WHICH COGNITIVE AND PERCEPTUAL SKILLS BEST DISCRIMINATE ELITE FEMALE HANDBALL PLAYERS

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Abstract:

The purpose of this study was to identify which cognitive and perceptual skills best discriminate elite female handball players according to the age group to which they belong. The sample consisted of 73 Portuguese national teams' female handball players, aged between 11 and 29 years, with an average of 7.5 (± 3.7) years of practice. The following tests were applied: Thurstone Identical Figures Test, Toulouse-Piéron Concentrated Attention Test, and the Nideffer Attentional and Interpersonal Style Inventory to evaluate perceptual skills, the polyreactiometer for Windows – PRWin to evaluate information processing, and an evaluation protocol for precision in anticipation using the temporal occlusion paradigm. The interpretation of the obtained discriminant function was based on the structure of the coefficients greater than |0.30|. The Seniors' age group is discriminated from that of Talents by their better reaction, perception, and attention times, namely, by the ability to integrate several stimuli simultaneously and by a better capacity to anticipate future events more accurately. This discriminating model can help coaches recruit players as well as improve psychological training programmes.

Key words*: team handball, information processing, discriminant function, perceptual skills, expertise, adults, juniors*

Introduction

Sport expertise has been defined as the ability to consistently demonstrate a superior sports performance (Janelle & Hillman, 2003; Starkes, 1993) and it is easily perceived by an observer. However, the perceptual and cognitive skills associated with it are much more difficult to observe. According to the aforementioned authors, these involve the ability to identify and capture information from the context in which the activity is taking place and integrate it with pre-existing knowledge in order to produce adequate responses.

In team sport games, and particularly in handball, the importance of the physical, technical and tactical performance components is well known, whereas the psychological component is occasionally relegated to a secondary role. However, the latter, in which the perceptual and cognitive abilities are inserted, should be observed more attentively as they are one of the decisive factors in sport expertise (Abernethy, 1993, Alves, 2004a; Ericsson & Pool, 2016; Moran, 2009; Starkes, 1993; Williams, Davids, & Williams, 1999).

It is at the level of the perceptual skills that the greatest differences between expert and non-expert athletes are observed, namely in pattern recognition and anticipation (Abernethy, 1990; Alves, 2004a) and decision-making (Ripoll, 2011). According to Williams and Reilly (2000), Moran (1996), and Alves (2004a), the perceptual and cognitive abilities are precisely the ones that best distinguish expert and non-expert athletes, and this differentiation is more difficult to make in physical and technical skills.

In collective sport games, and more specifically handball, players are constantly confronted

with complex and rapidly changing game contexts: they must gather information about the position of the ball, their teammates and opponents in order to produce quick and appropriate responses. These responses are subject to various constraints such as players' physical fitness and technical-tactical skills, team strategies or the audience and must be taken under pressure, as the opposing team is trying to restrict the time and space for them to occur (Williams, 2000), thus seriously testing the skills mentioned above.

Among the perceptual and cognitive skills are visual search, attention, anticipation, and decision-making. Visual search and attention are oriented towards appropriate clues, that is, essentially external information or context (Moran, 2009) allowing for the facilitation of the motor response in confrontation sports (Ripoll, 2011) as is the case of handball. On the other hand, anticipation is considered one of the characteristics that most distinguishes the performance of expert from non-expert players (Alves, 2004a; Williams, 2000). Nevertheless, for Baker, Coté and Abernethy (2003), the most important feature underlying an expert's performance in ball sports is decision-making.

In recent decades, a great number of researchers have tried to identify the factors that contribute to expert performance. Traditionally, these studies use an approach that identifies expert athletes competing nationally or internationally (Williams & Ford, 2008) comparing them with non-experts; yet several authors propose other approaches. Therefore, Ward and Williams (2003) mention that the contribution of perceptual and cognitive abilities to sporting expertise throughout the last phase of childhood, adolescence and early adulthood has received little attention from researchers. Abernethy (1991) also points out that more research is required, besides what is usually done concerning experts and beginners, to better understand the bases of perception at different levels of ability and at different stages of development, and, thus, obtain training programmes that are more adequate for different needs of various players. These aspects assume an even greater importance as it is known that players in handball finish their careers at relatively advanced ages (personal experience of the first author, as a player and a coach of female handball players). Consequently, the training stages should be properly planned, in the various areas, so that players achieve their maximum performance at the ideal age and do not abandon the sport prematurely.

Given the background, it is important to understand the factors that characterize various age groups to define learning strategies to be implemented during the sports development. In the present study, bearing in mind the recognized importance of these four skills (visual search, attention, anticipation, and decision-making), we want to identify which perceptive and cognitive skills best discriminate elite female handball players according to their age group, and move in the direction of "designing" appropriate cognitive-perceptual training programmes for various age groups.

Method

Participants

The sample consists of 73 female elite handball players who play in the five levels of the national team of the Handball Federation of Portugal: Talents (n = 16), Juniors C (n = 16), Juniors B (n = 16), Juniors A (n = 13), and Seniors (n = 12). The players' mean age is 16.1 years (standard deviation (SD = 7.5) and their average practice experience is 7.5 years (SD = 3.7) (See Table 1). Before data collection, approval was obtained from the lead authors' University Ethics Committee. Informed consent was obtained from all female players, heads of education (for those under the age of 18) and the Portuguese Handball Federation.

The criterion for the definition of expert/expertise in this investigation is based on the fact that the players have been invited to participate in the national teams' training preparation camp. This criterion is considered adequate for ball sports (Baker, et al., 2003).

Table 1. Means and standard deviations of age and years of experience

		Age		Years of experience	
Group	*n*	*M*	*SD*	*M*	*SD*
Talents (11-12)	16	12.6	0.6	4.4	2.0
Juniors C (13-14)	16	13.8	0.4	5.5	1.6
Juniors B (15-16)	16	15.7	0.4	7.2	2.2
Juniors A (17-18)	13	17.5	0.5	9.1	2.9
Seniors (>18)	12	23.6	2.6	13.5	2.9
Total	73	16.1	7.5	7.5	3.7

Note. n= sample size; M= mean; SD= standard deviation.

Testing procedure

The following tests were used to evaluate the four cognitive-perceptual abilities: 1) Identical Figures (IF) by Thurstone; 2) Concentrated Attention (CA) by Toulouse and Piéron; 3) Attention and Interpersonal Style Inventory (AIST) by Nideffer; 4) simple reaction time and choice reaction time; and 5) protocol to evaluate anticipation (Biscaia, 2013).

Perceptual velocity (PV). The Test of Identical Figures, by Thurstone (1938), adapted for the Portuguese population by the Centre for Psychometric Studies of the Army (internal document, not published), was employed. The test aims at measuring perceptual velocity, namely visual perception speed and easiness by means of identifying, as quickly as possible, the identical figure to that of the model presented, matching the largest number of responses and minimizing errors. The test's content is non-verbal consisting of 60 exercises, each composed of a series of five figures. The participants must identify and select, among them, the one that is identical to the highlighted model. The test is scored according to the number of correct answers, one point each out of the maximum of 60. The questionnaire was applied in a group with a duration of five minutes, and at the end all the correct answers were counted.

Attention focus and concentration. Toulouse and Piéron's Concentrated Attention Test (TP; 1986), adapted for the Portuguese population by Agostinho Pereira (Instituto de Superior de Psicologia Aplicada, internal document, not published) was used to evaluate the following components: execution velocity (EV), that is, the ability to perform quickly, and accuracy (A), namely the ability to maintain concentration. The test consists of finding as many of the same figures as the model, as quickly as possible, always trying to leave none unmarked and avoid marking the ones that are not equal, that is, being fast and precise. EV corresponds to the number of correctly barred signals (correct response, CR), therefore EV = ΣCR. Concentration is evaluated by the sum of wrong responses (WR) and omissions (OR) divided by the quotient of the correct answers, that is, E = (WR + OR) / CRx100. The questionnaire was applied in a group for 10 minutes.

Attentional style. To evaluate the attentional style, the Nideffer Attentional and Interpersonal Style Test (AIST) (1976), translated and adapted for the Portuguese population by Alves (Human Kinetics Faculty, internal document, not published) was applied. According to Weinberg and Gould (2001), the AIST allows for the measurement of one's attention and interpersonal style, being a generalized trait degree, through which an individual pays attention to the environment. The following Test of Attentional and Interpersonal Style (AIST) dimensions were obtained: BET (wide-external) – The higher the result on this scale, the greater the ability to focus attention on a wide variety of external stimuli (Nideffer & Sagal, 2001); BIT (wide-internal) – High results are good for organizing and integrating a wide range of internal information (i.e., thoughts, ideas, feelings and past experiences) (Nideffer & Sagal, 2001); NAR (narrow focus) – Individuals with high outcomes are good at narrowing their attentional focus, both externally and internally, according to the demands of the situation (Nideffer & Sagal, 2001); OET (external overload) – High results lead to mistakes because subjects are distracted by external stimuli that are not relevant to the task (Nideffer & Sagal, 2001); OIT (internal overload) – Individuals who have high scores make mistakes because they are distracted by their own thoughts at critical moments (Nideffer & Sagal, 2001); RED (Reduced Flexibility) – Individuals with high scores make mistakes because anxiety or anger interferes with their ability to shift the attentional focus from an external focus to an internal focus, or vice versa (Nideffer & Sagal, 2001);

The questionnaire consists of 12 items (two per dimension) in which the participants choose, on a 5-point Likert-type scale (ranging from 0 to 4), the most appropriate option. For each of the scales, a sum was obtained for both items, values varying from zero to eight. The questionnaire was applied in a group with no time limit.

To measure **Psychomotor Variables** (simple reaction time and choice reaction time using two and four stimuli) we used the Polireactiometer software for Windows (PRWin), which recorded times in milliseconds (ms) and performed all counting operations (times, errors and stimuli) by integrated circuits, so the following variables were obtained:

Simple reaction time (SRT). The time elapsed from the appearance of the stimulus, which is always the same, to the execution of the motor response, which is also always the same. In the centre of a computer screen a sequence of 30 visual stimuli was presented, identical in colour, duration and intensity, within three random intervals (250, 300 and 450ms); the player was expected to press a specific key as fast as possible (ms) on the computer keyboard. Therefore, it encompasses the time of pressure movement which is, however, almost insignificant.

Choice reaction time (CRT). Time interval that has elapsed since the appearance of one of two stimuli (CRT2) or four stimuli (CRT4) and the appropriate motor response. In the computer screen corners 32 visual stimuli were presented, with the same duration and intensity, but within random time intervals (250, 350 and 400ms). Each player had to respond correctly to each stimulus by pressing a key depending on where the stimulus was presented. The CRT calculation was made using the mean of

the correct answers. CRT2% and CRT4%—accuracy of response to two and four stimuli, respectively. DT2 and DT4—decision time for two and four stimuli, respectively, in accordance with the subtractive method (Donders, 1869/1969; Alves, 2004b). It corresponds to the difference between the choice reaction time and the simple reaction time obtained by the previously described methods (DT2= CRT2 – STR; DT4 = CRT4 – SRT; and DT = [DT2+DT4]/2)

To evaluate the **precision in anticipation (AP)**, the temporal occlusion paradigm (Bordini, et al., 2013) was used through a software developed for this purpose (video protocol for handball—ProtAnde). On a computer (Hp Touch Smart), 18 video clips of 10 seconds each (six clips for each response option) were screened, selected from the last Handball European Championships and Olympic Games Handball Women's tournament. The players watched the clips until a tactical decision was going to be made by the ball bearer, the image was interrupted and the player was asked to select a tactical decision by touching the 5'' monitor (pass, shot, dribble). The video was developed by Biscaia (2013) and validated by five handball experts specifically for this research. The interobserver accuracy was based on the Cohen's Kappa, and a good to excellent agreement amongst the experts was found, with an agreement of 87%. The measurement of this variable was obtained by the number of correct responses in the video protocol (ProtAnde). Only correct answers were considered. All participants went through a pre-test learning phase, which consisted of the presentation of three clips, thus ensuring a full understanding of the protocol. They were asked to accurately respond as quickly as possible.

None of the players had prior evaluation experience with either of the tests used.

Statistical analysis

For each of the variables under analysis, normality as well as variance homogeneity were evaluated. Descriptive statistics were expressed as mean (M) and standard deviation (SD). In order to determine the variables that best discriminate the differences between the groups and predict future performance, according to their discriminant characteristics, a discriminant analysis was performed. The assumptions were made, namely the independence of variables, normal multivariate distribution, and equal variance-covariance between the groups (Silva & Stam, 1995). The interpretation of the discriminant functions was based on the analysis of the structure of the coefficients greater than |0.30|, meaning that the variables with the greatest absolute value had a greater power of discrimination between the groups (Tabachnick & Fidell, 2000). The SPSS program, version 23.0, was used for data analysis and the significance level used was $p \leq .05$ for rejected null hypothesis.

Table 2. Means and standard deviations of cognitive and perceptual skills according to the age group

	Variables	Talents	Juniors C	Juniors B	Juniors A	Seniors
		M ± SD	*M ± SD*	*M ± SD*	*M ± SD*	*M ± SD*
Psychomotor test	SRT (ms)	655.83 ± 54.85	596.79±37.60	632.77 ± 41.99	584.89±30.34	524.53 ± 34.19
	CRT2 (ms)	710.58 ± 59.89	658.71±49.49	687.68 ± 51.78	615.75±28.48	595.42 ± 47.49
	CRT2 (%)	2.45 ± 3.11	4.46±3.57	3.12 ± 3.65	3.57+3.57	3.57± 3.72
	CRT4 (ms)	819.38 ± 86.28	774.61±52.72	775.46 ± 66.03	713.72±46.47	707.78 ± 44.60
	CRT4 (%)	0.33 ± 0.34	5.62±4.82	3.91 ± 4.73	3.84±4.06	3.88 ± 4.67
	DT2 (ms)	54.73 ± 35.13	61.92 ± 29.27	54.90 ± 33.16	30.85 ± 28.24	70.88 ± 44.89
	DT4 (ms)	163.55 ± 72.46	177.82 ± 39.47	142.68 ± 46.49	128.83 ± 54.81	183.25 ± 45.11
	DT (ms)	109.15 ± 51.37	119.87 ± 29.44	98.79 ± 36.25	79.84 ± 39.84	127.07 ± 40.84
IF	PV (nº)	51.31 ± 6.63	52.25 ± 7.00	56.25 ± 4.59	56.54 ± 4.17	57.83 ± 2.36
TP	EV (nº)	171.94 ± 37.89	209.81 ± 38.98	230.38 ± 54.74	219.15 ± 27.51	255.00 ± 32.20
	E %	12.34 ± 10,14	11.67 ± 9,72	14.00 ± 11,25	8.19 ± 6,09	11.38 ± 4,18
AIST	BET	4.94 ± 1,06	3.81 ± 1.27	5.00 ± 1.09	4.38 ± 1.32	5.58 ± 0.90
	OET	2.50 ± 1.03	2.50 ± 1.21	2.69 ± 2.12	2.85 ± 1.40	2.58 ± 1.08
	BIT	4.56 ± 1.03	4.38 ± 1.50	4.81 ± 0.91	4.38 ± 1.66	4.25 ± 1.05
	OIT	2.25 ± 1.00	2.88 ± 1.08	2.38 ± 1.62	3.38 ± 2.53	2.67 ± 1.49
	NAR	4.00 ± 1.75	4.13 ± 1.96	4.00 ± 2.03	4.69 ± 1.43	4.33 ± 1.30
	RED	2.81 ± 0.98	2.25 ± 1.29	2.50 ± 1.31	2.62 ± 1.44	2.75 ± 1.54
ProtAnde	PA (nº)	14.31 ± 0.87	15.00 ±1.15	15.06 ± 1.12	15.00 ±1.15	16.00 ± 1.20

Note. M=mean; SD=standard deviation; SRT=simple reaction time; CRT2=choice reaction time – two stimuli; CRT2%=percentage of wrong responses to reaction time – two stimuli; CRT4=choice reaction time – four stimuli; CRT4%=percentage of wrong responses to reaction time – four stimuli; DT2=decision time – two stimuli; DT4=decision time – four stimuli; DT=decision time – mean DT2 and DT4; PV=perceptual velocity; EV=execution velocity; E=concentration; BET=wide-external; OET=external overload; BIT=wide-internal; OIT=internal overload; NAR=narrow focus; RED=reduced focus; PA(nº)=precision in anticipation; IF=test of identical figure Thurstone; TP=Toulouse-Piéron's Concentrated Attention.

Results

Table 2 presents the means and standard deviation of the perceptual and cognitive skills for each age group.

Table 3 shows the structural canonical coefficients (SCC) and the statistical significance of the obtained functions. The analysis of the discriminant function indicated that: function 1 is responsible for 58.7% of the total variance and it is significant (p=.008); function 2 explains 21.6% of the total variance and is also significant (p=.004); functions 3 and 4 are not significant (p=.097 and p=.357, respectively), with function 3 accounting for 12.8% of the total variance, and the latter for only 6.9%. The results of discriminant function 1 revealed that variables SRT (SCC=.755), CRT2 (SCC=.573), CRT4 (SCC=.417), EV (SCC=-.405), and PA (SCC=.326) were the indicators that best discriminate between the age groups. In function 2, it is the BET variable (SCC=.471) that best discriminated between them.

As shown in Table 3 and Figure 1, the distance of the centroids of the groups and the structure of the coefficients describe the profiles that differentiate between the groups under study. The structure coefficients quantify the potential of each variable and maximize the mean differences among the five groups. The higher the coefficients' absolute value, the greater the contribution of each variable to the discriminant function.

The quality of suitability of the function found is high for the groups under analysis (Table 4). In Talents, eleven players (68.8%) were ranked, in Juniors C ten (62.5%), and in Junior B twelve (75.0%) in a universe of sixteen players for each of these echelons. In the Juniors A category, ten out of thirteen (76.9%) and in Seniors eleven of the twelve players (91.7%). The final reclassification percentage of the group is 74.0%.

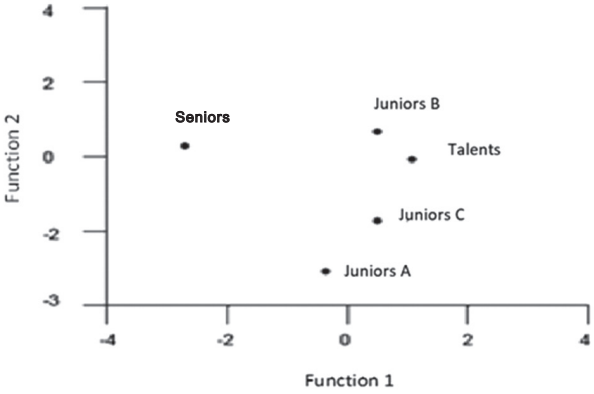

Figure 1. Territorial map of the players relative to their age group representing how widely dispersed the centroids are from one another in the standardised discriminant scores.

Table 3. Discriminant analysis for cognitive and perceptual skills according to the age group

Variables	Function (SCC)			
	1	2	3	4
SRT (ms)	.755[a]	.208	-.120	.016
CRT2 (ms)	.573[a]	.295	-.140	-446[a]
PA (nº)	-.326[a]	.129	.167	-.038
BET	-.130	.471[a]	-.429[a]	.196
BIT	.079	.123	.060	.060
CRT4 (%)	-.148	-.112	.589[a]	-.160
EV (nº)	-.405[a]	.275	.455[a]	.206
RED	-.009	.053	-.217	.121
CRT2 (%)	-.063	-.119	.202	-.136
DT (ms)	-.101	.060	-.123	-.759[a]
DT4 (ms)	-.096	-.021	-.150	-.719[a]
DT2 (ms)	-.088	.173	-.056	-.662[a]
CRT4 (ms)	.417[a]	.120	-.207	-.601[a]
PV (nº)	-.246	.218	.181	.594[a]
OIT	-.074	-.218	.137	.227
E %	.067	.195	.046	-.212
NAR	-.058	-.094	.006	.201
OET	-.011	-.001	.045	.177
Wilks' Lambda	.008*	.004*	.097	.357
Eigenvalue	2,002	.736	.439	.237
% of variance	58.7	21.6	12.8	6.9
Canonical Correlation	.817	.651	.552	.437

Note. SRT=simple reaction time; CRT2=choice of reaction time – two stimuli; PA(nº)=precision in anticipation; BET=wide-external; BIT=wide-internal; CRT4=percentage of wrong responses to choice reaction time – four stimuli; EV=execution velocity; RED=reduced focus; CRT2=percentage of wrong responses to choice reaction time – two stimuli; DT=decision time; DT4=decision time – four stimuli; DT2=decision time – two stimuli; CRT4=choice of reaction time – four stimuli; PV=perceptual velocity; OIT=internal overload; E=concentration; NAR=narrow focus; OET=external overload.

Table 4. Classification matrix for the players' actual and predicted age group according to cognitive and perceptual skills of the discriminant functions

Atual Group	Predict Group				
	Talents	Juniors C	Juniors B	Juniors A	Seniors
Talents (n=16)	68.8%	6.3%	12.5%	6.3%	6.3%
Juniors C (n=16)	18.8%	62.5%	0.0%	12.5%	6.3%
Juniors B (n=16)	12.5%	0.0%	75.0%	12.5%	0.0%
Juniors A (n=13)	7.7%	15.4%	0.0%	76.9%	0.0%
Seniors (n=12)	0.0%	0.0%	0.0%	8.3%	91.7%

Note. n= sample size

Discussion and conclusions

The objective of this research was to identify which perceptual and cognitive skills best discriminate elite handball players according to their age group, so that an estimate could be made as to which group each player might belong to.

Results revealed that only six out of the eighteen variables evaluated predicted expert performance better and contributed the most to maximize the difference between the age groups. The variables that had the greatest contribution to the discrimination and differentiation among the groups under study were: simple reaction time (SRT), choice reaction time at two and four stimuli (CRT2 and CRT4), precision in anticipation (PA), execution velocity (EV), and the ability to focus attention on a wide variety of external stimuli (BET), which is important in fast and open sports (Nideffer & Sagal, 2001) such as handball.

In the context of the perceptual and cognitive skills study, it has been demonstrated that the variables mentioned above, among others, are responsible for a large part of the variance in football abilities among adult groups (Helsen & Starkes, 1999).

Regarding the variables under study, the first function presents most variables (58.7%) and explains the differences between the echelons of Talents and Seniors: simple reaction time (SRT), choice reaction time at two and four stimuli (CRT2 and CRT4), execution velocity (EV), and precision in anticipation (PA).

In terms of broad external attention (BET) a percentage of 21.6% explains the difference between the same levels. In the game of handball, this is particularly important because players must simultaneously integrate several external stimuli. For instance, in a study of elite and sub-elite football players, Ward and Williams (2003) found that the amount of true variance between elite and non-elite groups, explained by the variables of perceptual and cognitive skills, was 47%. In our current research, the value of variance was 80.3%, confirming that the differences were explained by the perceptual and cognitive abilities that were highlighted in this study.

Hence, the performance at the Senior level (Table 2) is discriminated according to the best reaction times and by the highest test values in perceptual velocity, attention focus, and precision in anticipation, in which the Seniors' scores were better than that of other levels. These differences seem to be influenced by years of experience and, also, seem to be reflected in tactical and strategic aspects of game play.

Handball implies fast and complex context changes; thus, the players are faced with the need to quickly gather information regarding the position of the ball, opponents and teammates, and provide an adequate response under great time and space constraints. In such situations, the ability to anticipate future events based on cues from the context seems to be one of the key aspects in expert performance. In various game situations, elite players are able to perform certain actions as a result of their ability to "read the game" (Helsen & Starkes, 1999; Williams, 2000). For instance, an experienced player immediately responds with a movement along the cross trajectory, without previous warning, when she/he sees a teammate with the ball performing a path into the space of her/his specific zone to receive a back pass from her/him (central-lateral crossing) and play in her/his specific zone.

In this study, Senior players have more effective information-gathering strategies, they are faster and more precise and more accurately anticipate opponents' actions, thus achieving a better "reading" of the game. By having more effective information gathering strategies, they reduce the amount of information to be processed, thus reducing its complexity. These findings are in line with the results of a similar study that refers to this set of situations as leading to easier information processing in long-term memory and to a consequent and more effective response selection (Alves, 2004a). Furthermore, they also seem to agree with others performed in various sports (Abernethy & Russell, 1984; Allard, Graham, & Paarsalu, 1980; Helsen & Starkes, 1999; Williams, 2000).

These findings are in line with the current body of knowledge, demonstrating that perceptual and cognitive skills also reliably discriminate elite

groups between the ages of 11 and 29 (age range of the present investigation). Players of different sports in the age of Talents category are able to use their perceptual and cognitive abilities more effectively than their non-players counterparts (Alves, Figueiredo, & Brandão, 1985). The same is suggested in a study by Ward and Williams (2003) regarding football players (elite vs. sub-elite) in the same age group. Moreover, these authors point out that limited but high-quality training can have a significant impact on the acquisition and improvement of perceptual and cognitive skills at younger ages. We can assume that this is one of the reasons why the Talents players under study were summoned to the national team.

The ability to anticipate a future event (that is the adequate use of contextual information) and knowledge of what might happen (that is the integration of memory-stored information), during certain competitive situations, are fundamental components in expert performance (Williams & Ward, 2003), which was also verified in the present study. Therefore, with the increase of experience, expert players become better at predicting and adapting their responses. These skills may allow an expert player in defence, who marks her/his attacking opponent, to predict that another attacker, coming out from a cross to shoot from the opportunity provided by the guarded one, will not shoot over them, but will opt for a pass to the pivot on the defender's back, thus allowing the defender to intercept this pass. In this context, anticipation seems to be among the characteristics that best discriminate among different levels of expertise.

This was the case that Ward and Williams (2003) concluded in a football study, in which they analyzed the development of perceptual and cognitive skills. They also concluded that, from the age of nine, elite football athletes show perceptual and cognitive skills superior to their age peers, but with less capacity for football. They also added that recognition (long-term memory recall) of the structured game pattern shows a greater power of prediction than the age.

The discriminant functions' ability to correctly classify players in their age group was high, evidencing the quality of the same and the power of the structure coefficients in explaining the variability between the groups. Therefore, the results show that older echelon players can be distinguished from the rest based on a specific combination of variables related to reaction time, perceived velocity, wide-external attentional focus (BET), and precision in anticipation. These variables seem to be, potentially, good predictors for the placement of the players in their respective groups and may contribute to the selection of female players in the future.

The territorial map (Figure 1) provides an initial model for discriminating handball players. In this manner, evaluations of perceptual and cognitive skills, namely those mentioned above, for the purpose of identifying potential players in future selections, can be compared with the centroid groups. Furthermore, the territorial map provides information illustrating that, between the Talent and Senior groups, there are very distant performance profiles.

The results of this study, in conjunction with others in the same area (Ward & Williams, 2003; Williams & Grant, 1999), suggest that perceptual and cognitive training can be performed from the age of nine years. For example, McPherson and Thomas (1989), in a study of 8-10-year-old tennis players, showed that it was possible to improve decision-making when they followed specific instructions. However, this type of training should not be employed until young athletes have fully understood the rules of the game and have reached a certain competitive level (Williams & Ward, 2003).

In conclusion, the present study suggests that handball players develop perceptual and cognitive skills that improve with experience and the accumulation of sports practice, allowing them to have a more successful performance in the age groups to which they belong. The older players are able to efficiently use contextual and other information stored in their memory, which allows them to distinguish themselves from their younger partners. On the other hand, it also suggests that the variables identified in the present study, combined with the other mentioned in literature, such as anthropometric, physical, psychological, and technical-tactical factors, should be considered when attempting to detect a talented player.

References

Abernethy, B. (1993). Attention. In R. Singer, M. Murphey & L.K. Tennant (Eds.), *Handbook of research on sport psychology* (pp. 127-170). New York, NY: Macmillan.

Abernethy, B. (1990). Expertise, visual-search, and information pick-up in squash. *Perception, 19*(1), 63-77.

Abernethy, B. (1991). Visual-search strategies and decision-making in sport. *International Journal of Sport Psychology*, *22*(3-4), 189-210.

Abernethy, B., & Russell, D.G. (1984). Advance cue utilization by skilled cricket batsman. *Australian Journal of Science and Medicine in Sport*, *16*(2), 2-10.

Allard, F., Graham, S., & Paarsalu, M. (1980). Perception in sport: Basketball. *Journal of Sport Psychology*, *2*, 14-21.

Alves, J. (2004a). Mestria e Rendimento Desportivo: O Papel da Perceção. [Expertise and sport performance: The role of perception. In Portuguese.] *Revista Portuguesa de Ciências do Desporto, 4*(2) (Suplemento), 38-42.

Alves, J. (2004b). Processamento da Informação e Tipo de Desporto. [Information processing and type of sport.] *Desporto. Investigação e Ciência*, *4*, 49-60.

Alves, J., Figueiredo, I., & Brandão, L. (1985). Evolução do Tempo de Reação, Estudo Comparativo entre Crianças com e sem Prática Desportiva. [Reaction time evolution, comparative study between children with and without sports practice.] *Motricidade Humana*, *1*(1), 64-72.

Baker, J., Côté, J., & Abernethy, B. (2003). Sport-specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology, 15*(1), 12-15.

Biscaia, P. (2013). Desenvolvimento das habilidades percetivo-cognitivas no andebol feminino de elite. Estudo realizado com as seleções nacionais de Portugal. [Development of perceptual-cognitive skills in elite women's handball. Study carried out with the national teams of Portugal. In Portuguese.] (Unpublished Doctoral Thesis). Vila Real, Portugal: UTAD.

Bordini, F., Costa, M., Medina-Papst, J., Ribeiro, D., Okazaki, V., & Marques, I. (2013). Efeito da oclusão de informações espaciais na cortada do voleibol sobre a tomada de decisão defensiva em atletas com diferentes níveis de experiência. [Effect of occlusion of spatial information in volleyball cutting on defensive decision making in athletes with different levels of experience.] *Revistada Educação Física/UEM*, *24*(3), 331-343. doi:10.4025/reveducfis.v24.3.17006

Donders, F.C. (1969). On the speed of mental processes. *Acta Psychologica*, *30*, 412-431. doi: 10.1016/0001-6918(69)90065-1

Ericsson, K.A., & Pool, R. (2016). *Peak*: *Secrets from the new science of expertise.* New York, NY: Houghton Mifflin Publishing.

Helsen, W.F., & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, *13*(1), 1-27.

Janelle, C.M., & Hillman, C.H. (2003). Expert performance in sport: Current perspective and critical issues. In J.L. Starkes & K.A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 19-48). Champaign, IL: Human Kinetics.

Mcpherson, S.L., & Thomas, J.R. (1989). Relation of knowledge and performance in boys' tennis – Age and expertise. *Journal of Experimental Child Psychology*, *48*(2), 190-211.

Moran, A.P. (1996). *The psychology of concentration in sport performers*. New York, NY: Psychology Press.

Moran, A. (2009). Attention in sport. In S.D. Mellalieu & S. Hanton (Eds.), *Advances in applied sport psychology*: *A review* (pp.195-220). New York, NY: Routledge.

Nideffer, R., & Sagal, M.-S. (2001). *Assessment in sport psychology.* Morgantown, WV: Fitness Information Technology.

Ripoll, H. (2011). Do tratamento da informação à tomada de decisão no desporto. [From information processing to decision-making in sport.] In J. Alves & A.P. Brito (Eds.), *Manual de Psicologia do Desporto para Treinadores* (pp. 295-314). Lisboa, Portugal: Visão e Contextos.

Silva, A.P.D., & Stam, A. (1995). Discriminant analysis. In L.G. Grimm & P.R. Yarnold (Eds.), *Reading and understanding multivariate statistics* (pp. 277-318). Washington, DC: American Psychological Association.

Starkes, J.L. (1993). Motor experts: Opening thoughts. In J.L. Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise* (pp. 3-16). Amsterdam: Elsevier Science.

Tabachnick, B., & Fidell, L. (2000). *Using multivariate statistics.* Boston, MA: Pearson Allyn & Bacon.

Thurstone, L.L. (1938). *Primary mental abilities*. Chicago, IL: Univ. Chicago Press.

Ward, P., & Williams, A.M. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology*, *25*(1), 93-111.

Weinberg, R.S., & Gould, P. (2001). *Fundamentos de psicologia do esporte e do exercício* (2nd ed.). [Foundations of sport and exercise psychology. In Portuguese.] Porto Alegre, Brazil: Artmed Editora.

Williams, A.M. (2000). Perceptual skill in soccer: Implications for talent identification and development. *Journal of Sports Sciences, 18*, 737-750.

Williams, A.M., Davids, K., & Williams, J.G. (1999). *Visual perception and action in sport.* London: E. & F. N. Spon.

Williams, A.M., & Ford, P.R. (2008). Expertise and expert performance in sport. *International Review of Sport and Exercise Psychology*, *1*, 4-18.

Williams, A.M., & Grant, A. (1999). Training perceptual skill in sport. *International Journal of Sport Psychology*, *30*, 194-220.

Williams, A.M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Sciences*, *18*, 657-667.

Williams, A.M., & Ward, D. (2003). Perceptual expertise: Development in sport. In J.L. Starkes & K.A. Ericsson (Eds.), *Expert performance in sport: Advances in research on sport expertise* (pp. 219-250). Champaign, IL: Human Kinetics.

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