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Lukas Magnaguagno · Ernst-Joachim Hossner · Jürg Schmid · Stephan Zahno
Institute of Sport Science, University of Bern, Bern, Switzerland

Decision-making performance and self-generated knowledge in handball-defense patterns: a case of representational redescription

Over recent decades, research has made comprehensive attempts to understand the skills that contribute to superior anticipation and decision making in sports, especially in dynamic and highly time-constrained situations (Williams & Ford, 2008). In this respect, it has been of considerable interest to explore the nature of perceptual–cognitive expertise (Roca & Williams, 2016), which is classically understood as the capability to identify and process environmental information in order to facilitate response selection (Marteniuk, 1976). Empirically, it has been repeatedly shown that experts possess superior perceptual–cognitive skills compared to nonexperts and novices (Mann, Williams, Ward, & Janelle, 2007). These skills support successful anticipation (Williams, Casanova, & Teoldo, 2017) and particularly rely on (a) postural–cue usage, which regards the ability to pick up visual information emanating from the movements or body orientations of a subject such as an opponent (Smeeton, Hüttermann, & Williams, 2019), (b) pattern identification, which refers to the ability to detect familiarity and structure in an evolving situation (North & Williams, 2019), (c) visual search behavior, which regards the search strategy to extract the most pertinent information (Casanova, Oliveira, Williams, & Garganta, 2009), and (d) situational–probability estimation, which relates to the ability to generate accurate predictions of the options that might occur in a specific situation (Farrow & Reid, 2012).

In sport games, pattern identification is regarded as a strong predictor for decision making (Farrow, McCrae, Gross, & Abernethy, 2010; Williams & Jackson, 2019) and the use of situational probabilities as a powerful source of information (Farrow & Reid, 2012). However, the development of such skills is considerably underresearched (Williams, Fawver, Broadbent, Murphy, & Ward, 2019). So far, investigations have focused on superior performance of skilled players compared to less-skilled counterparts for situational probabilities (Abernethy, Gill, Parks, & Packer, 2001; Farrow & Reid, 2012; Helm, Cañal-Bruland, Mann, Troje, & Munzert, 2020; Magnaguagno, Zahno, Kredel, & Hossner, 2022) and pattern identification—more precisely, pattern detection (Magnaguagno & Hossner, 2020), pattern recognition (North, Williams, Hodges, Ward, & Ericsson, 2009; North, Ward, Ericsson, & Williams, 2011; Roca, Ford, McRobert, & Williams, 2013; Vater, Luginbühl, & Magnaguagno, 2019; Williams, Hodges, North, & Barton, 2006), as well as pattern recall (Gorman, Abernethy, & Farrow, 2012, 2015; North, Hope, & Williams, 2017; Raab & Farrow, 2015; Sherwood, Smith, & Masters, 2019; Smeeton, Ward, & Williams, 2004; van Maarseveen, Oudejans, & Savelsbergh, 2015). In contrast, the relevance of the intertwining between different perceptual–cognitive skills has received far less attention; even though it has been claimed that it is the interaction of these skills that facilitates decision making (Roca & Williams, 2016; Williams et al., 2017). Respective studies were generally dedicated to the use of postural cues in relation to one other perceptual–cognitive skill (Gorman et al., 2015; North et al., 2009; North et al., 2011). Even more rarely, studies examined the interaction of pattern identification and situational–probability estimation (as an exception, see Roca et al., 2013). The relationship between these perceptual–cognitive skills could be ascribed to the fact that players develop specific knowledge on patterns that, in turn, enables them to establish accurate expectations of likely events (Williams, Davids, & Williams, 2000).

However, only a few studies so far have tried to tackle the relationship between either pattern identification or situational–probability estimation on the one hand and players' actual performance on the other hand (North et al., 2009; North et al., 2011; Sherwood et al., 2019; van Maarseveen, Oudejans, Mann, & Savelsbergh, 2018). The cited studies each used difference operationalizations of player performance, such as coaches' ratings of players' on-field decision making (Sherwood et al., 2019), in situ decision-making scores (van Maarseveen et al., 2018) or assessments of anticipation from a third-person perspective (North et al., 2009; North et al., 2011). However, notably, none of these studies found a significant correlation between pattern identification and players' game performance.

Data Availability
The datasets generated and analyzed during the mentioned studies are not publicly available but are available from the corresponding author on reasonable request.

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Furthermore, since these studies did not assess pattern identification and performance within the same task but independently of each other, the relevance of the obtained findings seems to be limited.

Finally, research conducted on pattern identification and situational–probability estimation in sports has struggled to address the issue of ecological validity in the test conditions (Mann, Abernethy, & Farrow, 2010; Pinder, Davids, Renshaw, & Araújo, 2011). For example, tasks used for assessing pattern identification did not incorporate any motor-skill component as a core requirement of performance (Williams & Ericsson, 2005). Moreover, as stated by van Maarseveen et al. (2018), real-world demands have been examined in rather artificial settings with videos projected on a two-dimensional (2D) screen or even presented on rather small displays. Consequently, to the best of our knowledge, there are no experimental studies that have (a) successfully related either pattern identification or situational–probability estimation to game performance and (b) assessed these skills under high ecologically valid conditions within the same task.

Therefore, the current study aims to contribute to the current understanding by addressing the role of perceptual–cognitive skills in decision making in sports games. Specifically, we present findings on the relationship between handball players' ability to explicitly detect a game-specific pattern and to initiate correct real-world motor responses in a 3:3 immersive defensive task. Previous research in team handball showed, on the one hand, a consensus on the superior decision making of more experienced players compared to less experienced players in adult (Magnaguagno & Hossner, 2020) and youth players (Hinz et al., 2022; Magnaguagno et al., 2022) and, on the other hand, a tendency that experts outperform their counterparts in pattern recall (Raab & Farrow, 2015) as well as pattern detection (Magnaguagno & Hossner, 2020). With respect to the latter, however, recent research on youth handball players revealed no relevant differences (Magnaguagno et al., 2022).

To extend the knowledge about the relationship between the aforementioned factors of decision making and pattern detection, we used data collected in two previously published studies on the impact of contextual priors on performance (Magnaguagno & Hossner, 2020; Magnaguagno et al., 2022). However, as we used the data sets to conduct fundamentally different analyses, the presented empirical results should be regarded as original data of randomized controlled trials. In more detail, the available data sets allowed for unique analyses of the role of (a) pattern detection of teammates' defensive qualities on (b) the player's response correctness (c) as a function of the player's domain-specific experience. We based our analyses on the assumption that experts' superior decision-making facilitates the extraction of explicit knowledge of situational patterns through the process of "representational redescription", which regards a cyclical process of exploitation of internally stored information by iteratively changing its representational format so that implicit knowledge might turn into explicit knowledge (Karmiloff-Smith, 1994). This concept can be regarded as being in opposition to the standpoint that the extraction of explicit knowledge about situational patterns directly facilitates experts' superior decision making, as it has alternatively been proposed in respective research (e.g., Abernethy, Joseph, & Coté, 2005).

Experiment 1

Experiment 1 refers to the data set gathered by (Magnaguagno et al., 2022) in their study on contextual information in situations of different degrees of uncertainty. Elite youth handball players were compared with near-elite youth handball players in a between-participant design.

Method

Participants

Fifty-seven youth male handball players were recruited. This sample size resulted from the original study of (Magnaguagno et al., 2022), in which a statistical power analysis revealed an optimal total sample size of 60 participants. A post hoc analysis for an F-test and analysis of variance (ANOVA) design (i.e., main effects, within–between interaction) that was additionally conducted in G*power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) with the input parameters [averaged f] = 0.42, α err prob = 0.05, $N = 57$, numerator df = 3, and number of groups = 4, revealed a power [$1 - \beta$ err prob] of 0.73.

Elites ($n = 30$; $M_{age} = 17.13$ years, $SD = 0.94$) played in the highest national division. They had 8.53 years ($SD = 2.37$ years) of practice experience with 7.38 h ($SD = 2.33$ h) of practice per week, and 6.40 seasons ($SD = 1.77$ seasons) of competition experience with 22.27 games ($SD = 5.50$ games) per season. Near-elites ($n = 27$; $M_{age} = 16.93$ years, $SD = 0.87$) played in the lowest of three national divisions. They had 6.70 years ($SD = 2.48$ years) of practice experience with 5.00 h ($SD = 2.03$ h) of practice per week, and 5.30 seasons ($SD = 1.44$ seasons) of competition experience with 17.19 games ($SD = 5.80$ games) per season.

In both groups, only players who normally defended at the positions relevant to the present study were selected. However, to check experience differences, five separate one-way ANOVAs were conducted. As expected, elite players started playing handball earlier with regards to both practicing, $F(1, 55) = 8.10$, $p = 0.006$, $\eta_p^2 = 0.13$, and competition experience, $F(1, 55) = 6.55$, $p = 0.013$, $\eta_p^2 = 0.11$, they practiced more hours per week, $F(1, 55) = 16.76$, $p < 0.001$, $\eta_p^2 = 0.23$, and partook in more games per season, $F(1, 55) = 11.52$, $p = 0.001$, $\eta_p^2 = 0.17$, than their near-elite counterparts. No significant difference was found for age, $F(1, 55) = 0.74$, $p = 0.393$, $\eta_p^2 = 0.01$. The original study (Magnaguagno et al., 2022) was approved by the ethics committee of the University Faculty (reference number 2020-11-00003), and all participants provided informed consent prior to participation.

Apparatus, procedure, and measures

Participants were placed in a life-sized Cave Automatic Virtual Environment (CAVE) environment projecting real-world simulations of 3:3 handball situa-

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L. Magnaguagno · E.-J. Hossner · J. Schmid · S. Zahno

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Abstract

In sport games, perceptual–cognitive skills are discussed as a decisive aspect of players' expertise. However, an understanding of the relationship between these skills and actual game performance is limited, particularly, regarding the role of pattern identification and situational-probability estimation in performance. The present study thus aimed to examine how identification of teammates' defensive qualities relates to decision-making performance in a 3:3 virtual-reality defensive task. Examining data collected in two previously published studies, we analyzed the relationship between explicit pattern detection and response correctness, and also as a function of players' experience. Experience was operationalized as either expertise level (Experiment 1) or task-specific experience (Experiment 2). As expected, the explicit detection of a game-specific pattern was found to be facilitated by experience. However, the results imply that it is accumulated experience that enhances decision-making performance rather than the degree of self-generated explicit knowledge. This finding supports the notion of "representational redescription" as introduced by Karmiloff-Smith (1994). For sports practice, this suggests that the pattern identification demonstrated by skilled athletes should not be overestimated as a predictor of game performance, while the explicit provision of knowledge might be beneficial for less-skilled athletes, particularly in situations of high uncertainty.

Keywords

Perceptual-cognitive skills · Sport games · Expertise · Virtual reality · Response correctness · Pattern detection

tions from the perspective of the central defensive player on a 6.00 m × 3.75 m front wall, two 11.00 m × 3.75 m sidewalls, and the 6.00 m × 11.00 m floor. Their starting position was on the 6 m line that was—like all other handball-specific lines—projected on the floor, so that the distances to the sidewalls and front wall of the laboratory were 3 m. In this virtual-reality environment, the participants' perspectives almost perfectly matched to real-world defensive situations. The participants were thus instructed to act as they would as the central defender in a real-world environment with the ultimate objective to prevent goals.

A total of 144 experimental scenes ended with a 1:1 situation between one of the participant's teammates and the respective left or right offensive back. The defensive quality of the responsible teammate was systematically manipulated to be either weak or strong; with the weak teammate losing and the strong teammate winning the 1:1 situations in two-thirds of cases, respectively. The losing situations (weak teammate = 67%, strong teammate = 33%) consistently ended with a throw at the goal and the winning situations (weak teammate = 33%, strong teammate = 67%) with a foul according to the rules. To increase overall variance as well as ecological validity, the experimental scenes were complemented by 48 further scenes that consisted of typical handball situations but without a particular defensive or action outcome pattern.

Participants were tested individually in single sessions of 60 min. During this time, participants were allowed to accustom themselves to the experimental setup over four familiarization trials and, subsequently, partook in 192 experimental trials. Response correctness was calculated as the percentage of correct defensive actions—in losing situations a sideways move to support the teammate and in winning situations keeping the central position—over the last 48 experimental trials. To assess whether participants did not or did act according to the correct response, handball-experienced raters judged each of the participants' defensive actions by watching the footage. Subsequently, an explicit-knowledge test was conducted, in which participants had to specify whether their teammates differed in their defensive qualities or not, and if so, to identify the stronger defender by their jersey number. Pattern detection was coded on a continuum from misidentifying (= 0) over being unaware of (= 1) to correctly identifying (= 2) the difference between teammates' defensive qualities (for further details, see Magnaguagno et al., 2022). For the present analysis, participants were further assigned to one of two subgroups; namely either "detection" (code 2) or "no detection" (code 0 or 1).

Data analysis

Statistical tests were performed using SPSS 28.0.0 (IBM, Armonk, NY, USA). The relationship between pattern detection and response correctness was examined by calculating Spearman's Rho correlation coefficients (r_s) as an effect-size measure. Additionally, a 2 × 2 ANOVA was conducted to assess the effects of pattern detection (detection vs. no detection) and experience (near-elite vs. elite players) on response correctness. Partial eta square (η_p^2) was calculated as an effect-size measure according to Cohen (1988). The alpha level for all statistical tests was set a priori at $\alpha = 0.05$.

Results

As illustrated in **Fig. 1**, Spearman's Rho correlations revealed no significant relationships between pattern detection and response correctness; neither for near-elites ($r_s = 0.22$, $p = 0.279$) nor for elites ($r_s = 0.28$, $p = 0.131$). Only by tendency, we observe an increasing coefficient with greater experience, meaning that the relationship between pattern detection and response correctness was slightly more pronounced for elite players. This result implies that making correct decisions is *not* based on superior pattern detection.

As depicted in **Fig. 2**, **a** two-way ANOVA examining the influence of pattern detection (2) and experience (2) on response correctness revealed neither an interaction effect, $F(3, 53) < 0.01$, $p = 0.978$, $\eta_p^2 < 0.01$, nor a main effect for pattern detection, $F(3, 53) = 2.52$, $p = 0.118$, $\eta_p^2 = 0.05$. However, a significant main effect for experience, $F(3, 53) = 34.84$, $p < 0.001$, $\eta_p^2 = 0.40$, was found. While elites showed superior decision making (elites: $M = 67.41\%$, $SD = 9.04\%$; near-elites: $M = 53.32\%$, $SD = 8.30\%$), explicitly identifying the

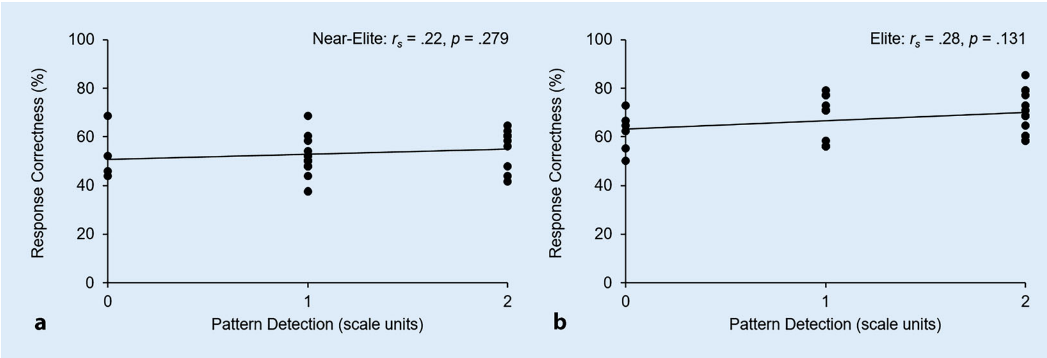

Fig. 1 ◀ Response correctness related to pattern detection (0 = misidentified, 1 = unaware, 2 = correctly identified) for near-elites (**a**) and elites (**b**)

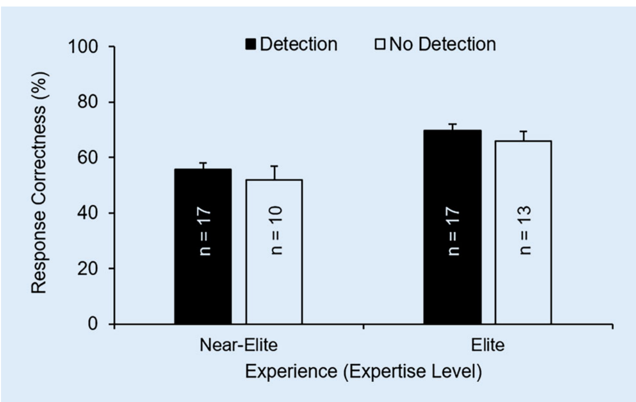

Fig. 2 ◀ Response correctness (*M* and *SE*) as a function of pattern detection (detection vs. no detection) and experience (near-elite vs. elite)

game-specific pattern only affected performance by tendency (detection: $M = 63.50\%$, $SD = 10.97\%$; no detection: $M = 58.86\%$, $SD = 11.06\%$).

Experiment 2

Experiment 2 refers to the data collected by Magnaguagno & Hossner (2020), who examined the impact of self-generated vs. explicitly acquired contextual knowledge on anticipatory performance in experienced adult handball players. Since—in contrast to Experiment 1—response correctness and pattern detection were assessed twice in testing, the role of experience (i.e., experimental phase) could in this case be examined in a within-participant design.

Method

Participants

Twenty-four male handball players ($M_{age} = 25.75$ years, $SD = 3.96$) were recruited. This sample size resulted from the original study of (Magnaguagno & Hossner, 2020), in which a statistical power analysis revealed an optimal total sample size of 14 participants. A post hoc analysis for an *F*-test and ANOVA design (i.e., repeated measures, within–between interaction) that was additionally conducted in G*power 3 (Faul et al., 2007) with the input parameters [averaged f] = 0.50, α err prob = 0.05, $N = 24$, number of groups = 3, and number of measurements = 2, revealed a power [1 – β err prob] of 0.99.

Players had 15.50 years ($SD = 4.48$ years) of handball-specific experience and on average 4.96 years ($SD = 3.86$ years) of playing experience on their highest individual level, which was either the highest or the fourth-highest national division (for further details, see Magnaguagno & Hossner, 2020). Only players who normally defended at the positions relevant to the present study were selected. The original study (Magnaguagno & Hossner, 2020) was approved by the ethics committee of the University Faculty (reference number 2017-12-00003), and all participants provided informed consent prior to participation.

Apparatus, procedure, and measures

The stimuli and setup were the same as in Experiment 1. In Experiment 2, however, the weak teammate *always* lost and the strong teammate *always* won his 1:1 defense situations. From a total of 96 experimental scenes, response-correctness measures were calculated as the percentage of correct defensive actions in the first 32 trials and in the middle 32 trials, respectively. Since in Experiment 2, the explicit information about the teammates' defensive strength was provided before the third phase and no assessment of pattern detection followed afterwards, the originally collected last 32 trials were excluded from the analysis. On this basis, the first and middle experimental phases were labelled as the (comparably) "early" and "late" phase, respectively. Similar to Experiment 1, the experimental scenes in Experiment 2 were complemented by 48 further scenes to increase ecological validity as well as overall variance.

Pattern detection was not only assessed finally after the "late" experimental phase but also between the "early" and "late" phases. To this end, after each phase, participants filled out a 30-item questionnaire in which—in order to hide the experimenters' focus—just two items were relevant to the research question at hand. These items referred to the quality of the two teammates' defense against body feints on the side of the throwing-arm. They had to be rated on the 4-point scale from *very good* (= 1) to *not good at all* (= 4). Pattern detection was measured as the difference between the ratings of the weak and the strong teammate; meaning that a maximum value of 3 corresponds to perfect pattern detection, while a value

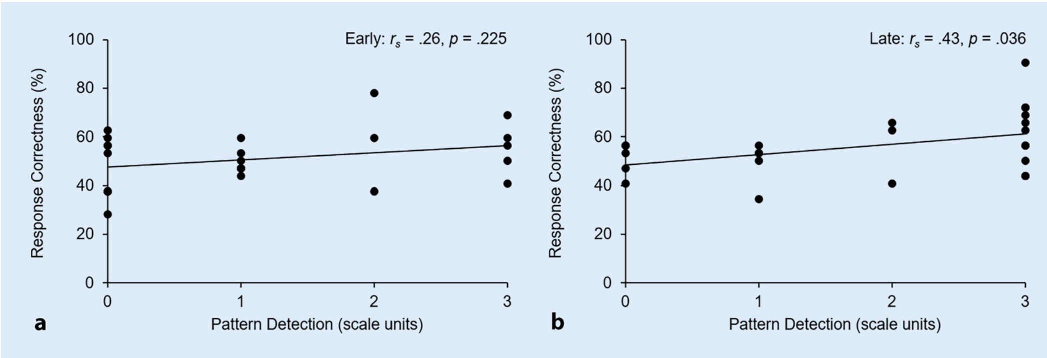

Fig. 3 ◀ Response correctness related to pattern detection (0 = unaware, 1 = tendentially identified, 2 = identified, 3 = clearly identified) after the early experimental phase (**a**) and the late experimental phase (**b**)

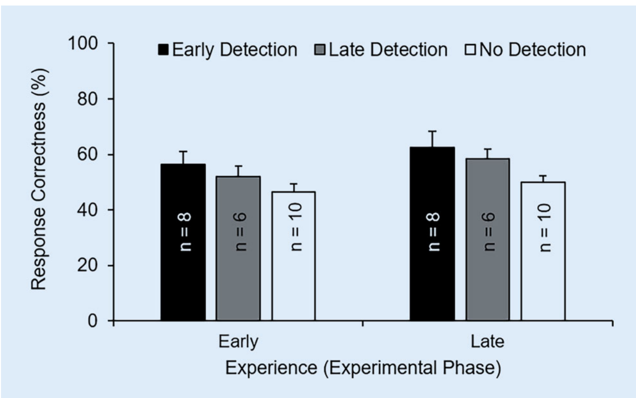

Fig. 4 ◀ Response correctness (*M* and *SE*) as a function of pattern detection (early detection vs. late detection vs. no detection) and experience (early vs. late)

of 0 reflects equal quality ratings for both teammates (for further details, see Magnaguagno & Hossner, 2020). To additionally conduct group comparisons for the present data analysis, participants with scores of 0 or 1 were regarded as nondetectors and participants with scores of 2 or 3 as detectors. The repeated-measurement design further allowed us to compare three post hoc subgroups; namely "no detection" (nondetectors after both the early and late phases), "late detection" (nondetectors after the early phase and detectors after the late phase), and "early detection" (detectors after both the early and late phases). Notably, no participant has been found who showed an early but not a late detection.

Data analysis

As in Experiment 1, Spearman's correlation coefficients (r_s) were calculated as effect-size measures to examine the relationship between pattern detection and response correctness. Here, the correlations were calculated separately for the early and late experimental phases. Additionally, a 3 × 2 ANOVA with repeated measures was conducted to examine the effects of pattern detection (early detection vs. late detection vs. no detection) and experience (early vs. late experimental phase) on response correctness. Partial eta square (η_p^2) was calculated as an effect-size measure according to Cohen (1988). The alpha level for all statistical tests was set a priori at $\alpha = 0.05$.

Results

As shown in **Fig. 3**, the Spearman's Rho correlations between pattern detection and response correctness revealed a positive, nonsignificant trend with a small effect size in the early experimental phase ($r_s = 0.26$, $p = 0.225$) and a positive, significant correlation with a medium effect size in the late experimental phase ($r_s = 0.43$, $p = 0.036$). This result implies that either decision making is improved by pattern detection with increasing experience or—vice versa—that pattern detection is enhanced by improved decision making as a function of increased experience.

As depicted in **Fig. 4, a** two-way ANOVA examining response correctness with the factors of pattern detection (3) × experience (2) and repeated measure on the latter revealed neither an interaction effect, $F(1, 21) = 0.36$, $p = 0.703$, $\eta_p^2 = 0.03$, nor a main effect for pattern detection, $F(1, 21) = 2.52$, $p = 0.105$, $\eta_p^2 = 0.19$. However, a significant main effect for experience, $F(1, 21) = 13.23$, $p = 0.002$, $\eta_p^2 = 0.39$, was found. While players enhanced their response correctness with increasing task-experience (early: $M = 51.04\%$, $SD = 11.46\%$; late: $M = 56.25\%$, $SD = 12.43\%$), pattern identification affected decision making only by tendency (early detection: $M = 59.37\%$, $SD = 14.61\%$; late detection: $M = 55.21\%$, $SD = 8.71\%$; no detection: $M = 48.13\%$, $SD = 7.86\%$).

Overall discussion

The current investigation aimed to examine the relationship between the explicit identification of a specific game pattern and decision-making performance in complex defense situations in handball. To this end, we made use of data on teammates' defensive qualities and players' response correctness collected over the course of two previously published studies. The present analyses extended the previous studies by assessing pattern detection and response correctness as a function of players' domain-specific experience, which was operationalized as either expertise level (Experiment 1) or experimental phase (Experiment 2).

In line with previous research (Mann et al., 2007), the results obtained from both experiments showed that—unsurprisingly—more experienced players outperformed their less experienced counterparts in decision making. We assume that the superior performance of the more experienced players is not just caused by accumulated training hours (cf. Scharfen & Memmert, 2019) since specific perceptual–cognitive training is required to develop a high-performance level rather than just years of hands-on experiences (Lidor, Tenenbaum, Ziv, & Issurin, 2016). From a cognitive perspective, the higher performance of expert athletes mainly depends on cognitive processes that mediate the interpretation of a stimulus and the selection of an appropriate response (Hodges, Chua, & Franks, 2003). In this context, the type of cognitive construct—the more representative the cognitive test is, the more sensitive the measure—and the sport specificity of the stimuli used in the task are the crucial factors to differentiate between higher and lower skilled athletes (Kalén et al., 2021). Consequently, the reported experimental setups seem to be appropriate to measure performance differences.

Surprisingly and in contrast to the majority of previous laboratory-based research (Gorman et al., 2012, 2015; Magnaguagno & Hossner, 2020; North et al., 2009, 2011, 2017; Sherwood et al., 2019; Williams et al., 2006), the findings of Experiment 1 showed that players of a higher expertise level were not explicitly more aware of the pattern compared to their counterparts (**Fig. 2**). With respect to the only other study which operationalized pattern identification as the ability to detect a pattern of play (Magnaguagno & Hossner, 2020), the discrepancy could be related to the distinctness of the pattern. While in the study of Magnaguagno and Hossner (2020) the pattern was valid in 100% of cases, a distinction of 67% was used in the Experiment 1.

For the main focus of the present research, only sparse evidence was found in support of the expectation that decision-making superiority is based on an increase in explicit domain-specific knowledge on the experimentally induced defense pattern (**Figs. 1 and 3**) as it was proposed by other researchers (e.g., Farrow et al., 2010; Williams & Jackson, 2019). In contrast, our results revealed an increase in decision-making performance as a function of experience and not as a function of pattern identification (**Fig. 2** and especially the late-detection subgroup in **Fig. 4**). At this point, it seems to be of particular interest that the participants of the late-detection subgroup did *not* show greater improvements in decision-making performance than participants who either had detected the pattern already in the early phase (early-detection subgroup) or were not able to detect the pattern at all (no-detection subgroup). This result implies that the late-detection subgroup's improvements in decision-making performance cannot be attributed to the gain of explicit knowledge on the game pattern from the early to the late phase of the experiment. Thus, we conclude that it is the experts' superior decision making that allows for better extraction of explicit knowledge on situational patterns; meaning that the extent of implicitly accumulated knowledge increases the chance of generating explicit knowledge in a process of "representational redescription" (Karmiloff-Smith, 1994; for decision making in sports, see also Magnaguagno & Hossner, 2020). This conceptualization obviously contradicts the classic position that the ability to explicitly identify patterns of play forms a prerequisite to superior decision-making performance in sport games (Abernethy et al., 2005; Williams & Davids, 1995; for comparable results, see North et al., 2009; North et al., 2011; Sherwood et al., 2019; van Maarseveen et al., 2018).

Moreover, the present findings should be regarded as a particularly relevant contribution due to the robustness of the findings—predominantly, since the experiments included both different age groups (i.e., youth and adult handball players) and varying teammates' strength patterns (i.e., more or less distinctive behaviors of either 67% or 100%). However, further research is required to sufficiently substantiate a directional causal path from decision-making performance to explicit pattern identification in sport games. Particularly, research to address the limitations of the present studies seems to be desirable, which include comparatively small sample sizes, the post hoc comparison of unequally sized subgroups in Experiment 2 as well as the laboratory-based design that—while maintaining high ecological validity—might only partially transfer to real-world conditions. Beyond, the transferability of findings in laboratory settings to real-world condition has been questioned also in regards to the kind of stimulus presentation, for instance, by Aksum, Magnaguagno, Bjørndal, and Jordet (2020) who reported discrepancies between real-world results on football players' visual fixation durations and respective laboratory-based findings. For our setup, however, we would like to stress that the temporal and spatial conditions were quite representative and that, on the one hand, it might be generally regarded as an extremely difficult problem to reproduce the complexity of the real world with its mental and physical demands as well as its multiple landscape of information while, on the other hand, securing experimental control. Nevertheless, we admit that future research should also focus on the stimulus-presentation aspect of ecological validity.

When—despite these limitations—pursuing the here unfolded line of argument, it can be concluded that players' explicit pattern identification should not be overemphasized as an indicator of decision-making performance in sports. Notably, this finding is supported by van Maarseveen et al. (2018) who argue that the ability to explicitly identify a pattern of play is not an underpinning skill of anticipation and decision making. Thus, it seems appropriate to discuss pattern identification as one of four perceptual–cognitive skills (e.g., Casanova et al., 2009) at least more differentially, in particular by distinguishing between implicit and explicit knowledge about a pattern of play. As a consequence for practice, this also implies that using an explicit pattern-identification test for the purpose of talent identification (Sherwood et al., 2019) or trying to improve this ability through interventions (van Maarseveen et al., 2018) seems to be questionable.

However, when concluding that explicit knowledge self-generated during practice improves performance to a lesser degree than accumulated practice itself, this certainly does *not* imply that the provision of explicit knowledge is useless or might even hamper decision-making performance (as it is, for instance, expressed in the re-investment theory by Masters & Maxwell, 2008). Rather, we would recommend discussing the controversial issue of information provision more cautiously. Especially, regarding practical implications for coaches, we would like to suggest that the acquisition of experienced players' implicit knowledge should be supported by deliberate play, thus allowing the players accumulate this knowledge implicitly. In contrast, it could be helpful to provide less-experienced players with explicit information to support their decision-making quality since they might not have gained sufficient expertise to generate this knowledge by themselves. As shown empirically by Magnaguagno et al. (2022), this suggestion particularly applies if the crucial knowledge would need to be generated under conditions of high uncertainty. Future research should thus focus not only on the interplay between game performance and perceptual–cognitive skills—such as the ability to explicitly identify game patterns—but also on situational probabilities as well as players' competence to handle game-immanent uncertainties.

Corresponding address

Lukas Magnaguagno
Institute of Sport Science, University of Bern
Bremgartenstr. 145,
3012 Bern, Switzerland
lukas.magnaguagno@unibe.ch

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Declarations

Conflict of interest. L. Magnaguagno, E.-J. Hossner, J. Schmid and S. Zahno declare that they have no competing interests.

For this article no studies with human participants or animals were performed by any of the authors. All studies mentioned were in accordance with the ethical standards indicated in each case.

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