Decision-making skills of high-performance youth soccer players: Validating a video-based diagnostic instrument with a soccer-specific motor response

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Introduction

In team sports like soccer, a multidimensional spectrum of performance factors is required to perform at the elite level. This has been acknowledged by Williams and Reilly (2000) who developed a heuristic model for the categorization of soccer talent predictors. The model identifies potential talent predictors across four core areas of sport science, including physical, physiological, psychological and sociological characteristics. While there seems to be an emphasis on physiological and physical characteristics in research and practice (Johnston, Wattie, Schorer, & Baker, 2018; Wilson et al., 2016), recently, there has been increased interest in the psychological attributes, such as perceptual-cognitive factors (Mann, Dehghansai, & Baker, 2017). Researchers have highlighted the importance of perceptual-cognitive factors for skilled performance, with findings showing highly skilled players possess superior decision-making, anticipation and situational probability proficiency compared to their less-skilled counterparts (e.g., Lex, Essig, Knoblauch, & Schack, 2015; Ward, Ericsson, & Williams, 2013).

The focus of the current study is decision-making as the cognitive performance factor. Causer and Ford (2014) define decision-making in sports as a cognitive process in which one uses knowledge about a (current) situation to select an appropriate decision, based on one's perceived ability to execute a context-specific motor skill. From a sporting perspective, the ability to make the correct decision during complex game situations, under high game pressure and time constraints is a key component of in-game performance (Höner, Larkin, Leber, & Feichtinger, 2020). Thus, decision-making has been shown to be an important skill, with several cross-sectional studies assessing decision-making performance and demonstrating that decision-making skills discriminate between skilled and less-skilled players in team sports (e.g., Diaz, Gonzalez, Garcia, & Mitchell, 2011; Lorains, Ball, & MacMahon, 2013; Woods, Raynor, Bruce, & McDonald, 2016). With respect to soccer, Ruiz Pérez et al. (2014) found Spanish club players with international experience demonstrated better decision-making performance in comparison to local level players. Further, Höner (2005) found youth national players had superior decision-making skills compared to local youth players, and additionally older players (i.e., U17 age group) had a significant decision-making performance advantage over younger players (i.e., U15 age group). While researchers have used an expertise approach to highlight superior performance of expert/elite players over novice/nonelite players (e.g., Ruiz Pérez et al., 2014) research is scarce within talent promotion programs (e.g., regional association or youth national teams; youth academies) with high-performance level (e.g., elite) players. This statement is emphasized in a recent meta-analysis which explored cognitive functions measurements with performance level as the moderator variable (Scharfen & Memmert, 2019). The results indicated, high-performance level athletes had superior performance, with a small to medium effect size, compared to low-performance level athletes. While there is a plethora of studies examining known group differences, a potential reason for the lack of research examining homogenous samples could lie in the fact that it is more difficult to find large effect sizes for discriminating athletes of a similar ability (Bergkamp, Niessen, den Hartigh, Frencken, & Meijer, 2019).

Despite the fact researchers have used cross-sectional approaches to discriminate between high- and low-performance decision-makers, Murr, Feichtinger, Larkin, O'Connor, and Höner (2018) highlighted in their systematic review that there is a significant gap in the literature concerning empirical evidence related to the predictive value of decision-making assessments. According to this review, only one investigation has used a video-based assessment to examine the predictive ability of decision-making skills in soccer. O'Connor, Larkin, and

Williams (2016) demonstrated a large significant effect in discriminating between selected and nonselected players within an Australian talent development program. However, it should be noted the prognostic period for this study was very short (i.e., the selection at the conclusion of the data collection), with further research required to investigate longer prognostic periods. Despite this positive result, more research is needed to develop valid and reliable measures that have a strong predictive value to assist the identification of high-performance level talent.

In addition to the lack of assessment within high-performance level groups, a further restriction of the current decision-making literature is the limited understanding of the potential performance differences between playing positions. From a physical perspective, researchers have found physiological and anthropometric differences across playing positions. For example, Rago, Pizzuto, and Raiola (2017) revealed midfielders and defenders completed more high-intensity running than forwards, and Boone, Vaeyens, Steyaert, Vanden Bossche, and Bourgois (2012) found central defenders are taller and heavier than midfielders and wing defenders. Therefore, it is possible that due to specific game-related roles of players in different positions (e.g., make goals, organize the build-up), in addition to physical capabilities, playing position may also influence decision-making ability (Deprez et al., 2015; Pocock, Dicks, Thelwell, Chapman, & Barker, 2019). An initial investigation by Höner (2005) attempted to address this issue and demonstrated that midfielders make better decisions compared to defenders and forwards. However, the results could be attributed to the situations used in the video scenes which presented more offensive decisions specific to midfield performance. Therefore, research is needed to address this limitation by attempting to measure decision-making performance in different game contexts, such as build-up (i.e., wing and central defense situations) and offensive (i.e., midfield and forward situations) game-based decisions.

Traditional diagnostic instruments used to examine decision-making, such as video-based tests, provide advantages in test execution or methodological control and have demonstrated the ability to discriminate skilled and less-skilled players (e.g., Roca, Williams, & Ford, 2012). However, a limitation of previous investigations is the video presentation stimuli which is often presented from a third-person perspective (i.e., television broadcast perspective; e.g., O'Connor et al., 2016). It has been suggested however, when developing sport-specific assessments, that researchers consider increasing the representativeness of a task (Bonney, Berry, Ball, & Larkin, 2019). Therefore, there could be a benefit of presenting the video stimulus from a first-person perspective which represents a more realistic perceptual environment compared to broadcast footage.

A further limitation of the current diagnostic instruments is the method of responding to the video presentation, with participants providing a verbal, written or button response (e.g., Larkin, O'Connor, & Williams, 2016; Ward & Williams, 2003). Currently, it remains unclear if these nonsport-specific responses correspond to real game situations and performance (van Maarseveen, Oudejans, Mann, & Savelsbergh, 2016). Overall, the extant research lacks studies examining decision-making competence on video-based measures which incorporate a sport-specific motor response. To address this limitation, Hagemann, Lotz, and Cañal-Bruland (2008) utilized a video-based decision-making training tool with a soccer-specific motor response. Using a similar visual-motor response (i.e., players had to pass the ball against different targets in the video), Frýbort, Kokštejn, Musálek, and Süss (2016) investigated the influence of varying exercise intensity on decision-making time and accuracy. Although these investigations provide the foundation for incorporating soccer-specific responses within laboratory-based decision-making training, to date no diagnostic instruments assess decision-making skills using a more representative task (e.g., participants dribble with the ball while watching the video stimuli and then execute their decision by passing to a player in the video). Travassos et al. (2013) reaffirmed this issue and emphasized that an expertise effect is more consistent if participants have to execute sport-specific actions in experimental studies. Hadlow, Panchuk, Mann, Portus, and Abernethy (2018) address these topics in a new classification framework to modify perceptual training in sport and emphasize the importance of high sport-specific stimulus and response correspondence.

Present study

With respect to their meta-analysis, Travassos et al. (2013) suggested further research is required to develop and examine the impact of decision-making instruments which integrate sport-specific perceptual (e.g., first-person perspective) task constraints and sport-specific (e.g., passing or shooting) skill executions. Therefore, this study aims to develop and evaluate a valid first-person perspective video-based diagnostic instrument which incorporates a soccer-specific motor response to the decision process and, thus, to provide a more representative task.

To address this aim, three objectives were pursued: In order to ensure a scientific sound assessment, the reliability of the diagnostic instrument was evaluated (Objective I). The focus of this study was on the criterion-related validity of the diagnostic instrument (Objective II). Here, both diagnostic and prognostic validation methods were used to examine positive relationships between the diagnostics' results and appropriate performance factors (i.e., age groups in middle to late adolescence, playing time in official matches of the current season, future draft in youth national team) resulting in three hypotheses:

Diagnostic validity:

H1 Decision-making skills improve across adolescent age groups (i.e., U16; U17; U19) Specifically:

- H1a: U17 soccer players demonstrate better decision-making skills than U16 players
- H1b: U19 soccer players demonstrate better decision-making skills than U16 players
- H1c: U19 soccer players demonstrate better decision-making skills than U17 players

H2 Players who played more minutes in official matches of the current season demonstrate better decision-making skills than players with less minutes.

Prognostic validity:

H3 Future youth national team players demonstrate better decision-making skills than nonselected players.

Finally, in an explorative analysis it was examined whether decision-making performance is influenced by playing position (Objective III).

Methods

Sample and design

The study sample consisted of 86 youth academy players, born between 1996 and 2001, from a professional German soccer club. The players competed in the highest German youth league, and thus belong to the top 1% of German players for their age groups (i.e., U16, U17, and U19). At the first measurement point the players were 15–19 years of age (median [M_{age}] = 16.7 years, standard deviation [SD_{age}] = 0.96) and were tested over a 3-year period (i.e., near the end of seasons 2014/15 to 2016/17), resulting in three measurement points (T2015, T2016, and T2017). Over the 3-year period, a total of 140 data points were collected. Due to the nature of professional youth academy selection processes (i.e., some players are deselected, and new players are recruited to the academy) which resulted in not every player being tested at all three time points (**Table 1**).

To examine the three hypothesizes, the study sample was separated into three subsamples. To assess diagnostic criterion-related validity (Objective II), potential differences between the independent variable age group (H1) were examined splitting the sample into three age categories (U16: $N = 41$, U17: $N = 55$ and U19: $N = 44$; H1a–H1c). A further analysis of the criterion-related validity was conducted on the independent variable playing status (H2) that was determined based on minutes played in official matches (i.e., U19/U17 German Youth Bundesliga and U16 Oberliga). Median split procedure was utilized to separate players into two categories: first team regular (i.e., who play more minutes than median; $N = 70$) and reserve players (i.e., who play less minutes than the median; $N = 68$). Further, to examine the predictive value of the decision-making diagnostic instrument relative to future youth national team status (H3), data of the respective first measurement point of all 86 players were captured. Players who participated at least in one German youth national team training course in subsequent seasons (i.e., 2015/2016; 2016/2017; 2017/2018) were identified as selected ($N = 16$), with all other players identified as nonselected ($N = 70$). Furthermore, with respect to the explorative analysis (Objective III), players were separated by playing positions as defined by their respective coaches (i.e., defenders [DF, $N = 55$]; midfielders [MF, $N = 61$]; and forwards [FW, $N = 24$]).

Decision-making diagnostic instrument

Stimulus materials Decision-making competence was assessed using a newly developed soccer-specific video-based diagnostic instrument. To create the

Abstract

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Abstract

Objectives. This study aimed to develop a valid video-based diagnostic instrument that assesses decision-making with a sport-specific motor response.
Methods. A total of 86 German youth academy players (16.7 ± 0.9 years) viewed game situations projected on a large video screen and were required to make a decision by dribbling and passing to one of three targets (representing different decision options). The test included 48 clips separated into two categories: build-up (bu) and offensive decisions (off). Criterion-related validity was tested based on age (i.e., U16, U17, and U19), playing status (i.e., minutes played in official matches of the current season) and in a prospective approach relating to future youth national team status (i.e., selected or nonselected). Finally, it was investigated whether decision-making competence was influenced by playing position (i.e., defenders vs. midfielders vs. forwards).
Results. Instrumental reliability demonstrated satisfactory values for SC_{bu} ($r = 0.72$), and lower for SC_{off} ($r = 0.56$). Results showed the diagnostic instrument is suitable for discriminating between playing status (SC_{bu}: $\Phi = 0.22$, $p < 0.01$; SC_{off}: $\Phi = 0.14$, $p < 0.05$) and between younger (U16) and older players (U17 > U16 in SC_{bu}: $\Phi = 0.24$ and SC_{off}: $\Phi = 0.39$, $p < 0.01$; U19 > U16 in SC_{bu}: $\Phi = 0.41$ and SC_{off}: $\Phi = 0.46$, $p < 0.01$); however, there was no difference between U17 and U19 players. Furthermore, the predictive value of the test indicates that future youth national team players make better decisions with respect to the build-up category (SC_{bu}: $\Phi = 0.20$; $p < 0.05$), whereas playing position did not significantly influence decision-making competence.
Conclusion. Results indicate the video-based decision-making diagnostic instrument can discriminate decision-making competence within a high-performance youth group. The outcomes associated with national youth team participation demonstrate the predictive value of the diagnostic instrument. This study provides initial evidence to suggest a new video-based diagnostic instrument with a soccer-specific motor response can be used within a talent identification process to assist with assessment of decision-making performance.

Keywords
Football · Talent identification · Adolescence · Perceptual cognitive factors · Athletic performance

Table 1 Data points collected with respect to age group and measurement time point

Age group	Measurement point			Total
	T2015	T2016	T2017	
U16	13	12	16	41
U17	21	17	17	55
U19	15	14	15	44
Total	49	43	48	140

diagnostic instrument, more than 300 dynamic on-ball decision-making situations, recorded from the first-person perspective of the ball carrier at different positions on the pitch (i.e., forward, midfield, wing defense, central defense; **Fig. 1**) were designed and filmed as part of a pilot study (Dieze, 2015). The footage of each situation moved like a player in possession of the ball and were reviewed by a panel of expert coaches (i.e., one UEFA pro-level, one UEFA A-level and two UEFA B-level). During the review process, a round table forum was held, whereby the panel discussed the outcome of each clip (i.e., best correct decision), until 100% agreement was reached. Following this detailed evaluation by the expert panel, 30 video scenes were selected as the most realistic game situations and were thus used for the study (24 testing scenes; 6 familiarization scenes).

To ensure a more comprehensive diagnostic instrument, the 24 testing video scenes were mirrored (i.e., the same scene presented from the opposite direction), creating a final diagnostic instrument of 48 game situations. Each situation was then classified as either offensive decisions (i.e., situations in forward and midfield positions where players create scoring opportunities) or decisions that occur in the build-up of a game (i.e., situations in defensive positions such as wing and central defense where players start offensive moves). For testing, the video scenes were projected on a 2.76 m wide × 1.50 m high video screen and were presented in four video blocks of 12 videos (i.e., forward; midfield; wing defense; central defense) completed by all participants. During the test, each video scene was 5–6 s in duration and had three possible passing options; however, in the forward category players had the choice between two passing options and one option to shoot at goal. Between each trial, a black screen remained for 6 s. Each clip commenced with the first frame of the video frozen for 1.5 s, to orientate the participants to the situation.

Procedure Each participant individually completed the test in the same indoor room at the youth academy over a 6-week period at each measurement point (i.e., T2015; T2016; T2017). At the commencement of each test, the participant was provided with a standardized instruction (e.g., "In each scene you start to dribble from one of five positions."; "A short freeze frame at the start of each video will help you to orientate to the current game situation."; "During the dribbling your decision is based on passing the ball to one of three targets that represent the position of your teammate."). Prior to each testing block, three familiarization video scenes were presented for participants to become accustomed to the procedures and the respective category situation. Participants were then able to ask any questions they had in relation to the video or response procedures. Following the familiarization videos, the 12 testing videos were presented. For each trial, participants were positioned with the ball on a starting position which represented the location on the pitch. As the video commenced the participants started to dribble with the ball while watching the evolving game situation on the screen. Prior to overstepping a limiting line or the video scene ending the participant provided a response by passing to one of three possible targets (i.e., supporting teammates in the video, **Fig. 2**). For each trial, the first author recorded the target (i.e., decision) the participants passed the ball to, while a research assistant placed a ball on the next starting position.

Dependent measures The decision-making accuracy for each video situation was assessed using a coding criterion of one for a correct decision (i.e., passing or shooting to the best option identified by the expert panel) and zero for an incorrect decision (i.e., passing or shooting to an option not rated the best). Only one correct option was determined by the expert panel for each scenario. Any trial where the participant missed a target or did not decide before the scene ended was also coded as a zero. Subsequently, participants' decisions from 48 testing video situations were used for calculating offensive (SC_{off}; i.e., mean value of 24 corresponding scenes) and build-up (SC_{bu}; i.e., mean value of 24 corresponding scenes) decision accuracy scores. Both scores (i.e., SC_{off} and SC_{bu}) were converted to a percentage of correct decisions. As the primary aim of the study was to determine decision-making accuracy, we did not calculate or assess speed of decision-making within the study.

Statistical analyses

Data were analyzed using SPSS version 24. Diagnostics' instrumental reliability (Objective I) was examined using a split-half procedure (odd-even-method corrected by Spearman–Brown formula; Lienert & Raatz, 2011) for players' first assessment results.

An examination of distributional properties revealed the decision-making accuracy scores SC_{off} and SC_{bu} were not normally distributed. A Mann–Whitney-U-test (as one-tailed hypothesis) was used to determine differences in SC_{off} and SC_{bu} between age groups, playing status and future youth national team status (Objective II, H1–H3). To explore mean differences between playing positions, nonparametric Kruskal–Wallis tests were conducted with post hoc pairwise comparisons (Objective III).

As the number of measurement points may influence decision-making scores and consequently the results in regards to the diagnostics' validity (due to memorable or habituation effects), a priori analysis was conducted to determine whether the number of measurement points correlated with the independent variables playing status, age group, future youth national team status, and playing position. The variables age group ($r_s = 0.18$; $p < 0.05$) and playing position ($r_s = 0.22$; $p < 0.01$) correlated with the number of measurement points. Therefore, in a second step and as an additional analysis for

Fig. 1 ▲ Example of a midfield scene used within the first-person perspective video-based decision-making diagnostic instrument

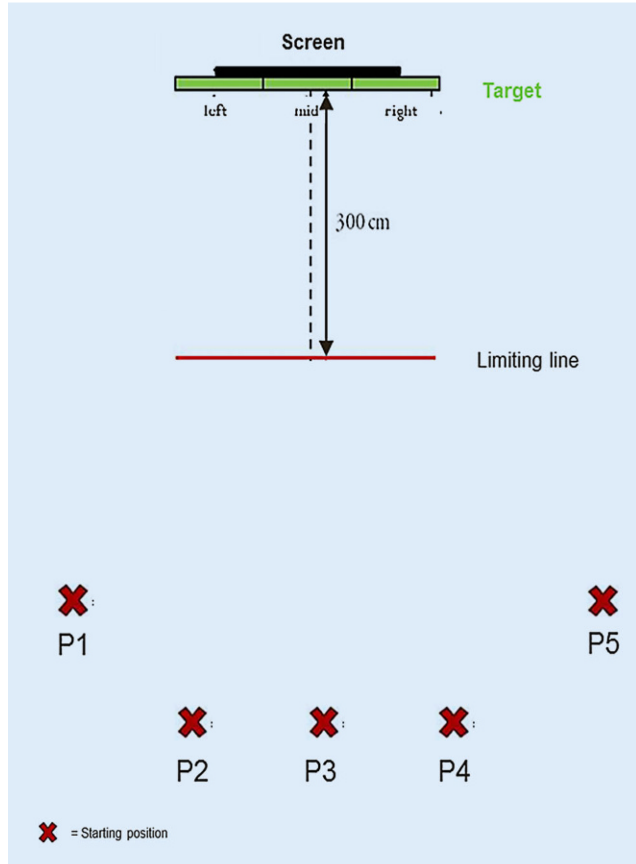

Fig. 2 ▲ The structure of the first-person perspective video-based decision-making diagnostic instrument experimental set up

the effects of age groups and playing position, the number of measurement points served as a manifest covariate. This was to assess whether the number of measurement points influenced the result pattern and statistical decisions with respect to age groups. As there is no statistical procedure controlling for a covariate in nonnormal distributional properties, ANCOVAs (analyses of covariance) were conducted in addition to Mann–Whitney-U-tests (post hoc analysis) to assess for possible influences of the number of measurement points on the results.

Effect sizes ω and Φ for nonparametric tests were calculated and classified in accordance to Cohen (1992). To determine the size of a possible population effect (within objective II and III), sensitivity was calculated by post hoc power analyses using G*Power version 3.1.9.7. G*power provides sensitivity calculations for mean comparisons between two groups only based on Cohen's *d*. The analyses determined the sensitivity for objective II ($\alpha = 0.05$, $1 - \beta = 0.85$, one-tailed), whereas H1 ranged from $0.56 \leq d \leq 0.60$, with H2 equal to $d = 0.47$, and H3 equal to $d = 0.77$. Regarding objective III, the power analyses ($\alpha = 0.05$, $1 - \beta = 0.85$, two-tailed) provided a range of $0.57 \leq d \leq 0.76$. Therefore, medium effect sizes could be detected within the present study. As the present study utilized Φ as an effect size, this corresponds to a range of Φ between 0.30 and 0.50. Due to the fact that only three measurement points are available for a very small number of players, a longitudinal study was omitted.

As H2 and H3 investigated a group prediction, additional stepwise logistic regressions were conducted. The overall model fit was examined with the likelihood ratio chi-square (X^2) test. The SC_{off} and SC_{bu} regression coefficients as well as the odds ratios e^{β} and their 95% confidence intervals were calculated with reference to the respective selection criteria (i.e., "reserve player" for H2; "non-selected" for H3). Finally, individual selection probabilities were determined for playing status and future youth national team status on the basis of a player's SC_{off} and SC_{bu}.

Results

Instrumental reliability demonstrated satisfactory values for build-up scenes ($r = 0.72$), and lower for offensive scenes ($r = 0.56$; Objective I). **Table 2** presents an overview of the decision-making scores relative to age (H1) playing status (H2) and future youth national team status (H3; Objective II). Mann–Whitney-U-tests identified significant differences (each $p < 0.01$) in decision-making competence between U17 and U16 (H1a; U17 > U16 in SC_{bu}: $Z = 2.35$, $\Phi = 0.24$ and in SC_{off}: $Z = 3.82$, $\Phi = 0.39$), as well as between U19 and U16 players (H1b; U19 > U16, SC_{bu}: $\Phi = 0.41$ and SC_{off}: $\Phi = 0.46$). However, no significant differences were found between the comparison of U19 and U17 players (H1c; U17 > U19 in SC_{bu}: $Z = 0.04$, $p = 0.48$ and U19 > U17 in SC_{off}: $Z = 0.69$, $p = 0.244$). In relation to playing status (H2) first-team regular players performed significantly better than reserve players in both build-up and offensive situations, with low to moderate effect sizes (SC_{bu}: $Z = 2.57$, $\Phi = 0.22$, $p < 0.01$ and SC_{off}: $Z = 1.69$, $\Phi = 0.14$, $p < 0.05$). With respect to the stepwise logistic regression, only build-up situations showed significance and therefore remained in the model ($\chi^2(1) = 8.00$, $p < 0.01$). The odds ratios e^{β} from the logistic regression

Table 2 Descriptive and inferential statistics for criterion-related validity with regards to age group (Objective II, H1), playing status (Objective II, H2), future youth national team players (Objective II, H3), and the explorative analysis of playing position (Objective III)

Variables	Decision accuracy score (%)	Descriptive statistics ($M \pm SD$)			Effect size			
					Post hoc analysis/Mann–Whitney U-test			Kruskal–Wallis test
Age group		U16	U17	U19	U16 vs. U17	U16 vs. U19	U17 vs. U19	
		($N = 41$)	($N = 55$)	($N = 44$)				
						Φ		
	SC_{bu}	66 ± 14	73 ± 14	71 ± 18	0.24**	0.41**	0.00	
	SC_{off}	63 ± 11	74 ± 13	75 ± 14	0.39**	0.46**	0.00	
Playing status		FTRP	RP		FTRP vs. RP			
		($N = 70$)	($N = 68$)					
					Φ			
	SC_{bu}	74 ± 13	67 ± 17		0.22**			
	SC_{off}	73 ± 13	69 ± 15		0.14*			
Youth national team		Selected	Nonselected		Selected vs. nonselected			
		($N = 16$)	($N = 70$)					
					Φ			
	SC_{bu}	73 ± 11	65 ± 16		0.20*			
	SC_{off}	69 ± 11	66 ± 13		0.08			
Playing position[a]		DF	MF	FW	DF vs. MF	DF vs. FW	MF vs. FW	
		($N = 55$)	($N = 61$)	($N = 24$)				
						Φ		ω
	SC_{bu}	71 ± 16	72 ± 13	63 ± 17	0.00	0.21	0.25*	0.44[#]
	SC_{off}	70 ± 16	73 ± 13	69 ± 9	0.07	0.07	0.15	0.15

FTRP First team regular player, *RP* Reserve player, *DF* Defenders, *MF* Midfielders, *FW* Forwards, SC_{bu} Decision accuracy score for build-up, SC_{off} Decision accuracy score for offensive

**$p < 0.01$, *$p < 0.05$; # $p < 0.10$

[a]Playing position correlated significantly with the number of measurement points. However, ANCOVAs (analysis of covariance) with the main factor playing position and the covariate number of measurement points demonstrated no changes in the statistical decisions regarding the multiple group comparison. Thus, the results pattern for playing position is independent of the number of measurement points

model indicated that a one standard deviation (SD = 0.153) increase in build-up score, improved the chance of being a first-team regular player by a factor of 1.65 (= $(e^{\beta})^{0.153} = 26.69^{0.153}$).

With respect to the prognostic validity (H3), Mann–Whitney-U-test demonstrated that selected players have a higher decision-making accuracy than nonselected players in build-up ($Z = 1.82$, $\Phi = 0.20$, $p < 0.05$) and offensive ($Z = 0.78$, $p = 0.217$) situations; however, only build-up situations provided a significant difference. Analyzing the prediction of future youth national team status with regard to the logistic regression models led to the same result as for the playing status variable. Only build-up score demonstrated significance and therefore remained in the model ($\chi^2(1) = 4.15$, $p < 0.05$). A one standard deviation increases in build-up score improved the chance of being selected for a future youth national team by a factor of 1.89 (= $(e^{\beta})^{0.153} = 64.20^{0.153}$).

Regarding playing position (Objective III), the results for the different subsamples (i.e. DF, MF, FW) in both build-up and offensive decision category ranged in mean from 69–72% with only one exception (i.e., the result of 63% from FW deviated in their nonposition-specific build-up category compared to other playing positions distinctly). Despite these facts, the Kruskal–Wallis tests did not reveal significant differences in any decision-making competence (SC_{bu}: $H(2) = 5.26$, $p = 0.072$; SC_{off}: $H(2) = 1.81$, $p = 0.404$). In terms of possible influences caused by correlations between the manifest variable, the number of measurement points, and the independent variable playing position, ANCOVA demonstrated no changes in the statistical decisions regarding the multiple group comparisons of playing position.

Discussion

The aim of this study was to develop a valid video-based decision-making diagnostic instrument which presented footage from a first-person perspective and incorporated a soccer-specific motor response. A further strength of the study was the video stimuli were not limited to one game situation, but rather different situations (i.e., build-up and offensive decisions). While there were no differences between playing positions, the study does provide a foundation for future research. In particular, the diagnostic instrument was developed as a measure to discriminate decision-making competence within a group of youth high-performance level players. Results showed the diagnostic instrument, which included realistic soccer video-scenes in combination with a soccer-specific motor response, is a suitable instrument for discriminating playing status and partially for age (U19 and U17 > U16). Further, it provides a more representative assessment compared to previous studies where the diagnostic instrument was limited by a lack of a soccer-specific response (e.g., Bennett, Novak, Pluss, Coutts, & Fransen, 2019). An additional aim was to examine the predictive value of the new video-based decision-making diagnostic instrument, with the findings indicating that in parts of the study (i.e., in build-up categories) future youth national team players perform better in the decision-making diagnostic instrument.

Using reliable diagnostic instruments is fundamental to scientific work. The implications associated with using a diagnostic instrument with a lack of, or unknown, reliability is whether the participant performance differences are due to random test error or actual performance changes of the participants (Gadotti, Vieira, & Magee, 2006). In comparison to the assessment of manifest variables (e.g., time, height, distance), the measurement of latent constructs such as decision-making competence poses a much larger challenge. While researchers have highlighted the limited reporting of reliability for new diagnostic instruments (Hadlow et al., 2018; Schweizer, Furley, Rost, & Barth, 2020), a key aim of the current study was to measure the reliability of the latent construct decision-making (Objective I). Here, an adequate level of reliability for the build-up situations was found; however, the lower reliability for offensive situations has to be considered as a larger limitation. A potential reason for the lower reliability of the offensive situations could be due to the restriction of range phenomenon within the high-performance level group (i.e., homogeneous expert samples) the study was conducted (Schweizer et al., 2020). Despite this limitation, the current study does provide a method for establishing the reliability of the offensive decision-making situations. In addition, future studies may improve the reliability of these situations by exchanging current lower reliability clips with newly developed higher reliability clips. Also adding more items to the diagnostic instrument could be an approach for improving the reliability and even reduce the need for large sample sizes (Schweizer et al., 2020).

This study advances current sport-based decision-making literature by demonstrating the ability to develop a decision-making diagnostic instrument in which the process of visual perception of in-game video-scenes (i.e., first person perspective) is more challenging by an additional soccer-specific motor action (i.e., dribbling) and response (i.e. passing). Traditional video-based instruments which assess decision-making performance generally present footage from a broadcast (i.e., television broadcast) or third person perspective associated with nonsoccer-specific decision response (i.e., written, verbal or button response). In this context, Mann, Farrow, Shuttleworth, Hopwood, and MacMahon (2009) indicated using a diagnostic instrument from first person-perspective is more realistic. However, it was noted this may be more difficult from a decision-making perspective than using footage from an aerial perspective, and therefore may provide more robust diagnostic instruments. Furthermore, it has been suggested the lack of sport-specific responses may limit the correlation between video-based tests and actual in-game decision-making performance (e.g., van Maarseveen et al., 2016). This is further supported by Travassos et al. (2013) who indicated that perceptual-cognitive assessments need to consider the task representativeness when developing sport-specific diagnostic instruments. By developing assessments, which consider representative task constraints, such as presenting decision-making situations from a first-person perspective, combined with a sport-specific motor response, enhances the validity of the assessment measure.

While the current study demonstrated the ability to differentiate U16 and older adolescent athletes (i.e., U17 and U19, objective II), developing a decision-making diagnostic instrument sensitive enough to differentiate performance of high-performing late adolescent athletes requires further investigation. A possible explanation as to why there was no significant difference between the U17 and U19 players (H1c) could be due to at least two possible reasons. First, from the perspective of the U19 team, the best players from the squad had already played for the senior professional team (i.e., in either the first or reserve/second team) and therefore were not able to participate in the investigation. In relation to the U17 group, two of the three U17 cohort squads in this study were very successful and participated in the finals of the German U17 championship (i.e., the highest level of competition at this age). Therefore, it seems feasible that despite the age difference with respect to U19 group, both groups were of a very similar performance level (limiting the studies' internal reliability with regard to discriminating between age groups). Second, this finding supports other studies to investigate age-related soccer-specific performance skill differences. For example, Huijgen, Elferink-Gemser, Post, and Visscher (2010) highlighted there were no improvements from ages 16 to 19 in dribbling and sprinting, which the authors attributed to the end of puberty. Furthermore, Beavan et al. (2019) revealed in a battery of cognitive function tests (e.g., Vienna Test System, which measures inhibition and cognitive flexibility) that there were no differences between U19 and U17 age groups. At this stage, further research is needed to explore whether there are peak developmental phases for cognitive factors such as decision-making.

A strength of this study is that the sample consisted of participants from one of the most successful youth soccer academies in Germany, thus, resulting in a very homogeneous high-level group. This is not a common approach used by researchers investigating soccer-specific decision-making skills as they have generally conducted cross-sectional studies comparing and identifying skill differences between groups of high-performance and low-performance level participants (i.e., sub-elite; intermediate; novice participants; Diaz et al., 2011;

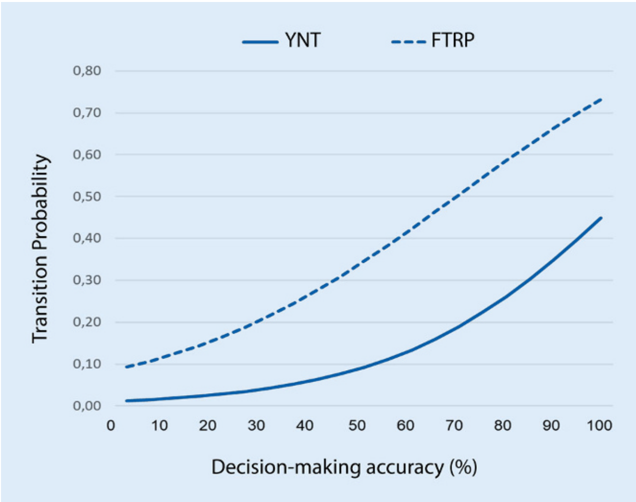

Fig. 3 ◄ Selection probabilities obtained from the logistic regression for reaching first team regular player (FTRP) and for drafting youth national team (YNT) status

Roca et al., 2012; Scharfen & Memmert, 2019). Therefore, while the findings of the current study indicated only a small significant effect size for discriminating playing status (H2), the possible reason for this may be attributed to the high sensitivity when comparing athletes within a homogeneous high-level group. This supports previous findings by van Maarseveen et al. (2016) who also failed to detect significant differences in perceptual-cognitive skills between talented female soccer players of a comparable highly skilled performance level (i.e., national soccer talent team). Nevertheless, the logistic regression models demonstrated that players with good decision accuracy on the diagnostic instrument will have a higher probability of being a first team regular player (SC_{bu}: Odds Ratio = 1.65; ◘ Fig. 3). Therefore, the results provide initial evidence to suggest the new diagnostic instrument can potentially identify more skilled individuals within a high-performance level youth group.

Further, in comparison to previous investigations which only assessed performance using a cross-sectional design (e.g., Höner, 2005), the current investigation implemented a prospective design to allow for a greater understanding of potential future soccer success (H3). The logistic regression model for SC_{bu} indicated that players who performed well on the assessment improved the chance of being selected (i.e., selected to participate in a German youth national team training course) by a factor of 1.89. The probability curve (◘ Fig. 3) increased more rapidly for higher SC_{bu} values and therefore results proved the diagnostics' prognostic relevance, as participants who perform better on the assessment are also more likely to be selected. This finding supports other video-based research which has demonstrated the ability to predict selection into high performing youth soccer programs (O'Connor et al., 2016). This indicates the possibility for a video-based diagnostic instrument with a soccer-specific motor response to be used within the talent identification process to assist with the assessment of players' decision-making performance. The nonparametric analysis demonstrated a small significant effect size for SC_{bu} and no significant difference for SC_{off} between selected and nonselected future youth national team players. However, this finding may have been limited by the relatively low number of participants selected into national youth programs ($N = 16$). Therefore, future research should consider increasing the number of national youth players in the sample to fully understand the potential decision-making skill differences between these high performing players (i.e., selected; nonselected for youth national team; Ackerman, 2014).

The present study extended the current research knowledge related decision-making assessments by developing a diagnostic instrument which incorporated decision situations from defense, midfield, and forward playing positions (Objective III). However, while assumptions were based on previous investigations which have demonstrated differences based on playing positions (e.g., Höner, 2005), the current findings did not reveal a significant difference. Despite this finding, the novel approach used in the study (i.e., provide the players video-scenes from different playing positions on the pitch) may enable more detailed comparisons between playing positions in future. Hence, research should divide playing positions in a stricter manner, for instance when considering the position of a forward, there may be specific differences between central forwards and wide forwards (i.e., wingers).

As this is one of the first studies to develop a decision-making diagnostic instrument which links visual perception of first-person video scenes and soccer-specific motor responses in the assessment, the findings should be considered with respect to several limitations. First, the execution-time of decision-making was not measured directly. Decision-making was only restricted by the length of the video scenes and a marked limiting line. Currently, there are different opinions about the importance of execution time with respect to decision-making. There seems to be the belief that experienced players make quicker and more accurate decisions compared to less skilled players (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). Nevertheless, a further development of the diagnostic instrument could include the measurement of execution-time to determine whether highly skilled players decide faster than less skilled players or whether they wait even longer for the perfect moment to execute the appropriate response. Second, the current sample was limited by the restrictions of testing within a professional sporting club environment. As such, several high-performing U19 athletes were not included in the sample due to professional club commitments. As a result, it may be possible that the lack of significant differences between U17 and U19 players in the current sample may not fully describe the potential age-related differences between these two groups. Therefore, future investigations should aim to sample all athletes from within an age group to ensure a true representation of the performance group. Finally, similar to other studies (e.g., Höner, 2005), this study limited the number of options (i.e., three option per situation) and the sport-specific motor response (i.e., players only had the options to pass or shoot). Future studies should also consider the development of diagnostic instruments which include other decision-making options, such as dribbling. While observational studies (e.g., recording decision-making skills in small-sided games) such as Romeas, Guldner, and Faubert (2016) have attempted to assess the whole spectrum of decision-making alternatives, it is a challenge developing such situations within a video stimuli. A possible alternative maybe developing diagnostic instruments that provide more graduations of decisions (i.e., best option; second best option; etc.), rather than current binary forms (e.g., Bennett et al., 2019). Further, off-the-ball decision-making in defensive game situations such as positioning close or far from the ball, which has not been assessed in the literature, should also be considered in future research.

Conclusion

Sport-based decision-making is a cognitive process in which athletes use their knowledge about a (current) situation to select an appropriate decision based on their perceived ability to execute a sport-specific motor skill response (Causer & Ford, 2014). While decision-making is defined by the ability to perceive appropriate stimuli and execute a sport-specific skill response, traditional video-based instruments assess decision-making using nonsport-specific responses such as verbal, written, or button responses (e.g., Roca et al., 2012). This study addressed this limitation by developing a valid first-person perspective video-based diagnostic instrument which requires a soccer-specific motor response (i.e., participants dribble with the ball while watching a video stimulus and then execute their decision by passing to a player in the video). The results indicate the video-based decision-making diagnostic instrument can discriminate decision-making competence within a high-performance youth group, in particular for playing status and to some extent age. Although the reliability of the diagnostic instrument is satisfied for the build-up category, future research should aim for higher reliability for all measured variables (e.g., offensive decision), by using the guidelines proposed, for example, by Schweizer et al. (2020). Further, the results demonstrate the predictive value of the new video-based decision-making diagnostic instrument, especially the build-up situation for national youth team selection. However, future investigations with a longer prognostic period (e.g., up to senior level) is of interest to strengthen the results. With respect to playing positions, no differences were found between positions; however, further examination of playing position on decision-making skills is warranted (e.g., are midfielder better decision-makers regardless on which area of the pitch the decision-making skill is required?).

Considering these results, this study provides initial evidence to suggest a soccer-specific video-based diagnostic instrument can be used within talent identification processes to assist with the assessment of players' decision-making performance. Finally, future decision-making assessment studies can use similar procedures to those employed in the current investigation to develop a valid and reliable video-based decision-making diagnostic instrument in other sports/domains. In addition, further exploration of the integration of motor specific responses with the video footage to create an even more realistic diagnostic instrument may be possible. One approach would be to use virtual reality technology to allow body parts (e.g., foot) interacting with the stimulus material or to measure a player's in situ task constraints.

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Compliance with ethical guidelines

Conflict of interest. D. Murr, P. Larkin and O. Höner declare that they have no competing interests.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The ethics department of the Faculty of Economics and Social Sciences at the University of Tübingen and the youth academy of the professional soccer club approved the implementation of this study. All players and legal guardians (i.e., parents) provided informed consent prior to participation in the study.

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