RUNNING HEAD: PERIPHERAL VISION AND YOUTH ATHLETES

Processing visual information in elite junior soccer players: Effects of chronological age and training experience on visual perception, attention, and decision making

Abstract

Processing information in peripheral vision is an important perceptual-cognitive skill in team sports. The relative contribution of various perceptual-cognitive skills to expertise in sports throughout adolescence has not been investigated in detail yet. The current study examined the effects of chronological age and training experience on perception, attention, and decision making in young soccer players. Sixty-five elite youth players were required to judge different game situations in a decision-making task involving both perceptual (object detection) and attentional (postural feature recognition) skills to perceive player configurations in the visual periphery. In general, performance decreased in the decision-making and feature-recognition tasks with increasing use of peripheral visual field, but not in the object-detection task. Superior performances were found for under 18 years old players compared to under 16 years old players especially in their attentional skills. Higher training experience effected decision-making and attentional performance. Overall, the findings provide insights and implications for training perceptual-cognitive skills in sport.

Keywords: feature recognition; object-detection; selection; youth athletes

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High-level sportspeople need to develop perceptual-cognitive skills to be successful in team sports (Williams, Ward, & Smeeton, 2004). However, debate continues about what these perceptual-cognitive characteristics of expert performance are (Broadbent, Causer, Williams, & Ford, 2015). The successful identification of these characteristics is thought to be important for informing subsequent training programs and developing future elite sportspeople (Williams & Ericsson, 2005).

Williams, Ford, Eccles, and Ward (2011) outlined important perceptual-cognitive processes of expert decision making that need to be understood. In order to identify the processes underpinning anticipation, researchers should investigate the recognition and use of task-relevant, postural information provided by the movements of teammates and opponents. Subsequently, researchers have tended to focus on the ‘postural’ information contained in the biological movements of opponents (Huys, Smeeton, Hodges, Beek, & Williams, 2008; Smeeton, Huys, & Jacobs, 2013), with relatively little research on the perceptual-cognitive processes that may be engaged when making anticipation and pattern recognition judgements (North & Williams, 2019). Huys et al. (2009) proposed that information for anticipation was picked up globally, implying that attentional processes for anticipation judgements were broader in experts than in novices.

A detailed investigation has been undertaken by Hüttermann, Memmert, and Simons (2014) and it has been shown that expert team players have an attentional focus 25 % broader across the visual field than novices. The authors used the attention-window task developed by Hüttermann, Memmert, Simons, and Bock (2013) which has proved as a valid method to measure the size and shape of the attentional focus. By presenting two stimuli simultaneously with varying distances between them in the visual periphery, it is possible to measure the ability to spread the focus of attention across visual space.

There are different gaze strategies that can be used when various objects have to be perceived in the visual periphery. Fixations can be employed with the fovea used to process detailed information—however, this strategy prevents the perception of multiple objects simultaneously. In contrast, gaze can be fixed between perceptually relevant areas and information can be processed concurrently using peripheral vision (Piras & Vickers, 2011). As the latter fixation can be dynamically adapted ("visual pivots" or "gaze anchors") - the approach of this gaze strategy is that the gaze is fixed while attention is distributed to various peripheral cues (Ripoll, Kerlirzin, Stein, & Reine, 1995). But regardless of the choice of gaze strategy, it is self-apparent that restrictions of peripheral vision pick up limit athletes' ability to identify other players or objects that are located in this part of their visual field. An effective decision making strategy requires the integration of the more salient visual (central and peripheral) information available while less salient sources of information should be ignored (Ryu, Abernethy, Mann, Poolton, & Gorman, 2013).

More recently, Hüttermann, Ford, Williams, Varga, and Smeeton (2019) examined differences in decision-making processes between team sports players and those that participated in individual sports. In order to better understand the attentional and perceptual processes underpinning their decision making, participants had to engage in a more basic measure of visual function by detecting the presence of opponent players as well as more complex processes of recognize the running direction of teammates across a range of angles of the visual field. According to the hierarchical object recognition account of visual processing (Riesenhuber & Poggio, 1999), the process of stimulus detection is seen as a more basic visual function than stimulus recognition because the latter requires detection of the stimulus and recognition of particular instances (i.e. postures) of stimuli (Verschae & Ruiz-del-Solar, 2015). Hüttermann, Ford et al. (2019) found that, whilst the test of the more basic object presence detection led to a greater accuracy score than the test of feature recognition (76 % vs 46 %), only the feature-recognition task performance was significantly greater in the team sports players than the individual sports players (55 % vs 36 %), suggesting that object/feature recognition may be an important perceptual-cognitive process to be developed. In other words, the capability to allocate visual attention to the periphery to pick up instances of postural orientation was a differentiating characteristic of team sport players, whereas perceiving the presence of opponents was something that both groups of participants could do successfully. However, data using this group comparison approach does not indicate how these skills might typically develop in skilled athletes.

It is well known that perceptual and cognitive skills account for much of the variance in soccer skills between adult groups (Helsen & Starkes, 1999). Ward and Williams (2003) examined highly skilled 9 years to 17 years soccer players' perceptual-cognitive skills in youth academies of English first division clubs and novices from primary and secondary schools. The study showed both a relationship between chronological age and perceptual-cognitive skills in soccer-unspecific tasks as well as differences between elite and sub-elite players in soccer-specific tasks. But this effect was no longer found with increases in chronological age. More precisely, older players altogether reacted faster to peripheral stimuli than younger players, and skill group differences were no longer found in players older than those in the U15 age group. This result indicates that the ability to detect stimuli in peripheral vision is no longer a differentiating characteristic by the age of 15, but greater task-specific experience in high-quality learning environments is important for performance on sport-specific tasks and differentiates elite and sub-elite soccer players. However, the multidimensional battery of tests used by Ward and Williams (2003) could not provide evidence that performance on those tests is causally related to on-field performance. Instead, higher test performances could have been linked back to experience rather than skillful in the game. Overall, the relationship between the perceptual-cognitive skills and the athletes' actual performance remained unclear in the described study.

In the current study, we aimed to examine perceptual cognitive processes of elite junior soccer players. Participants performed a decision-making task that included a postural feature-recognition (attention-based) and an object-detection (perception-based) task in each trial (see e.g., Klatt, Ford, & Smeeton, 2019, for research using the same task). The visual focus of attention is typically allocated across a part of the visual field. Visual attention is a prerequisite for conscious recognition of information. In general, people only consciously perceive those objects/events onto which they direct their attention at a given time (Dehaene, Changeaux, Naccache, Sackur, & Sergent, 2006). According to Hommel and colleagues (2019, p. 2289f) "[…] attention is the set of cognitive/neural mechanisms responsible for maximizing the efficient utilization of our limited capacities to process, store, and retrieve information". When performing the object-detection task participants "only" need perceptual abilities, while for the postural feature-recognition task attentional skills are needed. It was predicted that chronological age and training experience (Ward & Williams, 2003; Williams, Ward, Ward, & Smeeton, 2008) would affect young players' performances. Specifically, it was predicted that differences in chronological age and training experience would be found in the decision-making and postural feature-recognition experimental task that have been shown to differentiate skill groups, but not in the object-detection task that relies on more basic visual function (Hüttermann, Smeeton, Ford, & Williams, 2019). To explore how age and experience related to the ability to extract information in foveal and peripheral vision, decision-making, postural feature-recognition and object-detection task performance scores were correlated with Age and Playing Time in a Club separately across visual angle conditions.

Methods

Sample size estimation

Based on previous research examining the attentional window and decision making in sport (Hüttermann, Ford et al., 2019; Hüttermann, Smeeton et al., 2019; Klatt & Smeeton, 2020), a minimum sample size of 28 (per age group) was calculated using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009). This calculation was based on the main effect of visual angle in these previous studies having a median effect size (η^2) of .623 and a 50 % attenuation of this variable under training experience and chronological age conditions being predicted.

Participants

In total, 65 young male soccer players aged 14 to 17 years (M_{age} = 15.63 years, *SD* = 0.96 years) participated in the study. Data from two additional participants were excluded due to technical problems and three more participants had to cancel the testing because of longer-term injuries.

The players' year of birth was used to determine their chronological age. Because the sample included players born in two different years, it was examined whether this one-year difference has an influence on perception, attention, and decision-making processes. In general, the aim was to select a sample of players of whom it could be assumed, based on the work of Crognale (2002) as well as Malina, Bouchard, and Bar-Or (2004), that the development of their visual system is nearly completed.

At the time of data collection, the participants played in two different youth leagues (under 18 years: U18, $n = 33$; under 16 years: U16, $n = 32$)—in the highest German league of their age group respectively. The U18 players had an average age of 16.45 years (*SD* = 0.51 years) and the U16 players of 14.78 years (*SD* = 0.42 years), $t(63) = 14.489$, $p < .001$. While the U18 players participated in organized soccer for 9.62 years (*SD* = 1.68 years), the U16 players had played soccer in an organized club for 9.33 years (*SD* = 1.96 years), *t*(63) = 0.649, *p* = .519. In total, 15 U18 players indicated to have played soccer for more than ten years and 18 players less than ten years. There were also 15 players in the U16 group who had played for more than ten years and 17 players less than ten years. The U18 players reported to regularly practice for 8.82 hours (*SD* = 0.95 years) per week at the time of the data collection, the U16 players were active on average for 8.44 hours (*SD* = 0.76 years) per week, *t*(63) = 1.781, *p* = .08. All participants regularly participated in matches during the weekends.

All participants reported normal or corrected-to-normal vision (with either glasses or contact lenses) and had not participated in any sensorimotor research within the preceding six months. The study was approved by the ethics board of the leading university. Written consent was obtained from all participants prior to testing according to the Declaration of Helsinki in 1975.

Materials

Decision-making task. A decision-making task, which in previous studies has already been used to analyze athletes' decision making, attention, and perception (Hüttermann, Ford et al., 2019; Hüttermann, Smeeton et al., 2019), was selected as testing method. After two practice trials, each player completed 24 experimental trials. As can be seen in Figure 1, the test begins with the presentation of a fixation cross for 1000 ms. Subsequently, two stimuli are displayed, one at either side of the previously shown fixation cross. Teammates (white jerseys) and opponents (black jerseys) are used as stimulus material and are presented, randomly varying each trial, at one of eight horizontal positions (10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°) from the center of the projection. In each trial, two teammates are presented (white jerseys), one at either side of the center, who are randomly surrounded on either their right or left body side by zero, one, two, or three opponents. While opponents always move in the direction opposite to teammates, the teammates can move either towards the center or towards the side of the playing field (i.e., the center or the side of the projection). A still image of the respective game situation is presented to the participants for 300 ms. Subsequently, the participants' task is to put themselves in the position of the player in possession of the ball, and to, within a time limit of 4000 ms, make a decision on whether to pass or to keep the ball. However, the participant should only pass the ball if the respective teammate is not surrounded by any opponents and is facing towards him, that is, if the teammate is moving towards the center. The participant verbally communicates his decision (pass right, pass left, no pass) to the experimenter. After this, he is asked to indicate the exact running direction of both teammates, as part of the feature-recognition task. Finally, the object-detection task requires participants to indicate the number of opponents that surround the teammate on either side (cf. Klatt & Smeeton, 2020).

Procedure

All participants were tested individually in the laboratory. Before the test, participants provided personal information including information on their footballing experiences. Players were provided with information on the testing procedure in written form. Participants were given the opportunity to ask questions in case of any uncertainties. They stood approximately 1.40 m from a 2.80 m x 2.20 m white projection screen (90° horizontal maximum visual angle x 76° vertical maximum angle) on which the task was presented. Overall, testing took about 20 minutes per participant.

Data Analysis

In line with previous research applying the same task (e.g., Hüttermann, Ford et al., 2019; Hüttermann, Smeeton et al., 2019; Klatt & Smeeton, 2020), we examined differences between the decision-making, the feature-recognition, and the object-detection task performances using a four-way ANOVA with task (decision-making, feature-recognition, and object-detection task), and visual angle (10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°) as the within-subjects variables and age (U16, U18) and playing time (under 10 years, over 10 years) as the between-subjects variables.

While the four-way ANOVA was performed in order to examine the relative differences in performance of the subtasks (decision-making, feature-recognition, object-detection task), we performed separate additional repeated-measures analyses of variance (ANOVAs) for each of the three subtasks. We analyzed accuracy rate as the dependent variable, conducting an ANOVA with visual angle (10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°) as repeated measures within-subjects factor and chronological age (U16, U18) and playing experience (more than 10 years, less than 10 years) as between-subjects factors. For analyses in which the sphericity assumption was violated, we reported the value of ε from the Greenhouse-Geisser correction. Bonferroni-corrected pairwise comparisons were used to follow up significant main effects. To understand how performance on the decision-making, object-detection, and feature-recognition tasks related to chronological age and playing experience in club environments across visual angles, exploratory Pearson's product moment correlation coefficients were calculated.

Results

To examine our between-groups classifications of chronological age and training experience, independent samples t-tests were performed. Playing time was significantly higher in the more than 10 years group (M = 10.92 years, SD = 0.54 years) than in the less than 10 years group (M = 8.24 years, SD = 1.59 years), $t(42.92) = 9.324$, $p < .001$. Age differed between the U16 (M = 14.78 years, SD = 0.42) and U18 (16.45 years, SD = 0.51 years) groups, $t(61.66) = 14.531$, $p < .001$. However, there was no difference in playing time, $t(63) = 0.647$, $p < .001$, between the U16 (M = 9.33 years, SD = 1.96 years) and U18 (M = 9.62 years, SD = 1.68 years) groups. There was a main effect of task, *F*(1,122) = 70.218, $p < .001$, $\eta^2 = .535$, indicating that correct responses in the decision-making task (*M* = 89.21 %, *SD* = 19.79 %) were higher than in the object-detection task (*M* = 67.43 %, *SD* = 30.97 %), which in turn were higher than in the feature-recognition task (*M* = 56.02 %, *SD* =31.75 %) (all *ps* < .001). The ANOVA also revealed a significant four-way interaction effect between chronological age, training experience, visual angle, and task, *F*(14,854) = 1.912, $p < .05$, $\eta^2 = .030$. In order to follow up on this significant interaction, task-wise separate three-way ANOVAs were performed and results are presented below.

Decision-making task

The total amount of correct responses in the decision-making task was 89.10 % (*SD* = 9.54 %) of trials. The ANOVA with participants' accuracy rate in decision making as dependent variable revealed a significant main effect of visual angle, *F*(5.059,308.600) = 5.066, $p < .001$, $\eta_p^2 = .077$, $\varepsilon = .723$ (Mauchly's test of sphericity: $\chi^2(27) = 68.151$, $p < .001$): In general, accuracy decreased with increasing visual angles and became more variable (see Figure 2); Bonferroni-corrected follow-up pairwise comparisons showed significant differences between 70° and 10°, 20°, 30° and 60° conditions ($p < .05$). There was no significant effect of chronological age, *F*(1,61) = 3.059, $p = .085$. But there was a significant effect of training experience, *F*(1,61) = 4.544, $p = .037$, $\eta_p^2 = .069$. There was also a significant interaction effect between chronological age and training experience, *F*(1,61) = 6.981, $p = .010$, $\eta_p^2 = .103$ (see Figure 3): The U18 players who had played soccer less than ten years performed better than the U16 players who had also played less than ten years, $t(33) = 2.654$, $p = .012$, $d = .898$, with no performance difference between the players of both age groups who had played soccer for more than 10 years, $t(28) = 0.926$, $p = .362$. Bonferroni corrected post hoc comparisons had an adjusted alpha of 0.025. The interaction between chronological age, training experience, and visual angle tended towards being significant, *F*(7,427) = 1.995, *p* = .054, η_p^2 = .032. There was no other significant interaction effect (all p values > .05).

Object-detection task

The total amount of correct responses in the object-detection task was 66.33 % (*SD* = 22.34 %) of trials. To examine the identification rate of the number of opponent players, we conducted a further ANOVA with the same factors as before. The ANOVA revealed neither a significant effect of visual angle, *F*(7,427) = 1.579, *p* = .140, nor of training experience, *F*(1,61) = 0.003, *p* = .955. However, there was an effect of chronological age, *F*(1,61) = 4.599, *p* = .036, η^2 = .070: The U16 players (*M* = 59.90 %, *SD* = 22.37 %) performed worse than the U18 players (*M* = 72.57 %, *SD* = 20.77 %). There was no significant interaction effect (all p values > .05).

Feature-recognition task

In the feature-recognition task which required participants’ visual attentional skills, they achieved an average score of 55.71 % (*SD* = 17.31 %). The ANOVA to analyze the identification rate of the teammates’ running directions showed again a significant main effect of visual angle, *F*(7,427) = 6.291, *p* < .001, η^2 = .093, indicating that, in general, participants’ accuracy rate decreased with increasing angles between stimuli and became more variable (see Figure 4); Bonferroni corrected follow-up pairwise comparisons showed specific differences between 20° and 70°, 30° and 70°, 20° and 80° as well as 30° and 80° (*p* < .05). Furthermore, we found a significant effect of chronological age, *F*(1,61) = 6.199, *p* = .016, η^2 = .092: U18 players (*M* = 60.61 %, *SD* = 15.52 %) outperformed U16 players (*M* = 50.65 %, *SD* = 17.84 %). In addition, these participants who played soccer for more than ten years in a club (*M* = 61.25 %, *SD* = 17.13 %) had greater feature recognition than those players who played soccer for less than ten years in a club (*M* = 50.95 %, *SD* = 16.24 %), *F*(1,61) = 6.849, *p* = .011, η^2 = .101. There was no significant interaction effect (all p values

> .05), however, the interaction between chronological age, training experience, and visual angle tended towards being significant, $F(7,427) = 1.901$, $p = .068$, $\eta_p^2 = .030$.

Exploratory analysis

Correlations between task performances across the visual angles and age and playing time are reported in Appendix 1. Decision-making performance across visual angles showed significant positive relationships with 50° only for age ($r = .267$) and playing time ($r = .306$), $p < .05$. Object-detection performance correlated with age at 10° ($r = .328$) and 80° ($r = .332$), but not with playing time. Feature-recognition performance correlated with age at 10° ($r = .346$) and 50° ($r = .303$) and with playing time at 40° ($r = .266$).

Discussion

The aim of this study was to examine perceptual cognitive processes of elite junior soccer players. In line with the predictions, a four-way interaction of chronological age, training experience, visual angle, and task was found indicating that decision-making and feature-recognition task performances depended on chronological age, training experience, and visual angle. However, in the object-detection task, performance was only different between U16 and U18 age groups. These results indicate that recognizing task-relevant, postural information about teammates and opponents in the peripheral vision is an important perceptual cognitive process in elite junior soccer players' decision making. It further suggests that task-relevant experience as well as chronological age is important for the development of this skill.

The results from this study support and extend the proposal that recognizing task-relevant, postural information is an important perceptual-cognitive process present in athletes (Williams et al., 2011). Here, it is shown that the skill of picking up peripheral information is important as well as picking up information in the fovea. The exploratory analysis showed significant relationships between training time and decision-making and feature-recognition performance at visual angles associated with peripheral vision (50° and 40° respectively). No relationships between object-detection and training time were found across any visual angles indicating training time was not associated with object-detection. Relationships between decision-making and feature-recognition and chronological age were also found at 50°. The effect sizes (*r*) for the chronological age and training time effects were approximately similar indicating both factors were similarly important. However, there was also a relationship between feature-recognition and chronological age at 10° indicating foveal vision as also being important. Foveal and peripheral effects were also found for the relationship between chronological age and object detection. Typically, eye gaze methods have been used alongside spatial and temporal occlusion methods (Smeeton, Hüttermann, & Williams, 2019), but the eye gaze method is only suitable for foveal information pick up and it is not possible to determine information pick up from other areas of the visual field. Using eye gaze methods to understand how information is extracted from multiple player positions, North and Williams (2019) showed that expert soccer players spend more time fixating between forward players and the ball than novices. Using foveal vision, postural information as well as information concerning the relative position of them to other players is used. It may be the case that peripheral and foveal information pick up is used in combination to enable maximal use of the information (Murphy, Jackson, & Williams, 2019). In addition, it is shown here that postural information presented outside of foveal vision (visual angles beyond 10 degrees) can be picked up in the periphery of a mature visual system. Given that decision-making performance was superior in older players and those that had more experience playing at the elite level, it is argued that task specific practice is an important mechanism through which this decision-making process is developed (Ward & Williams, 2003).

What advantage does picking up postural information in peripheral vision have over saccading to pick up information through foveal vision? Mann, Causer, Nakamoto, and

Runswick (2019) have reported on studies showing that it is faster to covertly switch visual attention in the periphery rather than saccade to the new information extraction location (Ryu, Abernethy, Mann, & Poolton, 2015; Ryu, Mann, Abernethy, & Poolton, 2016). It may also be an advantage to use a global information extraction approach (Huys et al., 2009; Woolley, Crowther, Doma, & Connor, 2015), because information extracted globally is more deterministic (Huys et al., 2008). A broad attentional window allows more players to be picked up (Hüttermann, Memmert, & Nerb, 2019) and thus, positions of other teammates and opponent players can be better assessed leading to an overall better decision making (Murphy et al., 2019).

The results reported here are broadly in line with previous studies into perceptual-cognitive processes in decision making in sport using the same task. The four-way interaction showed that accuracy scores decreased in the postural feature-recognition and decision-making tasks with increasing visual angles between the peripheral stimuli, and that both older and more experienced players performed with greater accuracy on these tasks. However, in contrast to these previous studies, this effect was not found in the object-detection task, although performance on this task was greater than in the feature-recognition task. This can be explained by two differences with previous research. First, participants used in this study were all elite soccer players with mature peripheral vision (Crognale, 2002; Malina et al., 2004) and, therefore, all participants were able to detect players in the periphery (Hüttermann et al., 2014). Second, the stimuli in this study were presented up to 80° of visual angle. While previous studies have used a 210° immersive dome and presented the stimuli up to visual angles of 160° (cf. Hüttermann, Ford et al., 2019; Hüttermann, Smeeton et al., 2019; Klatt et al., 2019; Klatt & Smeeton, 2020), performance at the extremities of peripheral vision was not examined here. It may be the case that the interacting effects of chronological age and playing time are found when a greater number of visual angles are examined in the object-detection task.

There are some limitations and considerations for future research that need to be acknowledged. In order to examine a larger number of visual angles, the number of trials per angle was reduced in the current study. The main effect of visual angle across all tasks demonstrates reduced performance at larger visual angles and is consistent with previous studies (e.g., Hüttermann, Ford et al., 2019; Hüttermann, Smeeton, et al., 2019). However, future studies might reduce the number of visual angles and test a larger number of trials per angle to more precisely measure the visual angle threshold between success and failure at the tasks. Moreover, although the task used represented a soccer field with soccer players, we cannot fully label the task as soccer-specific because players were not required to make any soccer specific movement response. This response method should be considered in future research. Moreover, it should be considered that decisions that have to be make in real soccer game situations are oftentimes more complex than the challenge to decide whether to pass the ball to the left, to the right, or whether to control it/not pass at all. The further development of the design, e.g., through the presentation of more or less teammates (i.e. manipulating crowding, see Rosenholtz, 2016) and opponent players in game situations or through the presentation of dynamic stimuli, remains a challenge for future research. Furthermore, it is currently unclear exactly how recognizing postural information is integrated with decision-making performance and what developmental or practice activities result in the acquisition of this important perceptual cognitive process of recognize postural information in the visual periphery. Ford and colleagues (2012) as well as Roca, Williams, and Ford (2012) for example, already discussed the developmental activities that co-occur with superior anticipation and decision making in young athletes. Future research should be directed towards understanding the features of the practice environment (Ford & O’Connor, 2019) that allows this postural-feature recognition skill to be developed and how this information is used during decision making (see Müller & Abernethy, 2012, for a model in striking sports). Once this information is identified, it may be used to better inform training of decision-making skills (Broadbent et al., 2015). Moreover, intervention studies should be planned to investigate causal links between changes in attentional and perceptual performances in youth athletes during the development of expertise.

At 16-18 years old, most players have adopted a regular playing position (e.g., defender, midfielder, attacker) and have played in that role for at least a few years. Future research should examine the participants' preferred playing position. It can be assumed that the position-specific perceptual cognitive skills acquired might impact on perception of and attention to information extracted from peripheral vision (e.g., midfielders are usually required to scan all around them due to the position on the pitch, whereas for central defenders the play is typically in front of them). Furthermore, the hours accumulated in different types of soccer-specific activities (e.g., practice, play, competition) has been shown to have an impact on perceptual-cognitive skills as well. This information should be collected in future studies providing practice history profiles of the participants, similar to the approach taken by Williams, Ward, Bell-Walker, and Ford (2012).

Although we used football players presented on a green football pitch in the current study, the design differs from the behavior being required in a real soccer game. It is most important that players select and execute the best decision for their team in every game situation. The current design required participants to make the right decision (i.e., where to pass the ball) and also to perceive various teammates and opponent players simultaneously as all the information should be brought together for each trial. Participants made the correct decision (pass to the right/left side, no pass) in 89% of trials. This high percentage indicated that even though the players did not report all details correctly (e.g., number of opponent players and running direction of the teammates), they were very often able to attend to the information enabling them to make the correct decision. Possibly, they sometimes intuitively made the right decision without having seen all the necessary information.

In summary, perceptual cognitive processes in elite junior soccer players were examined. It was found that both chronological age and training experience influenced the recognition of postural feature in peripheral vision, whereas player detection was unaffected. It is concluded that the ability to recognize postural features in peripheral vision is an important characteristic of decision making in sports and requires a mature visual system, sufficient attentional capacity, and may be developed through extended task-specific practice.

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Figure legends

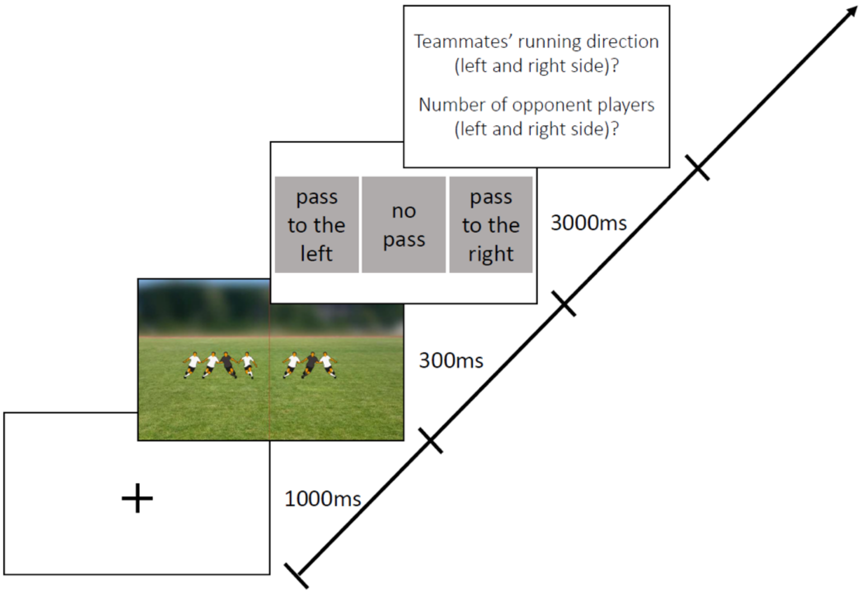

Figure 1. Sequence of events in one exemplary trial (modified from Hüttermann, Ford et al., 2019).

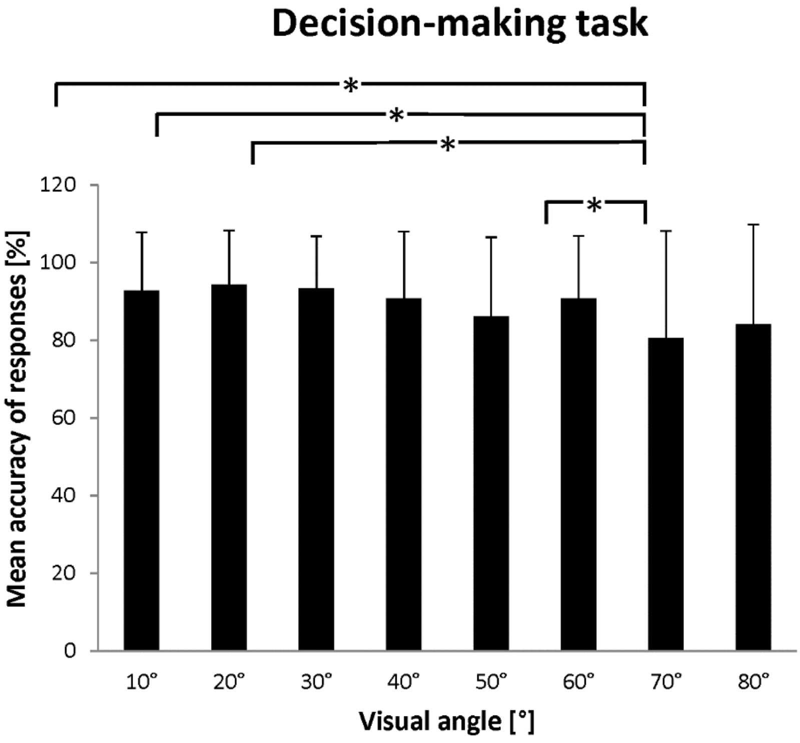

Figure 2. Mean decision-making accuracy (in percent) as a function of visual angles. Error bars represent standard deviations (*$p < .05$).

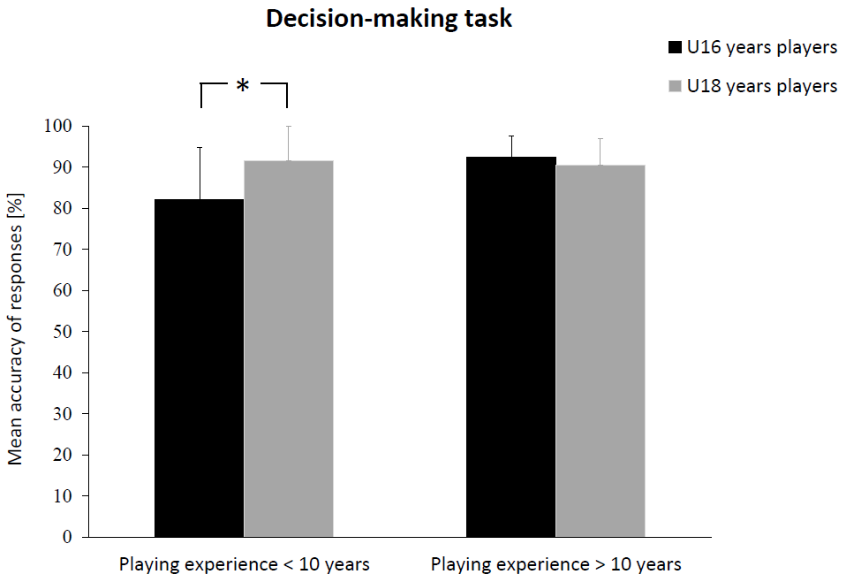

Figure 3. Effect of training experience on accuracy rate (in percent) in the decision-making task for U16 and U18 years players. Symbols represent across-participants means, and error bars represent standard deviations (*$p < .025$).

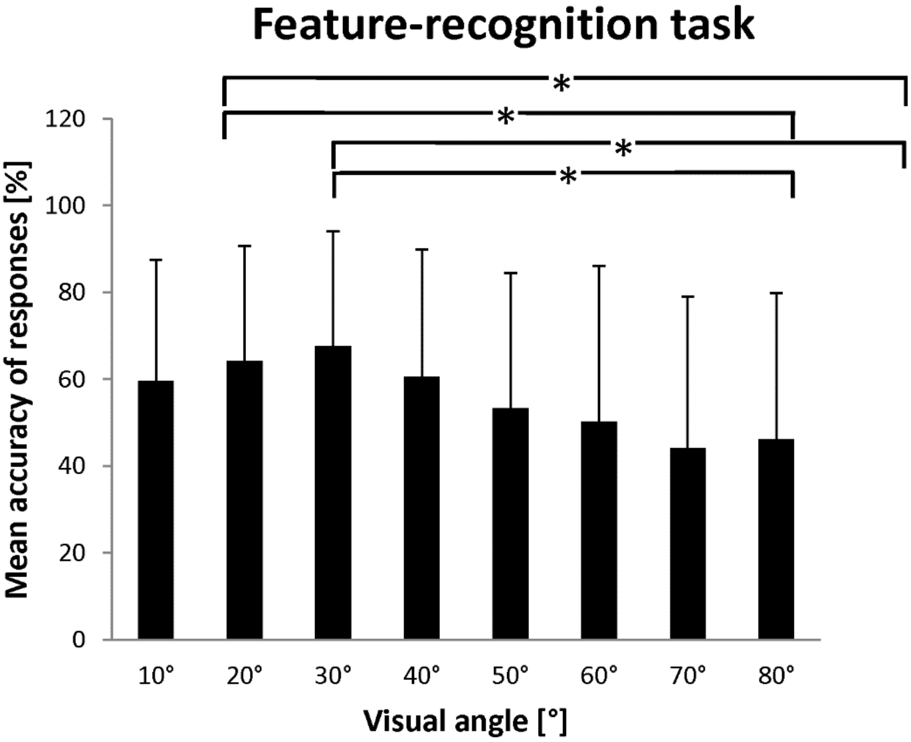

Figure 4. Mean decision-making accuracy (in percent) as a function of visual angles. Error bars represent standard deviations (*$p < .05$).