The association between perceptual-cognitive processes and response time in decision making in young soccer players

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Abstract

In soccer it is relevant to understand the roles of Systems 1 (intuitive) and 2 (deliberative) in perceptual-cognitive processes and how they influence response time when making decisions. The aim of this study was to analyse how response time in decision making managed by Systems 1 and 2 is associated to the perceptual-cognitive processes of young soccer players. Ninety young soccer players participated. Perceptual-cognitive processes were assessed through visual search strategies, cognitive effort, and verbal reports. Participants wore a mobile-eye tracking system while viewing 11-a-side match play video-based soccer simulations. Response time in decision making was used to create two sub-groups: faster and slower decision-makers. Results indicated that players with faster response time in decision making employed more fixations of shorter duration, displayed less cognitive effort, as well as a greater number of thought processes associated to planning. These results reinforce that there are differences in the way of using the perceptive-cognitive processes from the priority system in the decision-making process. It is concluded that faster decision making, managed by System 1, implies greater ability to employ visual search strategies and to process information, thus enabling increased cognitive efficiency.

Keywords: Expertise; Perception; Cognition; Eye-movements; Cognitive effort.

Introduction

A large body of research in soccer has provided solid evidence of how perceptual-cognitive processes are associated with decision-making performance (for a review, see Williams & Ford, 2013). These studies indicate that expert players (e.g., Ericsson et al., 2006; Roca et al., 2011; 2013; Vaeyens et al., 2007; Williams & Davids, 1998), with higher decision-making skill levels (Roca et al., 2012; Vickers, 1996) and higher tactical knowledge (Cardoso et al., 2019; Williams & Davids, 1995) display superior ability to use perceptual-cognitive processes. Notably, more skilled players are able to adapt their visual search behaviours, according to the specificity of the situation (e.g., 1vs.1, 2vs.2 or 11vs.11), by utilising more effective and assertive information search strategies (for details, see Vaeyens et al., 2007). Besides, these players are able to better manage their cognitive effort when making decisions (Cardoso et al., 2019) and to display better information-processing skills (Petiot et al., 2017).

However, in sports like soccer, the time for making decisions is a condition that should always be taken into account (Belling et al., 2015b, 2015a; Musculus et al., 2018), given that actions often take place within highly-complex and time-constraint situations, with constant pressure from opponents and limited space (Roca et al., 2011, 2018; Vaeyens et al. 2017). Therefore, it is common to see players with different characteristics regarding the utilisation of perceptual-cognitive processes and response time in decision making (Cardoso et al., 2019; Westbrook & Braver, 2015), which reflects the interindividual variability. Thus, players may be classified into each of two elementary categories: faster and slower decision-makers (Reyna & Brainerd, 2011). These two categories of decision making are often associated with and described in the dual-system theory (Reyna & Brainerd, 2011).

The dual-system theory assumes there are two decision-making systems: the first is evolutionarily primitive, therefore intuitive system (Evans, 2008; Mukherjee, 2010; Reyna & Brainerd, 2011; Tversky & Kahneman, 1983). The second is based on thought and analysis and is considered a deliberative system (for more detail see, Reyna & Brainerd, 2011). In the literature, they have been termed Systems 1 and 2, respectively, according to their phylogenetic and ontogenetic order of appearance (Evans, 2008; Tversky & Kahneman, 1983). System 1 is fast, intuitive and automatically modulates the perception and memory processes, thus generating an almost immediate response. Conversely, the deliberate thought process of System 2 is slower and requires a greater amount of time and cognitive effort for decision making (Evans, 2008; Reyna & Brainerd, 2011; Tversky & Kahneman, 1983). Hence, intuitive thinking is fast, automatic and unconscious, while analytical thinking is slow, controlled and conscious (Reyna & Brainerd, 2011). The two systems are complementary. Some authors have suggested that System 1 is related to the rewards circuit (e.g., limbic structures such as the ventral striated), while System 2 is more strongly associated with cognitive control and a higher number of interactions (e.g., dorsal and ventral prefrontal cortices) (e.g., Somerville, Jones, & Casey, 2011 and Rypma et al., 2006).

The relationship of Systems 1 and 2 with decision making has been reported in areas such as economics, management, neuroscience, among others (Beatty, 1982; Tversky & Kahneman, 1983). Although little explored in the sports context, some evidence points out that experienced athletes use more intuitive decision making to the detriment of deliberative decision making (Raab & Labord, 2003). These evidences seem to be associated to the more economic and efficient characteristics of the most experienced players with respect to the utilization of perceptual-cognitive processes (Raab & Johnson, 2007; Roca et al., 2012). In literature, researchers used some evaluations to induce chess players to time-constrained situations, and verified that chess masters made more mistakes (bad moves) in the games in which they had to make faster decisions (Lassiter, 2000). However, this finding was not observed in more dynamic sports, e.g., soccer, in which time constraints situations are typical of such sport environments (Belling et al., 2015b). This evidence may be a starting point for more specific investigations aimed to analyse how both systems (i.e., Systems 1 and 2) influence response time in decision making in soccer, as well as to explain the characteristics of the perceptual-cognitive processes related to response time in decision making. Nevertheless, there has been no reported studies yet that examined the associations between the perceptual-cognitive processes and response time in decision making.

Additionally, with respect to the assessment of perceptual-cognitive processes in soccer, literature has proposed some variables to be taken into account for evaluating players, particularly visual search strategies (Machado et al., 2017; Roca et al., 2018; Williams & Davids, 1998), cognitive effort (Cardoso et al., 2019; Eysenck et al., 2007), and information processing strategies assessed through verbal reports (Ericsson & Simon, 1984; Petiot et al., 2017; Roca et al., 2011, 2013). These three processes have been considered essential to decision making, and thus seem to highly affect decision-making response time (Cardoso et al., 2019; Roca et al., 2012; Williams et al., 1993; Williams, 2000). The three perceptual-cognitive processes mentioned above are directly related to the faster and more efficient responses that players present during the game (Cardoso et al., 2019; Maarseveen et al., 2018; Petiot et al., 2017). For example, Maarseveen et al. (2018) support one of the possible ways to obtain information and examine how players make decisions in complex situations and in a short time is by investigating the visual search strategies. Accordingly, visual search strategies are indicative of improved processes of selective attention to task-specific knowledge structures (Henderson, 2003). Besides, visual perception and motor components appear to be interconnected when motor decision-making is required, requiring even more perceptive speed for decision making (Maarseveen et al., 2018). Expert players, for instance, extract faster relevant information and are even able to capture advanced visual cues or identify game patterns (Vickers & Williams, 2017). In soccer, these relevant information's are: the ball, the players and all the space involved in the game (Roca et al., 2011, 2013).

In turn, the cognitive effort presents a relationship with the decision making. Cardoso et al. (2019), presented first-hand evidence on the associations between tactical knowledge (declarative and procedural) and cognitive effort. It has been shown that players who have greater declarative and procedural tactical knowledge need less cognitive effort to make decisions. These evidence reinforce that is possible that players who demand less time for decision making, have more efficient mechanisms of use and control of cognitive effort. Finally, some evidence points out that information processing in a more efficient way is strictly related to efficient visual search strategies and less cognitive effort, indicating that this is an aspect that can also directly affect the response time in decision making (Petiot et al., 2017).

With the purpose of providing concrete answers to the relationships between the response time in decision making and the perceptual-cognitive processes, the aim of this study is to evaluate how response time in decision making managed by Systems 1 and 2 is associated to perceptual-cognitive processes (i.e., visual search strategies, cognitive effort, and thought processes) of young soccer players. We hypothesised that soccer players, when making decisions managed by the distinct systems, display differences in the utilisation of perceptual-cognitive processes. Specifically, we assume that, in order to make faster decisions managed by System 1, players need better developed and more efficient perceptual-cognitive processes. Based on the presented literature in the field, more efficient perceptual-cognitive processes imply better visual search strategies, including more fixations of shorter duration for better screening of the environment (Roca et al., 2011, 2013; Vaeyens et al., 2007; Ward et al., 2003) as well as greater thought processes of planning, assessed through verbal report (Petiot et al., 2017) and better management of cognitive effort, assessed from pupil behaviour (Cardoso et al., 2019). This hypothesis presented above is based on the assumptions of dual-system theory, where the response time in decision making and their management by Systems 1 and 2, seem to have different characteristics in the use of the perceptual-cognitive processes (Mukherjee, 2010; Reyna & Brainerd, 2011; Tversky & Kahneman, 1983).

Methods

Participants

A total of 90 male youth soccer players from the youth teams of a Brazilian First Division club, with an average age of 16.7±3.1 years old participated. As inclusion criteria, all players had to participate regularly in the training sessions, with at least five weekly sessions of 1h and 30 min each, as well as playing in competitions at national and/or international level. All players had deliberate soccer practice time of over 3,500 hours.

Participants aged 18 years and over signed an informed consent, confirming they were aware of their participation in the study. As for participants under the age of 18, their legal guardians were also required to sign the consent. All research procedures were conducted according to the norms established by the National Health Council Resolution (466/2012) and the Declaration of Helsinki for research with humans. The project was approved by the Human Research Ethics Committee (CAAE, No. 01903818.7.0000.5153).

Data collection

Apparatus and task: A video test protocol and the *Mobile Eye Tracking*-XG (*Applied Science Laboratories,* Bedford, MA, USA) were used to assess response time and quality of decision-making, visual search strategies, cognitive effort and verbal reports. The *Mobile Eye Tracking* is a device that allows tracking and measuring the participant's central vision and pupil behaviour, through a system of cameras mounted on a pair of glasses. This equipment detects pupil and corneal reflection, determined by the reflection of an infrared light source on the corneal surface, displayed in a video image of the eye (Wilson et al., 2009).

The video test consisted of 11 scenes of offensive actions from official (11 vs. 11) soccer matches, from a third-person perspective, projected onto a large screen, and each scene had duration between 5 and 13 seconds. The scenes were taken from matches of the main European soccer top leagues (Spain, England, Italy, and Germany). The selected scenes had meet the following criteria: a) allow the visualization of attack and defense players during the presentation of the scene, and b) the visualization of the ball during the entire presentation of the scene (see, Cardoso et al., 2019). All the scenes presented to the participants were selected by a panel of six expert soccer coaches. The 11 selected scenes (from a total of 32 scenes analyzed) displayed 100% agreement among expert coaches with respect to the most appropriate responses to be taken by the participant at the time of video oclusion. Although small, this number of scenes allows the observation and extraction of reliable information on the variables related to the players' perceptual-cognitive skills and cognitive effort. Experiments using this protocol have been published in recent studies (see, Américo et al., 2017; Cardoso et al., 2019; Machado et al., 2017). During the experiment all 11 video sequences were presented and the screen image automatically occluded (black screen image) 100 milliseconds before the player in possession of the ball was about to perform a technical action with the ball. As soon as the videos clips were occluded the participant was asked to verbally respond, as quickly as possible, "what should the player in possession do?" at that moment and "why?".

The entire experimental protocol was conducted in a closed environment without external interference, with controlled sound (maximum 35 dB), brightness (the average values were 332 lux, with variation of less than 07 lux throughout the experimental protocol), and room temperature (24ºC). After setting up the room, the *Mobile Eye Tracking - XG* was adjusted and the 9-point calibration procedure was carried out with the participants. The test scenes were presented via projection on a retractable projection screen (TES - TRM 150V with

"Matte White" projection surface), with the following measurements 3.04 x 2.28 m. The video scenes were projected by a ceiling-mounted HD projector (Epson, Powerlite X14) with 2.0 x 2.0 m XGA resolution.

During the experimental protocol, participants were positioned standing 2.5m from the screen. This distance allowed the participant to view the entire test screen and avoided head movement during the experimental protocol. Before the start of the task, all test procedures were properly explained and the participant performed practice trials, in which two scenes were presented prior to the experiment, in order to ensure familiarity with the experimental protocol. The calibration of the Mobile Eye Tracking - XG was checked after every trial to ensure maximum accuracy. The entire test procedure took approximately 30 minutes for each participant.

During the experiment, all responses were recorded by a built-in microphone of the Mobile Eye Tracking - XG (ASL - *Applied Science Laboratories*, Bedford, MA, USA). After recording the test responses, the audio material was transcribed into digital format in *Word*® documents on a portable computer (POSITIVE Model *T* 3300 *Intel Core* ™ i3 processor).

Transcribed data were analysed and compared to the test's official expert rating panel (Mangas, 1999). After comparison with the expert panel, correct responses were awarded 1 point, whereas incorrect ones were not awarded any points. For the analysis of the time and quality of decision making, only the scenes to which participants responded correctly were used. From the overall collected data, 78.14±7.21% of the scenes were correctly responded and included in the analysis (see Table 1).

Visual Search Strategies: As for the visual search strategies, the criteria proposed by Williams and Davids (1998) were used to evaluate the central vision. Information about central vision was collected during the video assignment and recorded by the Mobile-Eye Tracking system. Since it involves the evaluation of visual stimuli in motion (video scenes), the algorithms cannot efficiently detect the exact fixation locations, and so it was decided that the frame-by-frame analysis method would be employed (Vansteenkiste et al., 2015). This method consists of reproducing the video frame-by-frame, manually deciding when a fixation starts and/or ends. Three measurement criteria were used: i) the mean fixation duration (in milliseconds); ii) the mean number of fixations per second, and ii) preferred fixation locations. Central vision measurements were evaluated using the ASL Results software.

A fixation was defined as the condition in which the eye remained stationary, within a 1.5 degree range of tolerance, and for a period equal to, or greater than 100 ms, or three video frames (Williams & Davids, 1998). Five specific locations were defined for analysis: i) player in possession; ii) ball; iii) teammates (attackers); iv) opponents (defenders) and, v) space (i.e., empty areas within the field, not occupied by any players). Values regarding preferred fixation location data were presented as percentages. The selection of the preferred fixation locations followed the recommendations of the literature (Roca et al., 2011, 2013; Williams & Davids, 1998).

Cognitive Effort: Cognitive effort was assessed through the pupillometry technique. The pupillometry enabling the assessment of important aspects of information processing at cognitive level in real-time, through precise measurements (Debue & Leemput, 2014).

In this study, pupil size was continuously recorded at a rate of 60 times per second (60Hz) using the Mobile-Eye Tracking system. The Mobile-Eye Tracking has a high degree of measurement accuracy, and the error rate of the equipment varies between 0.2 and 0.5 degrees. Pupil diameter measures were processed using the ASL GazeTraker software, which enables the measurement of pupil size and synchronisation with the video task. Pupil diameter measures were subsequently transferred to Excel for Windows spreadsheets. Video frames in which participants' gaze was not detected (due to blinks or excessive head movements) were excluded. No participants or test trials were excluded due to excessive data loss. All control measures of the data collection environment were carried out in order to reduce, as much as possible, the interference of external (e.g., sound, light variation) and internal (e.g., thermal discomfort, head movement) variables in pupillary responses.

We defined five different moments related to experimental task that were subsequently used to analyse pupil behaviour. This categorisation aimed to distinguish moments of the perceptual and information processing phases and, thus, indicate more precisely the relation of cognitive effort within experimental protocol. The first moment is the baseline of pupil diameter, represented by M0. This value was obtained from the smallest observed value of the pupil diameter between the end of calibration and the end of the experiment. Baseline pupil size was normalised considering that individual pupil sizes are generally different. Baseline values served as a reference for subsequent observations of miosis and mydriasis behaviors and their intensities. The other four moments were defined during the experimental protocol: M1) *Video* (phase in which the participant is watching the video); M2) *Processing* (phase comprising the end of the video and the start of the verbal response); M3) *Verbalisation* (phase in which the participant is verbally providing his decision) and; M4) *Recovery* (phase that considers the interval between the end of the participant's response and the start of the next scene). Pupil diameter data provided by ASL GazeTraker were converted into millimeters following the suggestion of Beatty and Lucero-Wagoner (2000). Subsequently, pupil data were adjusted in blocks according to the aforementioned four moments (Video, Processing, Verbalisation, and Recovery). Pupil diameter means were analysed in each of these moments. Cognitive effort data were displayed in relation to the variation of pupillary diameter in millimeters for each of the 4 moments. Positive values indicate pupillary dilation (mydriasis), whereas negative values indicate pupillary contraction (miosis).

Verbal Report: As for the data regarding verbal report behaviour, the responses provided by the participants in the video task were used. For these analyses, the verbal reports on the decisions made were used. Participants' responses were recorded and analysed according to the adaptation developed by Ward and collaborators (2003) of the original Verbal Reporting Protocol elaborated by (Ericsson & Simon, 1984). This adaptation was used in a recent study (to learn more, see Petiot et al., 2017). Following the analysis data were organised into four main report categories: a) monitoring instructions, described as recalls of current actions or descriptions of current events; b) evaluations, described as any form of comparison or assessment of events that are relevant to situations, tasks or contexts; c) predictions, described as anticipation or emphasis on future or potential events; and d) planning statements, described as the decision(s) in a course of action with the purpose of anticipating the outcome or potential outcome of an event. During the analysis of verbal reports, each scene was assigned with its dominant characteristic statement according to the four options described above. Three trained evaluators independently analysed all responses. In case of divergences between the evaluators' responses, two criteria were used to define the classification: 1) Higher number of responses (if two evaluators assigned one categorisation and a third evaluator assigned a different one, the largest number of notes was taken into account); 2) If the three evaluators disagreed, a meeting was held between them until a final decision was reached. In only 3 cases differences between the three evaluators occurred. The frequency of each type of dominant instruction was compiled and registered for further analysis.

Data Analysis and Categorisation of Groups Based on Response Time in Decision Making

After data collection and preliminary analysis, participants were categorised in two groups according to response time and quality of decision making. The response time in decision making was the criterion used to characterise the players' priority decision-making

Systems (Reyna & Brainerd, 2011). The categorisation of response time in decision making was made considering the average time (in seconds) between the final video frame and the start of participant's response with respect to their decision. The rate of data reading by the Mobile Eye Tracking (with a temporal resolution of 60 Hz) provided a high degree of temporal accuracy of the responses. As for the quality of decision making, as previously described, only the values of correct responses were used. Table 1 displays information on the percentage of correct responses in decision making for faster and slower response times during the test.

The 90 players were divided into three groups. We used response time in decision making performance data from the soccer-specific video test as an objective method to differentiate the 90 players. A third split approach was used where the participants ranked in the top 33% (n=30) and the bottom 33% (n=30) on the test were compared. We wanted to ensure that our criterion for stratifying skilled players into sub-groups was based on objective markers and that the two groups recorded scores were statistically different from each other. This exclusion approach follow the procedures of previous studies (e.g., Gonzaga et al., 2014; Roca et al., 2018; Williams et al., 2012). The G*Power 3.1.9.4® software was used to estimate minimum sample size following the procedures described by Faul, Erdfelder, Buchner, and Lang (2007). An a priori power analysis deemed a sufficient sample size of 28 player on each category based on =85% power ($1-\beta$), an alpha (α) of 0.05, and a large effect size (ES) ($d = 0.8$) (Faul et al., 2007). The faster group (n=30) displayed an average response time of 1.67±0.32 in decision making, while the slower group (n=30) took 5.91±1.83, on average, to respond. Statistical differences were observed between the two groups ($t_{(58)}=-11.091$; $p<0.001$; $d=2.44$). After the categorisation of the groups, statistical procedures were performed, considering the division of the groups with different response times in decision making as the independent variable.

[INSERT TABLE 1]

To analyse data distribution regarding visual search, cognitive effort and verbal report behaviour, the *Shapiro-Wilk* test was used, and data displayed normal distribution. The t-test for independent samples was used to compare the metrics for visual search strategies (i- mean fixation duration (in milliseconds), ii- mean number of fixations per second, and iii- preferred fixation locations), cognitive effort and verbal report, regarding the groups with different response time in decision making. In this analysis, the effect size was represented by the values of Cohen's *d*, according to the following classification: negligible effect (<0.19), small effect (between 0.20 and 0.49), intermediate effect (from 0.50 to 0.79), large effect (between 0.80 and 1.29) and very large effect (>1.30) (Rosenthal, 1996).

Cohen's Kappa values were used to describe reliability levels for the following measures: Video task, visual search strategies and verbal report. Intra-evaluator reliability analyses were performed after a 21-day interval, in order to avoid task familiarity issues (Robinson & O'Donoghue, 2007). A total of 10% of all data was re-analysed, as recommended by the literature (Tabachnick & Fidell, 2007). For the video task, two evaluators participated in this procedure and the reliability values found were between 89% and 97% for intra-evaluator, and between 83% and 93% for inter-evaluator. For the visual search strategies (durations and fixation locations), two evaluators participated in this procedure and the reliability values found were between 85% and 95% for intra-evaluator, and between 87% and 93% for inter-evaluator. For the verbal report, three evaluators participated in this procedure and the reliability values found were between 91% and 96% for intra-evaluator, and between 94% and 98% for inter-evaluator. These observed values are described in the literature as "almost perfect" (0.81 to 1), thus indicating the high level of agreement between evaluator (Landis & Koch, 1977). All statistical procedures were performed with SPSS 24.0 software and significance level was set at $p < 0.05$.

Results

Visual Search Strategies

When comparing the groups with different response times in decision making, the results of the t-tests pointed to significant differences between players for the following visual search measures: i) the mean fixation duration ($t_{(58)}$=-8.903, p<*0.001*, *d*=2.29) and ii) the number of fixations per second ($t_{(58)}$=-8.418, p<*0.001*, *d*=2.17). Players with shorter response time in decision making employed more fixations of shorter duration than players who were slower in verbalising their decisions. Table 2 presents the data on these measures.

[INSERT TABLE 2]

In the comparison of percentage preferred fixation locations between the groups with different response times in decision making, no significant differences were observed in any of the categories: i) Player in possession ($t_{(58)}$ =-1.950, p=*0.059*, *d*=0.50); ii) Ball ($t_{(58)}$=0.636, p=*0.527*, *d*=0.16); iii) Attackers ($t_{(58)}$=1.315, p=*0.194*, *d*=0.34); iv) Defenders ($t_{(58)}$=0.463, p=*0.645*, *d*=0.12) and, v) Space ($t_{(58)}$=1.917, p=*0.062*, *d*=.53) (see Figure 1).

[INSERT FIGURE 1]

Figure 1: Results of fast and slow groups in relation to the preferred fixation locations.

Cognitive Effort

By comparing cognitive effort between groups with different response times in decision making, t-test results point to significant differences between players in M2 (processing) ($t_{(58)}$=-4.355, p<*0.001*, *d*=1.12), M3 (response) ($t_{(58)}$=-3.659, p=*0.001*, *d*=0.93) and M4 (recovery) ($t_{(58)}$=-4.403, p<*0.001*, *d*=1.14) moments. It is possible to observe that the players with shorter response time displayed less cognitive effort during the analysed moments. As for the M1 moment, no difference was observed ($t_{(58)}$=0.594, p=*0.555*, *d*=0.08). The results of cognitive effort are displayed in Figure 2.

[INSERT FIGURE 2]

Figure 2: Results of the fast and slow groups regarding the variation of pupil diameter among the different moments of the test. Significant differences are indicated by (*).

Verbal Report Behaviour

The t-test results point to significant differences between players for the monitoring- ($t_{(58)}$=-3.902, p<*0.001*, *d*=1.01), and planning-related ($t_{(58)}$=3.991, p<*0.001*, *d*=1.03) response categories. Players with shorter response time in decision making provided more responses related to the planning category, whereas players with longer response time in decision making provided more responses from the monitoring category. No significant differences were found for the other categories (assessment - $t_{(58)}$=0.079, p=*0.938*, *d*=0.02; forecast - $t_{(58)}$=1.165, p=*0.249*, *d*=0.30). The results of the verbal report are presented in Figure 3:

[INSERT FIGURE 3]

Figure 3: Results of fast and slow groups in relation to verbalisation categories. Significant differences are indicated by (*).

Discussion

The aim of this study was to analyse how response time in decision making managed by Systems 1 and 2 is associated to the perceptual-cognitive processes (i.e., visual search strategies, cognitive effort, and verbal reporting on thinking) of young soccer players. Our findings showed that players with shorter response time in decision making employed more fixations of shorter duration and showed less cognitive effort in the information processing, decision verbalisation and recovery phases. the faster group also shower a greater number of thought processes associated to planning when compared to players with longer response time in decision making. These results reinforce our hypotheses and suggest the existence of a dual cognitive process, in which the priority use of one of the systems (e.g., System 1 or System 2) implies distinct perceptual-cognitive processes in the decision-making process.

Our findings indicated that response time in faster decision making, managed by System 1, suggests the utilisation of more advantageous perceptual-cognitive processes, as perceptual-cognitive processes turned out to be faster and more efficient for players who made fast decisions. This evidence reinforces the importance of the development of perceptual-cognitive processes for decision making in soccer, as well as the relevance of intuitive responses, managed by System 1. When assessing decision making of handball players, Raab and Laborde (2011) found that experts use little environmental information and trust the response intuitively generated. In addition, the decisions made in an intuitive way were generally better than the deliberative decisions. This evidence reinforces our hypothesis that in order to make decisions managed by System 1, players must have well-developed perceptual-cognitive processes that allow for greater efficiency and assertiveness.

Thus, in soccer, intuitive responses seem to allow players to make faster decisions with less cognitive effort in an environment where time is limited and a determining factor (Haier et al., 2005; Mann et al., 2007; Tversky & Kahneman, 1983). In this context, quick and intuitive decision making takes into account the ability to optimise visual search strategies (the perceptual process), and to prioritise metacognitive skills for information processing and, consequently, to respond quickly to task demands. (Reyna & Brainerd, 2011; Tversky & Kahneman, 1983). Thus, the ability to make quick decisions enables judgments and automatic responses with less cognitive effort (Evans, 2008). This fact can also be explained by the lesser dependence on more robust neural interactions by individuals that require less response time in decision making. (Rypma et al., 2006). Additionally, the unconscious, intuitive and automatic use of active resources of working and long-term (schemes) memories allows for faster responses with less cognitive effort (Henke, 2010; Reyna & Brainerd, 2011; Tversky &

Kahneman, 1983). On the other hand, when players have longer response time for decision making, System 2 requires an "awareness" about the whole decision-making process, substantially increasing the number of neural interactions and the use of working and long-term memory resources. Hence, the decision-making process becomes more analytical (i.e., slow, controlled and conscious), increasing the response time and cognitive effort required to accomplish the task (Evans, 2008; Tversky & Kahneman, 1983).

It should be noted that our results indicate that despite differences in visual search for the number and duration of fixations among players who made decisions at different speeds, there was no significant difference between groups, with respect to the preferred fixation locations. These findings indicate that perceptual processes *per se*, although important, as some studies suggest (Mann et al., 2007; Roca et al., 2011; Ward & Williams, 2003; Williams et al., 2012), may have less influence on the response time in making decisions compared to information processing itself. This possibility has already been suggested by Johnson and Raab (2003) in the assumptions of the "take-the-first" heuristic, in which being able to reduce as much as possible the number of elements that require attention increases the chances of making faster and more consistent decisions. Thus, based on these assumptions, it is important for the player to determine similarity rules in the situations he/she experiences in the game, changing the role of perception (e.g., visual search strategies) when deciding under pressure, from a broader to a more directed perception, which opens a window for investment of cognitive resources in information processing.

This modification of the role of perception can also be reinforced based on neurocognitive evidence, as, regardless of the action of the dorsal or ventral systems in controlling fixations, the human brain is relatively slow in processing visual information (to learn more, Corbetta & Shulman, 2002). Therefore, in a stimuli-rich environment such as a soccer game, perceptual skills may become overloaded (Evans, 2008; Reyna & Brainerd, 2011). Thus, it is up to the player to find ways to optimise the utilisation of perceptual-cognitive processes, which is carried out through the increase of information processing speed and that, according to our findings, enables the decrease of decision-making time. These results lead us to speculate that, although visual information is relevant to decision making, response time regarding this decision seems to be more closely linked to information processing mechanisms, in which greater and more conscious control of environmental information is replaced by more intuitive and faster processing.

With the purpose of identifying perceptual optimisation and faster information processing, some studies emphasised that the way players manage cognitive effort is essential to sustain performance levels (Cardoso et al., 2019; van der Wel & van Steenbergen, 2018; Verguts et al., 2015). Attempting to sustain a high cognitive effort over a long period of time seems to increase the odds of the player reaching the state of mental fatigue, and thus be more likely to contribute to performance decrement (Kunrath et al., 2020; van der Wel & van Steenbergen, 2018).

Given these characteristics, cognitive effort is an important variable to be considered in the training process and matches in soccer. This study reinforces this importance by showing that players with shorter response time in decision making seem to be more cognitively efficient, especially in the processing, response and recovery phases, indicating a better ability to recruit and manage the available cognitive resources. Thus, it is important to highlight that aspects inherent to experience and tactical knowledge, as well as the better ability to use long-term working memory, are the mechanisms responsible for optimising cognitive effort and information processing, favouring a quicker decision-making process (Baddeley, 1983; Cardoso et al., 2019; Ericsson et al., 2006; Reyna & Brainerd, 2011).

The results observed in our study on visual search strategies and cognitive effort were corroborated by the findings related to the verbal reports. Participants who displayed shorter response time in decision making generated significantly more planning verbalisations compared to those who took more time to respond. By their part, players who displayed longer response time in decision making employed more monitoring-related verbalisations, when compared to those with shorter response time. The differences in verbal reporting of both groups reinforce those observed in the perceptual-cognitive processes of participants with different response times in decision making. With respect to the group with shorter response time for decision making, verbal reports related to planning are associated to decisions on a course of action, with the purpose of anticipating a subsequent outcome or event (Ward et al., 2003). This result shows that the players with shorter response times in decision making optimise information processing and reduce decisional response time (Cardoso et al., 2019; Kahnemann & Beatty, 1967; Mann et al., 2007). This characteristic assists in processes with high association with fast decision making, such as the anticipation skill (Basevitch, 2020; Murphy et al., 2015; Roca et al., 2011, 2013). This fact may bring significant advantages for players when facing opponents in the game (Loffing & Cañal-Bruland, 2017).

With respect to the players with longer response time in decision making, we observed differences in the use of verbal reporting focused on monitoring. This form of verbalisation refers to the ability to analyse the situation, and recall – based on current actions or event descriptions – the best response options (Ericsson & Simon, 1984). This finding suggests that players with longer response time in decision making demand more time, as well as perceptual and cognitive resources to grasp the context, and only make decisions following this process, which may ensure greater assertiveness in many situations (Petiot et al., 2017). However, as the game is played in high intensity most of the time, players' chances of success may be reduced if they cannot be fast enough (Ericsson & Simon, 1984; Ward et al., 2003).

In general, response time in decision making seems to be directly associated to perceptual-cognitive processes, thus indicating that employing Systems 1 and 2 demand distinct perceptual-cognitive processes. It is possible to observe that players who require less time to make decisions have better information processing skills, which may improve their ability to plan and anticipate a situation, and therefore solving a problem during the game, besides demanding less cognitive effort throughout this process (Mann et al., 2007; Williams et al., 2012).

Future studies should address a more detailed assessment of cognitive effort measures through pupillometry. For example, it is important to consider the relationship between cognitive effort (pupillary behavior) and player's fixation location. This analysis allows, in the first place, to reduce the effect of an aspect related to local luminance, i.e., the amount of light reflected in the exact location of the screen where the player is fixating his gaze, in addition to enabling a more detailed comprehension about how cognitive effort is related to this fixation. A limitation of this study is the scene display time that presents a relatively large temporal variation (5 to 13 seconds) which could potentially affect players' perceptual-cognitive processes.

Conclusions and practice implications

In conclusion, this article provides evidence for the perceptual-cognitive advantages of players with shorter response times in decision making. The importance of the information processing phase as the most relevant for the context of decision was also observed. However, for further studies, we suggest the joint assessment of the three processes (i.e., visual search strategies, cognitive effort, and processing strategies), as well as the response time, in order to support our findings. In addition, future research should seek to identify the associations between perceptual-cognitive skills and decision making, as well as their influence on game performance. The present paper also provides relevant information on how perceptual-cognitive processes are associated to Systems 1 and 2.

With respect to the practical implications of our findings, two aspects are worth highlighting: the first one refers to the influence of training in the process of performance enhancement. At this point, training should be organised in order to stimulate players' decision making in a quick and intuitive manner, increasing the player's ability to process information and make correct decisions. In this sense, it is necessary to use instruments that allow to evaluate players’ response time in decision making in different game situations. With this information in hand, it will be possible to design training in a more individualised way considering the characteristics of the team and the players, always focusing on activities that stimulate faster decision making, particularly in situations in which they need to improve response time. One strategy to decrease response time in training is to resort to time and/or space constraints on activities.

Another aspect refers to the need to develop specific soccer tools, that enable the assessment and control of cognitive effort in training and match contexts, since this measure is a direct indicator of players’ information processing capacity and cognitive wear and recovery, which are associated to his/her chances of reaching a state of mental fatigue (Cardoso et al., 2019; Kunrath et al., 2020). Thus, if one can objectively control this variable, as is already possible for the physical, physiological, technical, motor and tactical components (Filetti et al., 2017; Naito & Hirose, 2014; Teoldo et al., 2011), and considering that most current soccer teaching and training methodologies include cognition as a core aspect of periodisation (Teoldo et al., 2015), it will enable the access to objective information that support the improvement of training organisation and systematisation and, consequently, of players’ development.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1: Mean (± SD) and range of the percentage of correct answers in decision making between groups with different response times in decision making.

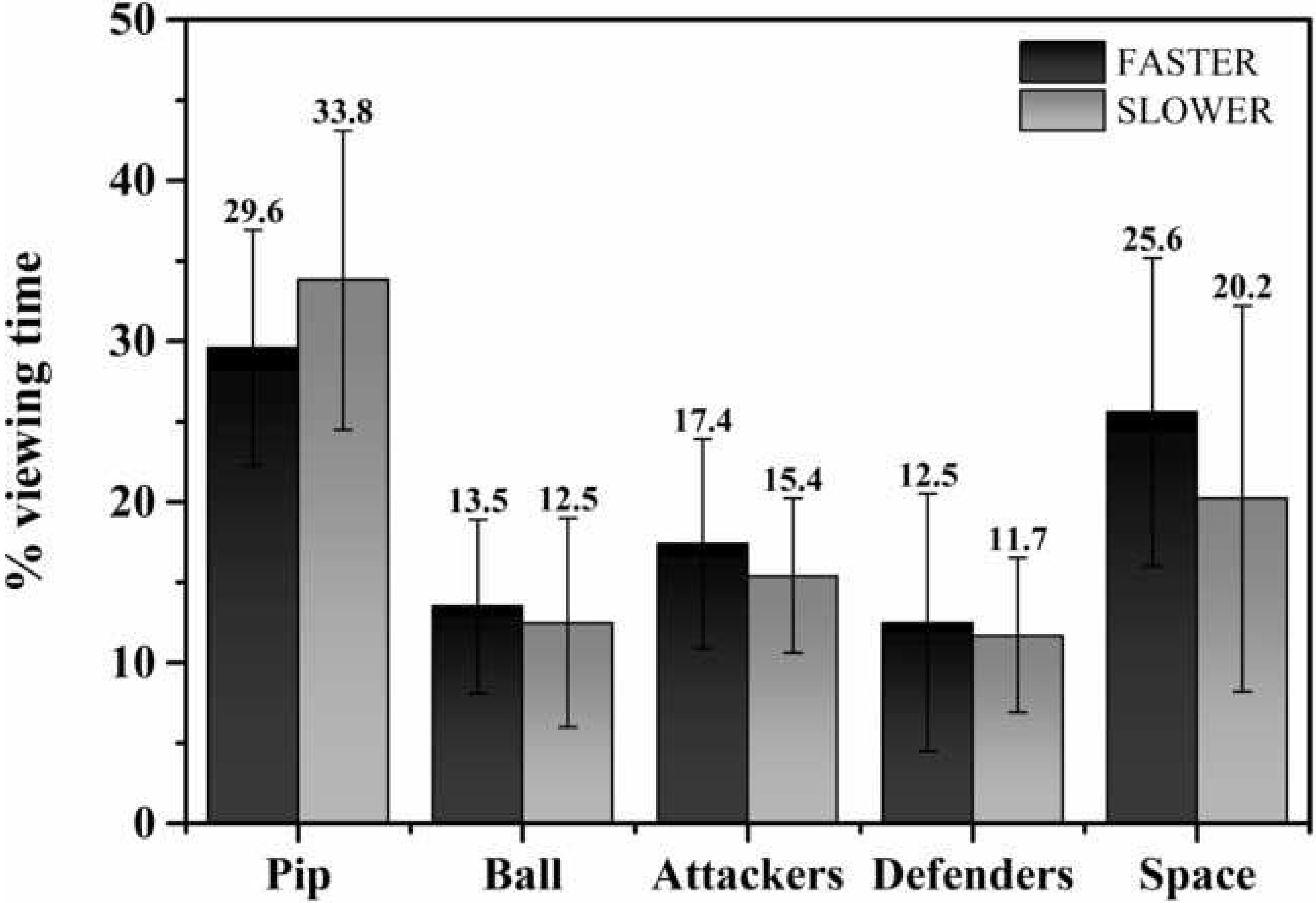
Variables	Faster (n=30)		Slower (n=30)	
	Means±SD	**Min. – Max.**	**Means±SD**	**Min. – Max**
% of correct answers *	79.08±7.87	34.36 – 100	77.19±6.55	45.45 – 100

* All analyses consider only the scenes whose answer was correct. Thus, in addition to time, this work considers the quality of decision making in subsequent analyses.

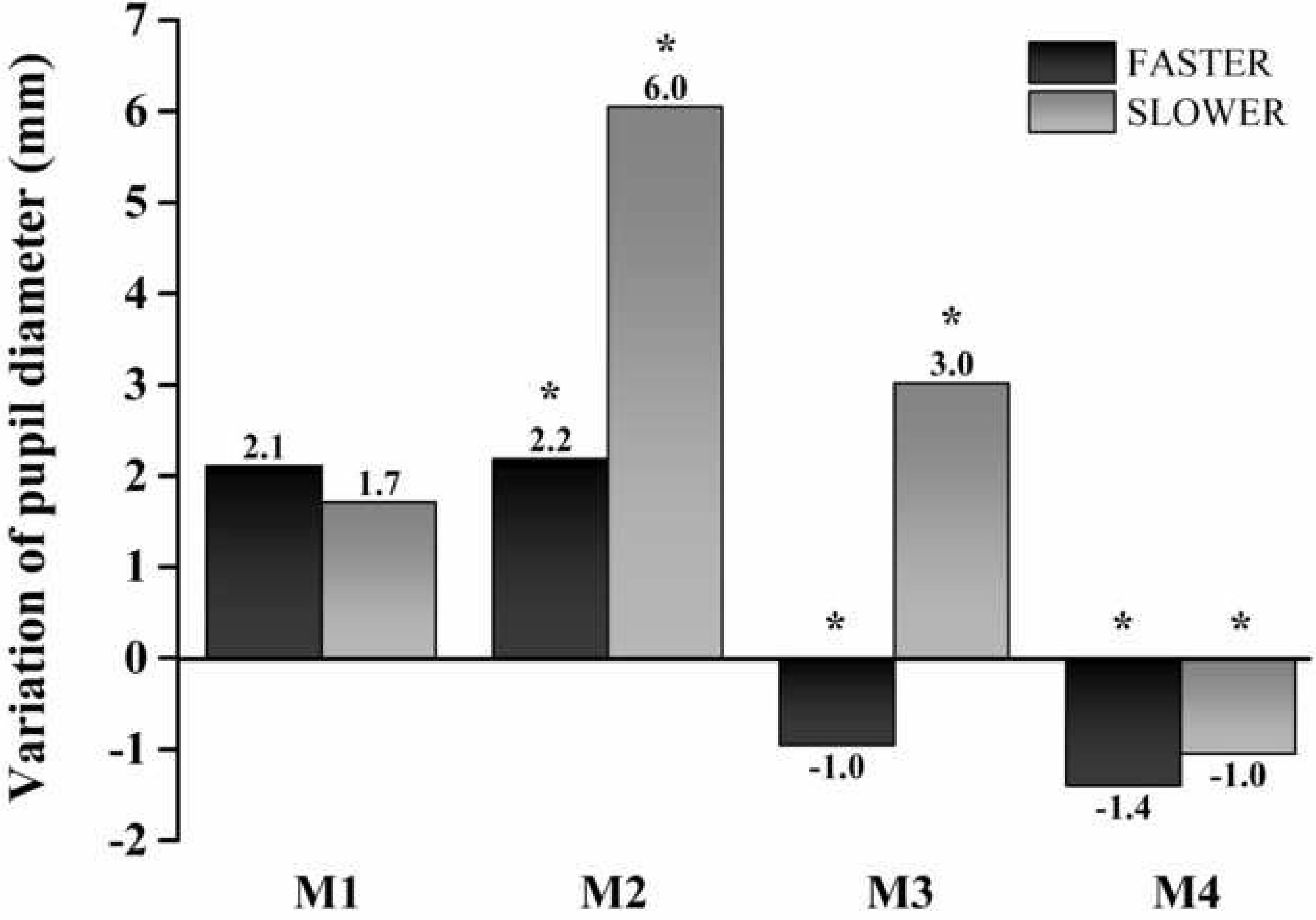
Table 2. Mean (± SD) fixation duration and number of fixations (per second) between groups with different response times in decision making.

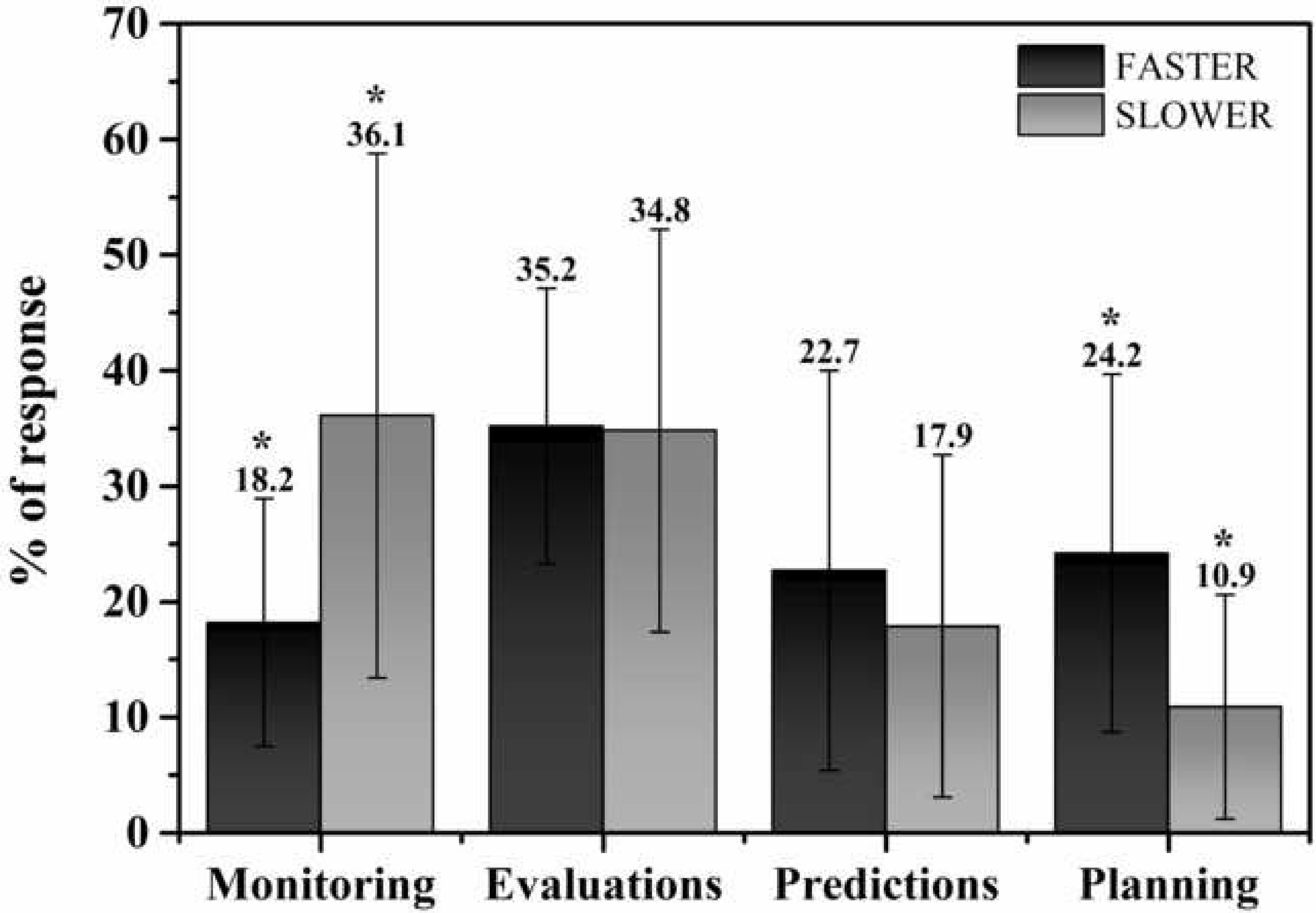
Search rate	**Faster (n=30) Means±SD**	**Slower (n=30) Means±SD**	**t-test**	***p***	***d***	***r***
Fixation duration (ms)*	520.00±197.84	905.89±131.19	-8.903	*<0.001*	2.29	0.75
No. of fixations/s*	5.81±1.68	2.25±1.60	-8.419	*<0.001*	2.17	0.73

*Significant differences



50
40
30
20
10
0
% viewing time
FASTER
SLOWER
29.6
33.8
13.5
12.5
17.4
15.4
12.5
11.7
25.6
20.2
Pip
Ball
Attackers
Defenders
Space


Variation of pupil diameter (mm)
7
6
5
4
3
2
1
0
-1
-2
FASTER
SLOWER
2.1
1.7
*
2.2
*
6.0
*
-1.0
*
3.0
*
-1.4
*
-1.0
M1
M2
M3
M4


70
60
50
40
30
20
10
0
% of response
FASTER
SLOWER
*
18.2
*
36.1
35.2
34.8
22.7
17.9
*
24.2
*
10.9
Monitoring
Evaluations
Predictions
Planning