusion of the two kinds of passes did not change the size (according to Cohen, 1988) and significance of any of the effects either. To prevent redundancy, we will only present the results from the total sample of 1379 passes, including long balls and clearances.

Effects of contextual features on passing decisions

The chi-square tests indicated that all the regression models calculated for all the pass categories were fitted significantly to the data (all $p < 0.001$). Pseudo R^2 measures ranged from a Cox and Snell R^2 of $CS = 0.076$ (NOO = 2) to $CS = 0.228$ (NOO = 0) and from a Nagelkerke's R^2 of $NK = 0.151$ (NOO ≥ 5) to $NK = 0.455$ (NOO = 0). **Table 1** shows how the various types of contextual features related to the decisions of playing specific passes. Considering the parameter estimates for

[1] Due to their function and usually outlying positions, goalkeepers were excluded from the analyses.

[2] Due to the small number of passes with an NOO of 5–8, these passes were merged to one category.

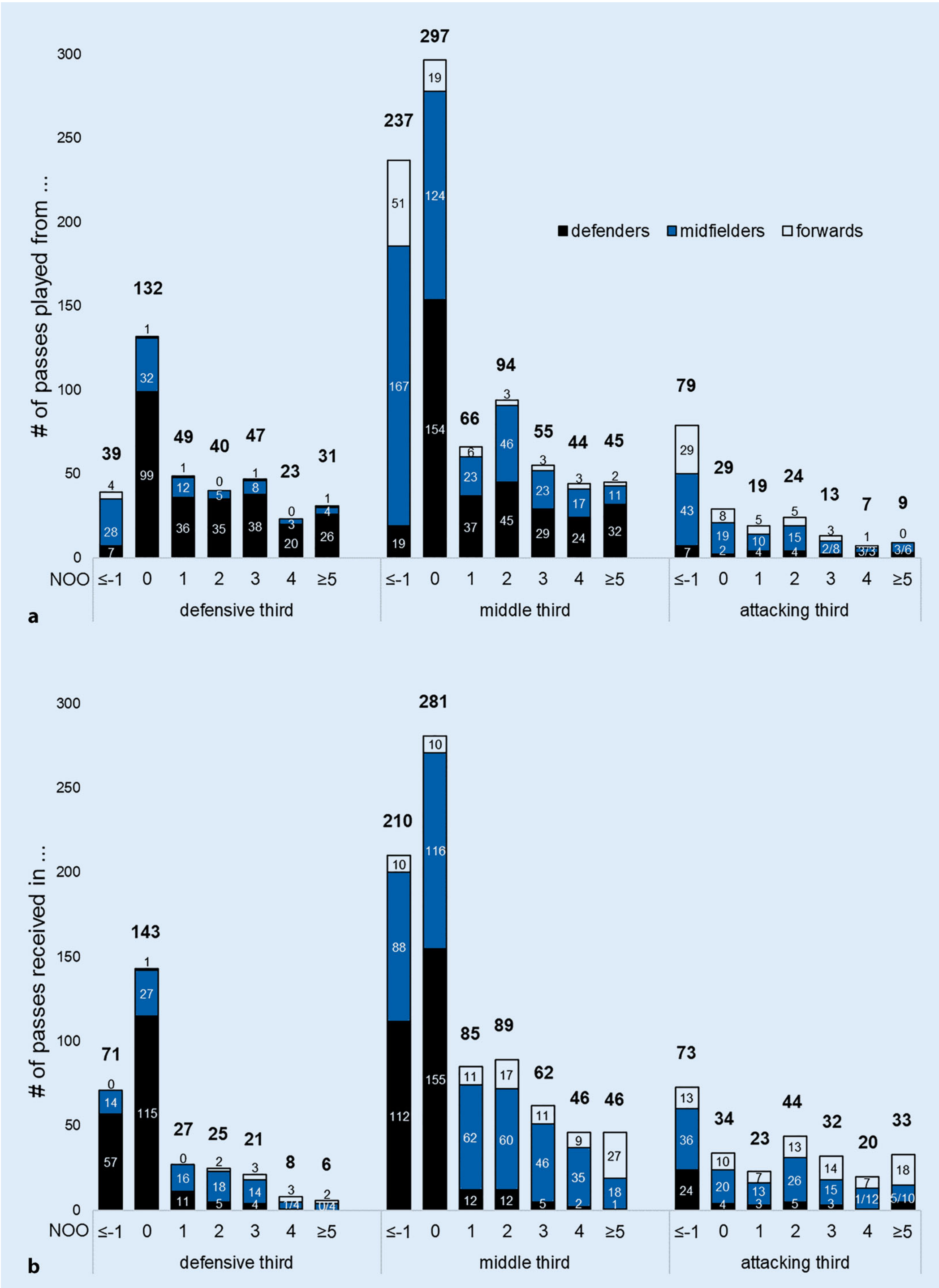

Fig. 2 ◀ Passes categorized according to their number of outplayed opponents (NOO), the zone in which they were played (**a**) or received (**b**), and the position of the player (defender, midfielder, forward) playing/receiving the pass

the passes that did not outplay any opponent, it is found that all contextual features relate significantly to the players' decisions to play these passes. The odds ratio (OR) for the passing lane indicates that a change of the openness of a passing lane to a team member from one quintile into the more open quintile increased the odds for receiving such a pass by a factor of 2.75. The significant main effect for distance indicates that the odds for receiving a pass in this category is affected by how far away team members are from the ball carrier. The team members closest to the ball carrier had a 1.92 times higher odds for receiving a pass than those in category 2 (second closest to the ball carrier; 1/0.52). The odds for receiving passes further decreased for team members in categories 3 (by a factor of 1/0.43 = 2.33), 4 (by a factor of 1/0.13 = 7.69), and 5 (by a factor of 1/0.06 = 16.67). The OR estimate for defensive coverage indicates the players' tendency to pass the ball to loosely defended team members. A change in the closest defender's distance to a team

Table 1 Parameter estimates for the situational context variables on passing decisions categorized according to the passes' numbers of outplayed opponents (NOO)

Predictor	NOO = 0 (*n* = 458 passes)		NOO = 1 (*n* = 134 passes)		NOO = 2 (*n* = 158 passes)		NOO = 3 (*n* = 115 passes)		NOO = 4 (*n* = 74 passes)		NOO ≥ 5 (*n* = 85 passes)	
	OR (CI95%)	***p***	**OR (CI95%)**	***p***	**OR (CI95%)**	***p***	**OR (CI95%)**	***p***	**OR (CI95%)**	***p***	**OR (CI95%)**	***p***
Openness of passing lane	2.75 (2.28–3.30)	0.000	1.67 (1.35–2.07)	0.000	1.31 (1.10–1.55)	0.002	1.03 (0.87–1.23)	0.713	0.91 (0.73–1.12)	0.367	0.99 (0.81–1.23)	0.956
Distance (main)	–	0.000	–	0.000	–	0.000	–	0.000	–	0.003	–	0.003
Category 1 vs. category 2	0.52 (0.38–0.70)	0.000	0.36 (0.22–0.61)	0.000	0.33 (0.20–0.52)	0.000	1.12 (0.68–1.83)	0.658	1.55 (0.80–2.99)	0.189	4.60 (1.87–11.31)	0.001
Category 1 vs. category 3	0.43 (0.29–0.62)	0.000	0.12 (0.06–0.28)	0.000	0.18 (0.10–0.35)	0.000	0.33 (0.16–0.67)	0.002	0.64 (0.28–1.49)	0.301	6.58 (2.58–16.80)	0.000
Category 1 vs. category 4	0.13 (0.07–0.24)	0.000	0.17 (0.08–0.39)	0.000	0.19 (0.09–0.39)	0.000	0.25 (0.10–0.59)	0.002	0.30 (0.10–0.93)	0.036	4.80 (1.76–13.07)	0.002
Category 1 vs. category 5	0.06 (0.03–0.14)	0.000	0.09 (0.03–0.29)	0.000	0.09 (0.03–0.26)	0.000	0.06 (0.01–0.29)	0.000	0.28 (0.08–0.91)	0.035	5.06 (1.70–15.09)	0.004
Defensive coverage	1.24 (1.19–1.30)	0.000	1.01 (0.93–1.08)	0.901	1.02 (0.96–1.09)	0.495	0.97 (0.91–1.05)	0.459	1.04 (0.94–1.14)	0.445	0.82 (0.74–0.91)	0.000
Running speed	1.07 (1.04–1.11)	0.000	1.13 (1.07–1.21)	0.000	1.16 (1.10–1.23)	0.000	1.12 (1.05–1.19)	0.001	1.23 (1.13–1.34)	0.000	1.17 (1.08–1.25)	0.000

OR odds ratio, *CI95%* lower and upper 95% confidence intervals for the odds ratio. The degree of freedom for the main effect of distance is $df = 4$. It is $df = 1$ for all other parameters

member by one unit (e.g., the defense becoming looser) increased that team member's odds for receiving passes by a factor of 1.24. Finally, when the players' running speed increased by one unit, their odds for receiving a pass increased by a factor of 1.07. To sum up, passes that did not outplay any opponent were passes played to loosely defended, moving team members with open passing lanes and positions in an areal proximity to the ball carrier. Interpretations of the OR estimates for the other pass categories can be carried out in much the same way. We will forgo repeating detailed descriptions of the estimates for the remaining pass categories, adopting a more comparative perspective instead.

It can be observed that the openness of the passing lanes no longer significantly relates to decisions to play passes with an NOO ≥3. One could interpret that the openness of a passing lane was no feature relevant to the decision of playing such passes. Furthermore, the effect of the team members' defensive coverage on passes with no outplayed opponent disappeared for passes with an NOO = 1 to 4. This means that the team members' defensive coverage by opponent players does not differentiate players that received a pass from those that did not in these categories. For passes with an NOO ≥ 5, the OR is in the opposite direction of those with no outplayed opponent. While loose defense by opposing players may be considered a criterion for making passes that do not outplay any opponents, a loose defense was no contextual condition that had to be met for athletes to decide to play passes outplaying one or more opponents.

The main effect of the team members' distances is significant across all pass categories. This means that team members' distances to the ball carrier related to the team members' odds of receiving a pass. However, the tendency to pass the ball to players in the closest quintile decreases starting at an NOO = 3. Here, the odds of receiving a pass are no different for players in the closest quintile compared to those in the second closest quintile. For passes with an NOO = 4, the odds for passes do not differ for the team members in categories 1 to 3. Finally, for passes

Table 2 Variables describing the behaviors of pass receivers in completing passes categorized according the passes' numbers of outplayed opponents (NOO)												
	NOO = 0 (n = 458 passes)		NOO = 1 (n = 134 passes)		NOO = 2 (n = 158 passes)		NOO = 3 (n = 115 passes)		NOO = 4 (n = 74 passes)		NOO ≥ 5 (n = 85 passes)	
	Median	*IQR*	*Median*	*IQR*	*Median*	*IQR*	*Median*	*IQR*	*Median*	*IQR*	*Median*	*IQR*
Covered distance (m)	2.16	2.73	2.50	3.08	2.68	3.72	2.90	3.61	3.68	3.78	4.50	4.33
Running speed (m/s)	1.93	1.77	2.42	1.95	2.94	1.93	2.58	2.20	3.04	3.02	3.55	2.69
Δ running speed (m/s)	−0.15	1.39	−0.31	1.68	−0.05	1.77	0.11	1.70	−0.00	2.62	0.84	2.33

IQR interquartile range, ***Running speed*** running speed of pass receivers at the moment of ball reception, Δ ***running speed*** refers to the difference in the pass receivers' running speeds from the moment of the pass being played to the moment of the pass being received

with an NOO ≥5, the odds for passes increased for all team members located further away (categories 2 to 5) than those closest to the ball carrier (category 1).

A significant effect of running speed on passing decisions can be observed across all pass categories. Thus, regardless of a pass's NOO, the fact that a player was running faster than other team members increased the odds for a pass to that team member. It is noticeable that the effects of the open passing lanes, areal proximity, and defensive coverage on passes played decrease, while the effect of running speed increases as the passes' NOOs become higher.

Contributions of ball receivers to completing passes

The Kruskal–Wallis test showed that the distances covered by pass receivers were significantly different for the different pass categories ($H(5) = 69.071$, $p < 0.001$). When five or more opponents were outplayed, the median distance (4.50 m) covered by the players receiving the pass is double that of the players receiving a pass that did not outplay any opponent ($Mdn = 2.16$ m; **Table 2**). The Jonckheere–Terpstra test, a rank-based, nonparametric test for ordered differences among classes, was employed to test whether the trend between the ordinal independent variable NOO and the ordinal dependent variable distance is statistically significant. The test confirmed the significant trend of higher median distances covered by players receiving passes with higher NOO ($J = 240{,}179$, $z = 7.665$, $p < 0.001$). Coupled with the finding that the odds for receiving high NOO passes were higher for more distant team members, these results suggested that the distances covered by pass receivers relate to the distances of the passes (the travel time of the ball). A highly significant correlation of $\rho = 0.49$ between the passes' lengths and the distances covered by pass receivers confirmed the medium to strong relation (Cohen, 1988).

The Kruskal–Wallis test revealed that passes with a different NOO were received at significantly different running speeds ($H(5) = 78.223$, $p < 0.001$). The higher the NOO, the faster the ball receivers were running at the time of ball reception. The trend of increasing speed when the NOO increases is statistically significant ($J = 246{,}077$, $z = 8.773$, $p < 0.001$).

Finally, the changes in running speed from the time of the pass being played to the time of ball reception were significantly different across the different pass categories ($H(5) = 32.102$, $p < 0.001$). Negative values indicate that the ball receivers lower their running speed for ball reception, while positive values indicate an increasing running speed from the moment of the pass until the time of pass reception. The trend of an increase in running speed along an increase in the passes' NOO is statistically significant ($J = 219{,}758$, $z = 3.830$, $p < 0.001$).

Discussion

In this study, we used position data to take an explorative look at passes that differ with regard to their NOOs. We found significant effects of open passing lanes to team members, team members' areal proximity to the ball carrier, loose defense by opponents, and team members' running speed on passing decisions. Except the significant effect of the team members' running speed found across all pass categories, the effects of the contextual features on passing decisions differed across the various pass categories. In general, the passes' NOOs became higher as the tendency to pass to loosely defended team members with open passing lanes and positions near the ball carrier decreased. For passes with an NOO of ≥5, the effects of team members' distance and defensive coverage even showed inverted signs. Significantly often, such passes were played to tightly defended team members that were not in the immediate vicinity of the ball carrier. Overall, our findings indicate that decisions to play high NOO passes differ from decisions to play low NOO passes with regard to how contextually embedded passing options are prioritized. Compared with passes with a low NOO, based on their relationships with features of the current game context, passes with a high NOO could be considered somewhat "risky" passes.

Concerning the contributions of the ball receivers to completing passes, we found significant differences in the distances covered, running speeds, and changes in running speeds across the various pass categories. Overall, there were statistically significant trends of greater distances and higher (increases in) running speeds for athletes completing passes with a higher NOO. For the passes analyzed in this study, a higher contribution on the part of the pass receivers was usually needed to complete passes with higher NOOs. The finding that the pass receivers tend to cover larger distances when the NOO increases also means that the ball was passed to areas that were significantly farther away from the ball receivers' current positions when playing passes with a high NOO as compared with those with a low NOO. One could speculate that, in their "planning" of a pass, these passing athletes anticipate developments that are farther from the current game situations than when playing passes with a lower NOO. That athletes receiving passes with high NOOs tend to increase their running speed from the moment the pass is played to the moment it is received indicates that the anticipation of the passer was usually complemented by a reactive adjustment on the part of the receiving players.

Before discussing implications for research, we shall point to the study's shortcomings. First, the analyzed data stem from five halftimes of championship games played between semiprofessional U18 teams. The teams' playing level and the comparably low number of analyzed passes currently prevents generalizability of the results. Second, we used a static variable to operationalize the openness of a passing lane. A more comprehensive way of determining how open a passing lane is could include dynamic movement models based on speeds and running directions (e. g., Rein et al., 2017; Williams, Davids, & Williams, 2005). Third, we were unable to define the passes' height because the data were 2D. With regard to the openness of passing lane variable, this means that the effect estimates could be biased downward. Our interpretation that well-defended passing lanes were no decision-relevant feature for passes with a NOO ≥3 still holds. However, passes played over opponents could be accountable for this finding. Fourth, the study does not consider incomplete passes. Our dependent variable is derived from the information of which team member received the pass. Using game data only, we were unable to define the intended pass receivers of incomplete passes with certitude. Interviewing athletes after the games would yield this information. Adopting an ecological approach to comparing the decisions that lead to completed as compared to those that lead to incomplete passes could represent an interesting avenue for gaining further insights into the role of contextual features for passing decisions and for determining those types of features that should be considered alerting cues.

In the analyzed sample, high NOO passes were played by players on different playing positions, from and to different zones of the playfield. We ruled out that the results leading to our interpretation of high NOO passes being risky are solely due to long balls and clearances included in our dataset. An implication from a practical point of view is to define the circumstances under which riskier passes may be played as opposed to those under which they should not be played. The considered types of contextual features alone do not provide an unambiguous explanation of these circumstances. For example, a team member being loosely defended increased that team member's odds for receiving a pass not outplaying any opponent, but it did not increase that player's odds for receiving passes with an NOO ≥1. The pass receivers' position relative to the own or opponent goal is a candidate contextual variable to explain the varying effects of loose defense on passes with different NOO. For example, a through ball to a tightly defended team member may be worth taking the risk when the team member is positioned in the attacking third but considerably less so when he is in the defensive third. In line with this possible explanation, a higher percentage of passes with a positive NOO was received in the attacking third (59%) than in the defensive third (29%). Along similar lines, the percentage of passes not outplaying any opponent was higher for passes played/received in the defensive third (36 and 47%, respectively) than for passes played/received in the attacking third (16 and 13%, respectively). The pattern may reflect the teams' tactics of using more secure passes in the defensive third (e. g., during position play), and the need of riskier passes as a means to create space and scoring opportunities in the usually well-defended attacking third. A more general explanation for the varying effects of loosely defended team members on passes with different NOOs could be the subjective utility (e. g., Bar-Eli, Plessner, & Raab, 2011) the passer expects his team to obtain from a pass if it is completed. The higher this expected utility is, the more risk athletes may be willing to take, and the smaller the effect of a normally alerting contextual feature on passes may be. This explanation is more general insofar as it is applicable to any area within the playfield. However, it is one that will not be testable using objective game data only.

One of the main implications for future research is adding variables that could offer further insight into how contextual features relate to passing decisions and that could eventually explain why contextually embedded passing options are prioritized differently across different game situations. Another implication is to adopt the presented approach to localizing the contextual features that relate to other kinds of high-quality passes. Such passes could, for example, be based on expert ratings or differentiated according to less immediate effects the passes may have in given situations. The finding that 73% of the pass sequences leading to ball possession in the attacking third included at least one pass with an NOO of ≤0 indicates that the contribution of these passes to team performance parameters may go underestimated if judged exclusively upon their NOO. In fact, there are highly valuable and difficult passes that will have an NOO of zero. In operationalizing the NOO of a pass, the distance of the ball carrier to the mid-goal is used as the main point of reference. It can be thought of as the radius of a circle running through the position of the ball carrier, the mid-goal being the center of that circle. By definition, passes to team members located on or outside of the circle line will have no NOO greater than zero. Yet, such passes may still reduce the number of opponents currently able to intervene in the game, optimizing a team's options to carry on the play. When switching play, for example, a pass to the other side of the playfield may create space for the ball receiver until the defending players have reorganized their positions. Another example are passes played from positions near the opponent goal. Here, the curvature of the circle line is increased. A pass from near the goal line to a team member positioned on the circle line but in front of the goal will have an NOO of zero, too. However, the pass may create the opportunity for a more open shot at goal and optimize the shooting angle. Thus, the NOO's validity in defining a pass' quality may be improved when used in combination with other criteria.

Given that the contextual features considered in this study represent (theoretically) permanent sources of perceptual information, one might be tempted to interpret the findings with regard to the potential role the different types of perceptual information play in athletes' passing decisions. In this light, it is important to keep in mind that our regression models estimate the effects of the contextual features on passing decisions based on the total number of potential pass receivers. Because athletes may take decisions based on more locally available information (e.g., Bourbousson & Fortes-Bourbousson, 2016), it will be interesting to estimate the effects of the same predictors in regression models considering only team members and contextual information in the visual range of the ball carriers. Results could be indicative of the way athletes rely on specific perceptual information for their decisions to play specific passes. Eventually, such research could represent an important step in determining relevant sources of perceptual information that might help establish educational programs in football.

To conclude, this study is among the first to explore factors involved in completing passes that differ with regard to their NOO. Adopting an ecological approach, it illustrates how objective position data can be used to analyze passing decisions and the contributions of ball receivers to completing passes within naturally occurring game environments. The presented approach can be adopted to analyze passes of teams playing at higher levels, of individual athletes, or passes categorized according to other criteria than those considered in this study.

Corresponding address

Silvan Steiner
Institute of Sport Science, University of Bern
Bremgartenstr. 145,
3012 Bern, Switzerland
silvan.steiner@ispw.unibe.ch

Acknowledgements. We thank Nicolas Emery for his help in programming MATLAB.

Compliance with ethical guidelines

Conflict of interest S. Steiner, S. Rauh, M. Rumo, K. Sonderegger and R. Seiler declare that they have no competing interests.

This article does not contain any studies with human participants or animals performed by any of the authors.

References

Aquino, R., Puggina, E.F., Alves, I.S., & Garganta, J. (2017). Skill-related performance in soccer: A systematic review. *Human Movement*, *18*(5), 3–24. https://doi.org/10.1515/humo-2017-0042.

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, *7*, 653–676.

Bar-Eli, M., Plessner, H., & Raab, M. (2011). *Judgment, decision-making and success in sport*. Chichester: John Wiley & Sons. https://doi.org/10.1002/9781119977032.ch3.

Bourbousson, J., & Fortes-Bourbousson, M. (2016). How do co-agents actively regulate their collective states? *Frontiers in Psychology*, *7*, 1732. https://doi.org/10.3389/fpsyg.2016.01732.

Chawla, S., Estephan, J., Gudmundsson, J., & Horton, M. (2017). Classification of passes in football matches using spatiotemporal data. *ACM Transaction of Spatial Algorithms and Systems*, *3*(2) https://doi.org/10.1145/3105576.

Clemente, M.F., Martins, F.M.L., Couceiro, S.M., Mendes, S.R., & Figueiredo, A.J. (2014). Evaluating the offensive definition zone in football: A case study. *South African Journal for Research in Sport, Physical Education and Recreation*, *36*(3), 25–37.

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

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd edn.). Hillsdale: Erlbaum.

Eid, M., Gollwitzer, M., & Schmitt, M. (2015). *Statistik und Forschungsmethoden* (4th edn.). Basel: Beltz.

Ensum, J., Pollard, R., & Taylor, S. (2003). Applications of logistic regression to shots at goal at association football. In T. Reilly, J. Cabri & D. Araújo (Eds.), *The Proceedings of the fifth World Congress on Science and Football*. Science and football, (Vol. V, pp. 214–221). Abingdon: Routledge.

Evangelos, B., Aristotelis, G., Ioannis, G., Stergios, K., & Foteini, A. (2014). Winners and losers in top level soccer. How do they differ? *Journal of Physical Education and Sport*, *14*, 398–405.

Frencken, W.G.P., Lemmink, K.A.P.M., & Delleman, N.J. (2010). Soccer-specific accuracy and validity of the local position measurement (LPM) system. *Journal of Science and Medicine in Sport*, *13*, 641–645.

Gonzalez-Rodenas, J., Lopez-Bondia, I., Calabuig, F., James, N., & Aranda, R. (2015). Association between playing tactics and creating scoring opportunities in elite football. A case study in Spanish Football National Team. *Journal of Human Sport and Exercise*, *10*(1), 65–80. https://doi.org/10.14198/jhse.2015.101.14.

Heck, R.H., Thomas, S.L., & Tabata, L.N. (2014). *Multilevel and longitudinal modeling with IBM SPSS* (2nd edn.). New York: Routledge.

Hosmer, D.W., & Lemeshow, S. (2000). *Applied logistic regression* (2nd edn.). New York: Wiley.

Hughes, M., & Franks, I.M. (2004). *Notational analysis of sport: Systems for better coaching and performance in sport*. London: Routledge.

Lago-Ballesteros, J., Lago-Peñas, C., & Rey, E. (2012). The effect of playing tactics and situational variables on achieving score-box possessions in a professional soccer team. *Journal of Sports Sciences*, *30*, 1455–1461.

Lienert, G.A., & Raatz, U. (1998). *Testaufbau und Testanalyse* (6th edn.). Weinheim: Beltz.

Link, D., & Hoernig, M. (2017). Individual ball possession in soccer. *PLoS ONE*, *12*(7), e179953. https://doi.org/10.1371/journal.pone.0179953.

Liu, H., Gómez, M.Á., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match variation in elite football teams. *Journal of Sports Sciences*, *34*, 509–518. https://doi.org/10.1080/02640414.2015.1117121

Memmert, D., & Raabe, D. (2017). *Revolution im Profifußball. Mit Big Data zur Spielanalyse 4.0*. Berlin: Springer.

Ogris, G., Leser, R., Horsak, B., Kornfeind, P., Heller, M., & Baca, A. (2012). Accuracy of the LPM tracking system considering dynamic position changes. *Journal of Sports Sciences*, *30*, 1503–1511.

Reed, L. (2004). *The official FA guide to basic team coaching*. London: Hodder & Stoughton.

Reedwood-Brown, A. (2008). Passing patterns before and after goal scoring in FA Premier League Soccer. *International Journal of Performance Analysis in Sport*, *8*(3), 172–182.

Reep, C., & Benjamin, B. (1968). Skill and chances in association football. *Journal of the Royal Statistical Society. Series A*, *131*, 581–585.

Rein, R., & Memmert, D. (2016). Big data and tactical analysis in elite soccer: Future challenges and opportunities for sports science. *SpringerPlus*, *5*, 1410. https://doi.org/10.1186/s40064-016-3108-2.

Rein, R., Raabe, D., & Memmert, D. (2017). "Which pass is better?" Novel approaches to assess passing effectiveness in elite soccer. *Human Movement Science*, *55*, 172–181.

Siegle, M., Stevens, T., & Lames, M. (2013). Design of an accuracy study for position detection in football. *Journal of Sports Sciences*, *31*, 166–172.

Steiner, S. (2018). Passing decisions in football: Introducing an empirical approach to estimating the effects of perceptual information and associative knowledge. *Frontiers in Psychology*, *9*, 361. https://doi.org/10.3389/fpsyg.2018.00361.

Steiner, S., Rauh, S., Rumo, M., Sonderegger, K., & Seiler, R. (2018). Using position data to estimate effects of contextual features on passing decisions in football. *Current Issues in Sport Science*, *3*, 9. https://doi.org/10.15203/CISS_2018.009.

Stevens, T. G., de Ruiter, C. J., van Niel, C., van de Rhee, R., Beek, P. J., & Savelsbergh, G. J. (2014). Measuring acceleration and deceleration in soccer-specific movements using a local position measurement (LPM) system. *International Journal of Sports Physiology and Performance*, *9*, 446–456.

Tabachnick, B. G., & Fidell, L. S. (2014). *Using multivariate statistics* (6th edn.). Harlow: Pearson.

Tenga, A., Holme, I., Ronglan, L. T., & Bahr, R. (2010). Effect of playing tactics on achieving score-box possessions in a random series of team possessions from Norwegian professional soccer matches. *Journal of Sports Sciences*, *28*, 245–255.

Turvey, M. T., & Shaw, R. E. (1995). Toward an ecological physics and a physical psychology. In R. L. Solso & D. W. Massaro (Eds.), *The science of the mind: 2001 and beyond* (pp. 144–169). New York: Oxford University Press.

Williams, A. M., Davids, K., & Williams, J. G. (2005). *Visual perception and action in sport*. London: Taylor & Francis.