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Executive functioning profiles in elite volleyball athletes: Preliminary results by a sport-specific task switching protocol

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A R T I C L E I N F O

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A B S T R A C T

Executive functions (EF) are crucial for the athletes' success, and they are even more essential in *open skill* sports (e.g. volleyball and football). In these sports, due to continuously changing conditions, goal-directed behaviours need to be repeatedly adjusted and corrected. One of the most important EF is the ability to continuously switch between two different tasks being required in a random sequence. We used a task-switching protocol in elite volleyball athletes, usually playing different roles, with the aim of evaluating if each role is characterized by specific switching abilities. On the basis of the specific competences requested by the game, thirty-six elite volleyball athletes were assigned to three groups: Strikers, Defenders and Mixed. Each player completed a customized sport-specific task-switching paradigm. Data evidenced that each role has specific characteristics. In Reaction Times, the Strikers were the fastest to answer to stimuli, while the Defender group provided a worse performance, particularly when defensive actions, that probably require more cognitive elaboration, had to be processed. Different effects emerged by the Errors. In fact, the Mixed group, which was the one with more expertise, appeared to be more accurate in the responses.

Although preliminary, these results showed a minimal degree of cognitive flexibility for highly specialized Strikers and a maximum level for Mixed, allowing thus to highlight specific profiles of athletes. Data observed indicate the possibility to develop a test assessing the executive domain during the recruitment in a team, revealing a useful tool for choosing the most suitable role.

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1. Introduction

Sport science suggests that the success of an athlete depends on several factors that include physical and technical skills, emotional control and cognitive abilities (Weinberg & Gould, 2015). With respect to the cognitive domain, executive functions (EF) are essential (Alvarez & Emory, 2006; Miyake & Friedman, 2012). EF are higher-order cognitive abilities including multiple aspects of cognition, such as problem solving, planning, sequencing, selective and sustained attention, inhibition, utilization of feedback, multitasking, selecting goals, cognitive flexibility and ability to deal with novelty (Dunsky et al., 2017; Vestberg, Reinebo, Maurex, Ingvar, & Petrovic, 2017). Such combination of cognitive skills allows the athlete to join the action and, especially, to respond to non-routine situations (Friedman et al., 2006). EF are often defined as the "highest-level" cognitive functions, being involved in the control and regulation of all cognitive processes. Moreover, by means of specific anatomic and functional connections between the prefrontal cortex and the limbic system, EF also regulate physiological activation and arousal, suggesting an important role even in the control of emotional processes (Kelley, Wagner, & Heatherton, 2015).

In sport, EF have been deeply investigated since they mediate adaptation to changing situations and modulate attention as well as the recalling of game strategies (Williams & Ericsson, 2005). As a consequence, they can reasonably be seen as fundamental sports' prerequisites, especially in *open skill* sports. In fact, open skill sports, such as football and volleyball, take place in a relatively unpredictable and constantly changing environment, and hence need movements and goal-directed behaviours to be continuously adapted and readjusted (Nuri, Shadmehr, Ghotbi, & Moghadam, 2013). It follows that in these sports a successful athlete must be able to continuously keep track of the gaming situations, compare them to past experiences, make decisions as quickly as possible, or even quickly block planned choices that might be no longer suitable.

Recently, Vestberg and colleagues (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012) showed that senior elite and semi-elite soccer players had significantly better performances in different EF tasks in comparison with a standardized control group. In this line, other studies showed that professional athletes in other open skill sports such as ice hockey and rugby performed significantly better than amateur athletes in EF tasks (Faubert, 2013) and this seems true also for other sports, whether open or closed, such as basketball (Cortis et al., 2011), synchronized swimming (Albinet, Abou-Dest, André, & Audiffren, 2016), as well as individual sports such as tennis (Shim, Carlton, Chow, & Chae, 2005). These evidences suggest that expert open skill players develop specific patterns of dynamic visual interaction with the environment and flexible behaviour (Ripoll, 1988; Starkes & Allard, 1983). In fact, converging evidence showed that experts, in comparison to novices, form anticipatory representations of ongoing actions, relying mainly on reading the body kinematics of the opponents, thus predicting the actions of the other players (Aglioti, Cesari, Romani, & Urgesi, 2008; Tomeo, Cesari, Aglioti, & Urgesi, 2012; Urgesi & Makris, 2016). Moreover, it has been evidenced that expert soccer players develop considerable attentional capabilities such as attaining and maintaining an alert state (Verburgh, Scherder, van Lange, & Oosterlaan, 2014). Beside the refinement of visuo-perceptive-motor abilities and attentive processes, the expert players must be proficient in *cognitive flexibility*, defined as "the capability to adjust behavioural responses to environmental changes" (Miyake et al., 2000). Such cognitive ability, strictly related to EF, allows the development of a flexible game behaviour, not only for what concerns the adaptation of one's own behaviour to the context, but also for predicting the behaviour of other players. Namely, during the game, each player is required to evaluate very quickly all the possible strategies, choose the preferred one and, if necessary, change what he/she had planned to do in order to adapt to continuously changing environments and game choices.

In sport, these abilities, also known as "game intelligence" (Stratton, Reilly, Williams, & Richardson, 2004), are seen as indicators of EF and are usually investigated by means of task-switching paradigms (for a review see Logan, 2003) (for a review see Logan, 2003). Switching ability, in fact, is strongly correlated to cognitive flexibility.

In task-switching, two different tasks are performed in rapid succession and according to a random sequence of task presentation, so that the task to be executed might change from one trial to the next ("switch" trial), or be repeated ("repetition" trial). Task-switches are usually slower and less accurate than task repetitions, and this difference is often referred to as the "switch cost" (SC). This cost is thought to reflect the time needed for the executive control processes to reconfigure the cognitive system for the execution of a new task (Meiran, 1996; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001). Thus, the SC can be considered an operational measure of the executive control (Couyoumdjian et al., 2010; Foti et al., 2015; Koch, Poljac, Müller, & Kiesel, 2018; Yin, Wang, Pan, Liu, & Chen, 2015).

In the present study, we have analysed cognitive flexibility in elite volleyball athletes in order to investigate the relationship between the role played by an athlete and the required executive processing skills. Such feature could help to identify an "executive style", similar to the well recognized attentive style (Nideffer, 1976). To this aim, we used a developed a tailored task-switching protocol to assess switching ability in athletes. We selected athletes playing five different roles, subdivided in three categories on the basis of the specific competences: Strikers (opposite and middle hitters), who have as main objectives both to attack and prevent opponents' attacks; Defenders (setters and liberos), who have to counteract and neutralize attacks received from the rival team; Mixed, represented by spiker outside hitters who are specialized in both offensive and defensive actions, usually characterized by greater strategic and tactical competences (Table 1). Such subdivision is in agreement with the guidelines of the Fédération Internationale De Volleyball (www.fivb.org/EN/Development/document/FIVB_DEV_Top_Volley_Manual_eng.pdf).

These competences related to the role played are strongly linked to specific cognitive processes depending on the type of action. In fact, the execution of a technique (as it occurs in the attack) requires faster processing than the organization of a tactic (as it occurs in the defence action) that integrates all the elements of the game environment. On the basis of this distinction, it is important to group the individual roles into three categories: attack, defence and mixed, in order to highlight the relationship that exists between the type of action and the cognitive processing.

Table 1
Division of three experimental groups on the base of offensive and defensive fundamentals in volleyball.

Fundamental categories		Roles in volleyball				
		Middle hitter	Opposite hitter	Outside hitter	Libero	Setter
Offensive fundamental	Service	+	+	+	−	+
	Attack	+	+	+	−	−
Defensive fundamental	Service reception	−	−	+	+	−
	Defence	−	−	+	+	+
	Block	+	+	+	−	+
		Resultant categories				
		Strikers	Strikers	Mixed	Defenders	Defenders

2. Materials and methods

2.1. Participants

Twenty-seven Italian males elite volleyball athletes aged between 18 and 30 years (mean age: 25.03 ± SD 5.23) participated in the study. All athletes had about 13 years of experience in volleyball (mean: 12.86 ± SD 3.34) and at the moment of the experiment they were playing in the Italian national volleyball championships or had already played in it before. All athletes trained 5 days a week, 2–4 h per session.

The athletes were subdivided into three groups according to the specific requests of each role during the game: *Strikers* (opposite and middle hitters; N = 12); *Defenders* (setters and liberos; N = 12) and *Mixed* (spiker outside hitters; N = 12). In according to the Fédération Internationale De Volleyball, we distinguished the three roles on the basis of offensive and defensive fundamentals in volleyball, excluding the set that is proper of the setter. In Table 1 the division in the three categories is reported.

None of the participants had a history of medical, neurological or psychiatric disorders, nor of medication or drug intake. The entire investigation was conducted in gyms, temporally distant from training sessions and according to the principles established by the Declaration of Helsinki. The whole experimental protocol has been approved by the Internal Review Board of the University of L'Aquila (#22/2017). Written informed consent was obtained from all participants before the investigation.

2.2. Procedure

Athletes were tested individually in a dimly lit, soundproofed room near the gym and before every sport training session. They were asked to seat in front of a 15-inch computer monitor, at a distance of 50 cm, and to complete the task switching protocol (described below). At the beginning of each session, task instructions were both displayed on the screen and explained verbally to participants, emphasizing the need for both accuracy and speed.

2.3. Task-switching protocol

The task-switching ability was assessed by means of a task-cueing procedure, which involved performing two tasks in rapid sequence in randomized order, and presenting a cue on each trial that indicated the task to be performed on the subsequent target stimulus. To this end we developed a customized task-switching protocol, in which the two tasks consisted of judging whether an action was an attack or a defense (task A), and if the shirt colour of the portrayed subject was red or white (task B): the corresponding cue was, respectively, a rhombus and a square. Participants used their left and right index fingers to respond. The same two response keys on the computer keyboard ("A" for left and "L" for right index finger) were used for both tasks. The recording of both stimuli presentation (6 blocks, composed of 64 trials each) and responses were managed by a custom software (Superlab version 4.0.2 for Windows). A schematic illustration of the task-switching paradigm is showed in Fig. 1.

In order to assess performance, in according to Couyoumdjian et al. (2010), the following four parameters were analysed: switch trials [median reaction times (RTs) in trials where a shift from one task to another was asked, B-A or A-B]; repetition trials [median RTs in trials where the same task was repeated, A-A or B-B]; switch cost ["cost" of the athlete to move from one task to another calculated by the "switch-repetition" subtraction]; errors [calculated as proportion of wrong and missing responses].

2.4. Data analysis

Statistical analyses have been performed on the following dependent variables: median RTs (in ms) of both repetition and switch trials, switch cost, and angular transformations of the proportion of errors. As briefly summarized before, switch cost was computed as the difference between RTs on switch trials and RTs on repetition trials. For each participant, the proportions of errors were computed including both wrong and missing responses. Before the statistical analysis, this variable was submitted to an angular transformation, $y = \text{arcsen}[\text{sqr}(p)]$, where sqr(p) is the square root of the proportion.

The group of participants (divided into Strikers, Defenders, and Mixed) and the type of Trial (namely Switches and Repetitions)

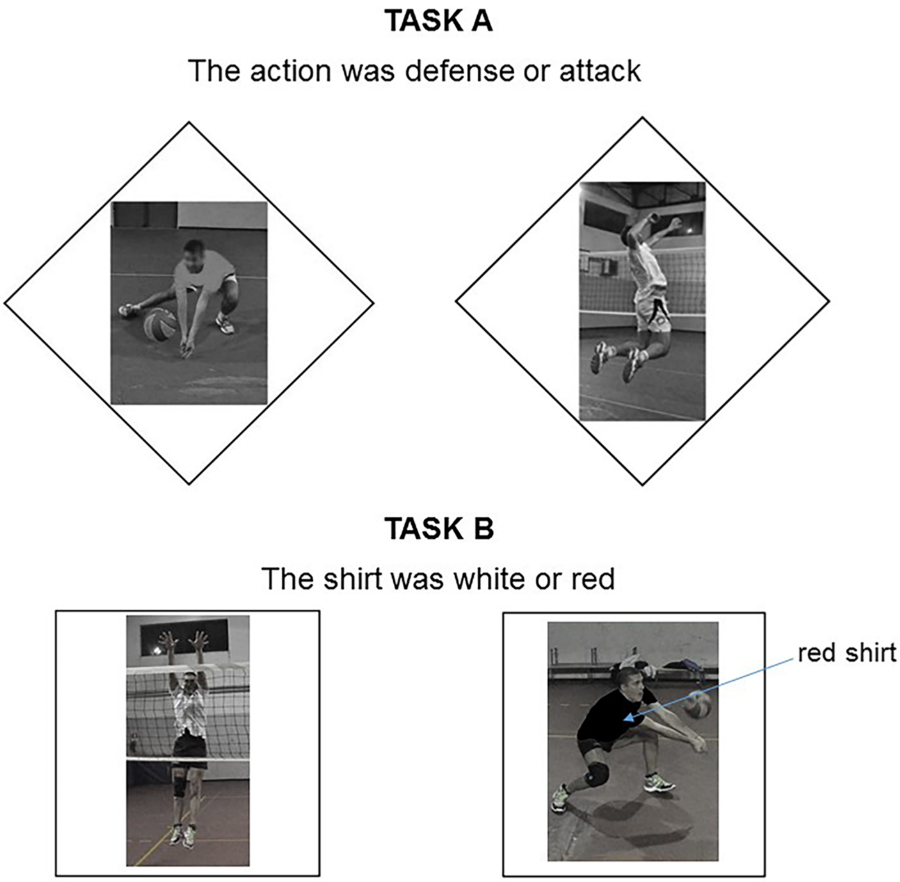

Fig. 1. Schematic representation of the task-switching paradigm. In task A, the athlete has to judge whether the action was an attack or a defence, while in task B whether the shirt colour of the portrayed subject was red or white. Written informed consent was obtained from the athletes for the publication of this image.

have been both included in the analyses as independent variables. The RTs have been analysed by a mixed analyses of variance (ANOVA), considering Group (Strikers; Defenders; Mixed) × Trial (Switch; Repetition). Conversely, switch cost and proportions of errors have been analysed by one-way analyses of variance (ANOVA) directly comparing the performances of different Groups (Strikers; Defenders; Mixed). For all the analyses, in case of statistically significant effects, *post-hoc* analyses corrected for multiple comparisons (Bonferroni test) have been carried out. Statistical analyses have been carried out with Statistica 8.0 (Statsoft Inc.).

For each dependent variable the assumptions of normality and homoscedasticity have been verified using the Shapiro-Wilk and Levene's tests, respectively. In the following, results will be reported separately for measures of speed (reaction times and switch costs) and accuracy (errors).

3. Results

3.1. Reaction times (RTs)

ANOVA revealed a significant Group effect ($F_{(2,33)} = 3.42$; $p = .05$; $\eta p^2 = 0.17$) indicating that Strikers were faster with respect to both Defenders ($p = .029$) and Mixed ($p = .015$). Also, a significant effect for Trial emerged ($F_{(1,33)} = 24.98$; $p = .00001$) showing that Repetition were quicker than Switch ($p = .0006$). Finally, the interaction Group × Trial was statistically significant ($F_{(2,33)} = 4.78$; $p = .02$; $\eta p^2 = 0.22$; see Fig. 2A). *Post-hoc* comparisons on interaction revealed that Defender and Mixed players obtained higher RTs in Switch than in Repetition trials (Defender: Switch *vs.* Repetition: $p = .0018$; Mixed: Switch *vs.* Repetition: $p = .0009$). Moreover, in switch trials, the mixed group obtained significantly higher RTs than the other players (Mixed *vs.* Defender: $p = 0.05$; Mixed *vs.* Strikers: $p = 0.001$), followed by Defenders (Defenders *vs.* Strikers: $p = .006$), while Strikers obtained the lowest RTs.

In order to understand if the RTs were influenced by the type of action observed, a control analysis was run: in the switch condition, median RTs were analysed comparing attack and defense actions with a mixed two-way ANOVA Group (Striker; Defender; Mixed) × Type of action (Attack; Defense). The Type of action resulted to be statistically significant ($F_{(1,33)} = 6.42$; $p = .01$;

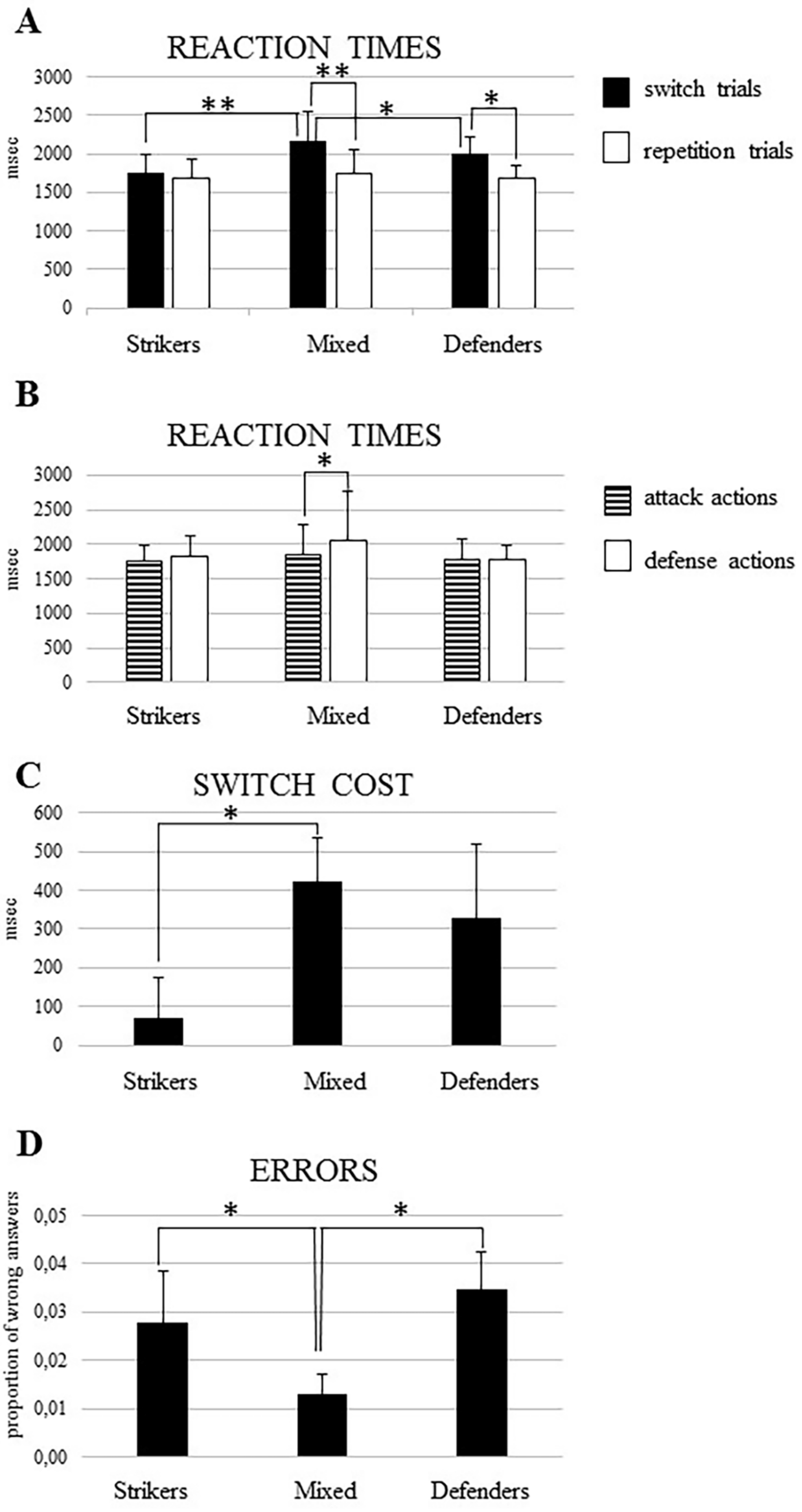

Fig. 2. Reaction times, switch costs and error proportion in striker, mixed and defender athletes. Data are expressed as median ± SD (A, B, C) and proportion of wrong answers ± SD (D). The asterisks indicate the significance level of *post-hoc* comparisons among groups (*$p < .05$; **$p < .01$; ***$p < .001$).

$\eta p^2 = 0.19$) showing that Attack actions showed slower RTs (1795 ± 324 ms) than Defense ones (1875 ± 411 ms). Also, the interaction Group × Type of action was significant ($F_{(2,33)} = 3.25$; $p = .04$; $\eta p^2 = 0.16$), and this effect depended mainly on the differences within the mixed group, where athletes took longer to process defensive actions as compared to attacking ones (*post-hoc* comparison: $p = .006$, as shown in Fig. 2B). No other effect resulted to be statistically significant.

3.2. Switch cost

A similar trend to the one observed with RTs was seen with the switch cost. Here, one-way ANOVA revealed a significant effect ($F_{(2,33)} = 4.20$; $p = .02$; $\eta p^2 = 0.20$) evidencing that mixed group' players showed higher switch cost with respect to other groups (Fig. 2C). *Post-hoc* comparisons revealed a significant difference only between mixed and striker groups ($p = .015$).

3.3. Errors

With respect to accuracy, the ANOVA revealed a significant effect ($F_{(2,33)} = 3.34$; $p = .05$; $\eta p^2 = 0.17$) (Fig. 2D). *Post-hoc* comparisons on groups revealed that players of the mixed group were more accurate in performing the task with respect to the other two groups (Mixed *vs.* Striker: $p = .048$; Mixed *vs.* Defender: $p = .047$; Striker *vs.* Defender: $p = .89$).

4. Discussion

In the present study, we analysed the cognitive flexibility in elite volleyball athletes by means of a customized, sport-specific switching task, in which the players were requested to evaluate pictures of attack and defensive actions taken during real situations. The main result is that each role has definite characteristics related to specific cognitive abilities and that the performance is much influenced by the degree of expertise.

Analysing the switching ability of players belonging to each category (Strikers, Defenders and Mixed), we observed that each role has highly different performances, suggesting a different cognitive processing modality.

Looking at the RTs, Strikers were the fastest to answer to stimuli, independently of the kind of trial and type of action, while mixed and defenders groups showed a marked difference between the switch and repetition trials, being more vulnerable (i.e. showing a poorer performance) when the task to be completed changed in consecutive trials (Fig. 2A). The control analysis concerning the type of action confirmed that the mixed group provided a poorer performance when defensive action had to be processed (Fig. 2B). A similar picture was seen with the switch cost data: the Mixed group has the highest switch cost as compared to the other two groups, even if only the difference with the strikers reaches statistical significance (Fig. 2C). Such reduced speed of processing in Mixed athletes was counterbalanced by an optimal accuracy: they appeared more accurate than the other groups (as depicted Fig. 2D).

These data could be interpreted on the basis of the different cognitive load that attack and defensive actions require. In fact, the attack actions are very fast because mainly based on S-R processes in which the “Stimulus” is the arriving ball and the “Response” is the very rapid modality of the reaction depending on very few variables (interferences) such as changes of opponents’ defensive wall position. Furthermore, attack actions must be very fast in order to avoid a defensive response. Technique is the main competence needed by strikers and the more the training, the greater the speed of the movement’s sequence. Furthermore, this kind of assail action is facilitated because it is mainly individual and does not need particular planning and/or synchronization with teammates. This data is in accordance to Elferink-Gemser and collaborators that showed that cognitive flexibility does not play a central role for expert table tennis players. Such players, similarly to our Strikers, play in fairly ‘fixed’ patterns of how to return the ball (Elferink-Gemser et al., 2018).

Differently, the motor cognitive processes involved in defensive actions request the player to organize (or participate to) the tactic, in order to successfully counteract the opponents’ attack. In this case, the motor cognitive processing required is more complex, because the defender has to take into account also other information, such as the teammates’ wall position in the field or possible vulnerabilities in the rival team arrangement. Moreover, the defender, in order to anticipate and predict the action of the other, must process body kinematics information of adversary players (Aglioti et al., 2008; Tomeo et al., 2012; Urgesi & Makris, 2016) and, at the same time, mentally represent the sequence of finalized movements of the opponents in order to understand their scope (Rizzolatti & Sinigaglia, 2010). Hence, the action of the Defender is mainly incorporated in the system/team game. This concept is much easier to understand if we look at strategic sports, such as volleyball, that involves a simultaneous processing of a substantial amount of information regarding teammates, opponents, field positions and ball features, and that often requires to cope with highly variable situations (Singer, 2000; Voss, Kramer, Basak, Prakash, & Roberts, 2010). For these reasons, defensive actions require more time to be processed and the competences needed are both technical (individual competences) and defensive tactical (team competences).

The role of the Mixed players is even more complex, since they have to be experienced not only in technique and defensive tactic but also in technical and offensive tactic (Table 1). Thus, their motor cognitive processes are strongly dependent upon the efficiency of cognitive flexibility, because they need expertise to switch the behaviour (technique and defensive and offensive tactic) in relation to environmental changes, Mixed players have also the need to adjust their current role to a very variable environmental situation. As previously underlined, task-switching requires the ability to change the cognitive abilities in relation to changing context and as the more precisely this change is done, the more time it takes. In fact, the mixed group obtained significantly higher RTs than the other groups, but with much more accuracy in the responses (Fig. 2D). This data is in accordance with other sport psychology studies based on the analysis of EF that showed how the experience acts on pre-attentive mechanisms, facilitating the offensive tactic (Ottoboni, Russo, & Tessari, 2015).

Our data interpretation is in line with the Norman and Shallice model of Attentive Supervisor System (Norman & Shallice, 1986) (SAS) that hypothesize that the behaviour is regulated according to a “competitive selection” process between different “schemas” or action plans that belong to the individual. According to this model, each schema has at any time some degree of activation, depending on the amount and intensity of activating signals received. This competitive selection process would be done automatically. We are not aware of this competitive selection process because the right schema at a given moment is the one that has reached the highest level of attention and automatically wins over the others. However, such selection requires time to work efficiently. Probably for this reason, the Mixed player processes the information relying on competitive selection, hence in a time-consuming manner, while Strikers and Defenders (with lower reaction times) play out their attack or defense basic schemas at the expense of accuracy, suggesting a “mental inflexibility”. Interestingly, if we give a look into what actions takes longer to the Mixed athletes, we realize that they process the judgments related to defensive action much more slowly as compared to the ones related to attack (Fig. 2B). This is probably explained by the fact that action plans for defence, as previously explained, are multiple and more complex.

In according to this interpretation, it has been suggested that there are costs and benefits to expertise, so that the inflexibility of experts might make them unable to adapt to new task demands, at least in some occasions (Bilalić, McLeod, & Gobet, 2008).

Based on these considerations, we put forward the possibility to identify an “executive profile” of each of the three categories analysed, based on the degree of cognitive flexibility required by each. As a consequence, we can imagine a continuum line where Strikers are at one extreme, characterized by a minimum degree of cognitive flexibility, and Mixed are the other extreme, characterized by a maximal degree of cognitive flexibility; Defenders would be placed in the middle of this hypothetical continuum. Furthermore, it is plausible to retain that the cognitive rigidity of Strikers is intrinsically linked to competences of the specific role and, as noted above, they have very similar game characteristics to tennis players, who exhibit a low degree of cognitive flexibility (Elferink-Gemser et al., 2018). This hypothesis could allow to design a specific psychological test in the future, with which the degree of cognitive flexibility of athletes will be evaluated, in order to assign/confirm to every athlete the best suited role to his/her individual skills. In this line, it has been demonstrated that neuropsychological assessment on executive abilities can predict the successes of top soccer players (Vestberg et al., 2012). Therefore, identifying the “executive profile” of each of these three categories could allow the creation of a tool that can predict success in volleyball and tailor the training of cognitive abilities according to the athletes' needs.

The present study has some limitations. Firstly, the sample size needs to be increased: this could offer the opportunity to highlight differences between different players with a stronger statistical power. This way, even other aspects could be taken into account, such as individual differences that might modulate the observed effects. Moreover, it could also be interesting to compare the degree of cognitive flexibility observed in volleyball elite athletes with others open skill sports, to assess if different sports could be characterized by (or could require) different levels of executive abilities. Indeed, other studies from open skill sport indicated that elite athletes compared with novice players present higher executive performances with respect to spatial attention, divided attention, working memory and mentalizing capacity (Huijgen et al., 2015; Mann, Williams, Ward, & Janelle, 2007; Vestberg et al., 2017), thus suggesting the relevance of cognitive evaluation in sport (Starkes & Deakin, 1984). Therefore, the fact that “top-players” actually have superior executive abilities could change the way of looking for young talents and future champions considering, however, that experience has a significant weight in paving the way for success. In this context, identifying a specific executive profile for each open skill sport, and planning a program of development of executive abilities, would mean to further investigate the importance of “higher-level” cognitive functions for talent identification and development in a new concept of sport and cognition. In this line, it will be interesting to evaluate in the task switching protocol the performances of novice volleyball athletes, non – athletes or younger athletes, in order to evaluate whether switching ability is acquired by experience or is innate. This research line will be important for the discovery of talents in sport.

5. Conclusion

In conclusion, it is important to underline that by means of the present modified and customized task- switching protocol, it is possible to outline an executive style of volleyball elite athletes, characterized by a minimal degree of cognitive flexibility for highly specialized athletes and a maximum level for spiker outside hitters. Such specific profile will allow the development of a tool to identify cognitive abilities during the recruitment in a team and to evaluate the aptitude in order to choose the most suitable role. Finally, through an initial assessment, trainers will direct their training program and evaluate improvements in their athletes.

Authors’ contributions

All authors designed the research. SM and GDA performed the research. FF, GC, and LM analyzed the data. FF, GS, LM, GC and PS wrote the paper. All authors read, revised, and approved the final manuscript.

Ethical standards

For the present research, all participants gave informed written consent. All procedures performed in present study were in accordance with the 1964 Helsinki declaration and all the experimental protocol has been approved by the Internal Review Board of the University of L’Aquila.

Conflict of interest statement

No conflicts declared.

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References

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience, 11*, 1109–1116.

Albinet, C. T., Abou-Dest, A., André, N., & Audiffren, M. (2016). Executive functions improvement following a 5-month aquaerobics program in older adults: Role of cardiac vagal control in inhibition performance. *Biological Psychology, 115*, 69–77. https://doi.org/10.1016/j.biopsycho.2016.01.010.

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: A meta-analytic review. *Neuropsychology Review, 16*, 17–42. https://doi.org/10.1007/s11065-006-9002-x.

Bilalić, M., McLeod, P., & Gobet, F. (2008). Inflexibility of experts – Reality or myth? Quantifying the Einstellung effect in chess masters. *Cognitive Psychology, 56*, 73–102. https://doi.org/10.1016/j.cogpsych.2007.02.001.

Cortis, C., Tessitore, A., Lupo, C., Pesce, C., Fossile, E., Figura, F., et al. (2011). Inter-limb coordination, strength, jump, and sprint performances following a youth men's basketball game. *The Journal of Strength & Conditioning Research, 25*, 135–142. https://doi.org/10.1519/JSC.0b013e3181bde2ec.

Couyoumdjian, A., Sdoia, S., Tempesta, D., Curcio, G., Rastellini, E., De Gennaro, L., et al. (2010). The effects of sleep and sleep deprivation on task-switching performance. *Journal of Sleep Research, 19*, 64–70. https://doi.org/10.1111/j.1365-2869.2009.00774.x.

Dunsky, A., Abu-Rukun, M., Tsuk, S., Dwolatzky, T., Carasso, R., & Netz, Y. (2017). The effects of a resistance vs. an aerobic single session on attention and executive functioning in adults. *PLoS One, 12*, e0176092. https://doi.org/10.1371/journal.pone.0176092.

Elferink-Gemser, M. T., Faber, I. R., Visscher, C., Hung, T. M., de Vries, S. J., & Nijhuis-Van der Sanden, M. W. G. (2018). Higher-level cognitive functions in Dutch elite and sub-elite table tennis players. *PLoS One, 13*(11), e0206151. https://doi.org/10.1371/journal.pone.0206151.

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports, 3*, 1154. https://doi.org/10.1038/srep01154.

Foti, F., Sdoia, S., Menghini, D., Vicari, S., Petrosini, L., & Ferlazzo, F. (2015). Out with the old and in with the new – Is backward inhibition a domain-specific process? *PLoS One, 10*, e0142613. https://doi.org/10.1371/journal.pone.0142613.

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science, 17*, 172–179. https://doi.org/10.1111/j.1467-9280.2006.01681.x.

Huijgen, B. C. H., Leemhuis, S., Kok, N. M., Verburgh, L., Oosterlaan, J., Elferink-Gemser, M. T., et al. (2015). Cognitive functions in elite and sub-elite youth soccer players aged 13 to 17 years. *PLoS One, 10*, e0144580. https://doi.org/10.1371/journal.pone.0144580.

Kelley, W. M., Wagner, D. D., & Heatherton, T. F. (2015). In search of a human self-regulation system. *Annual Review of Neuroscience, 38*, 389–411. https://doi.org/10.1146/annurev-neuro-071013-014243.

Koch, I., Poljac, E., Müller, H., & Kiesel, A. (2018). Cognitive structure, flexibility, and plasticity in human multitasking – An integrative review of dual-task and task-switching research. *Psychological Bulletin, 144*(6), 557–583. https://doi.org/10.1037/bul0000144.

Logan, G. D. (2003). Executive control of thought and action. In search of the wild homunculus. *Current Directions in Psychological Science, 12*, 45–48. https://doi.org/10.1111/1467-8721.01223.

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology, 29*(4), 457–478. https://doi.org/10.1123/jsep.29.4.457.

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 22*, 1423–1442. https://doi.org/10.1037/0278-7393.22.6.1423.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*, 8–14. https://doi.org/10.1177/0963721411429458.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100. https://doi.org/10.1006/cogp.1999.0734.

Nideffer, R. M. (1976). Test of attentional and interpersonal style. *Journal of Personality and Social Psychology, 34*, 394–404. https://doi.org/10.1037/0022-3514.34.3.394.

Norman, D., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwarts, & D. Shapiro (Eds.). *Consciousness and self-regulation: Advances in research and theory* (pp. 1–18). New York: Plenum. https://doi.org/10.1007/978-1-4757-0629-1_1.

Nuri, L., Shadmehr, A., Ghotbi, N., & Moghadam, B. A. (2013). Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport. *European Journal of Sport Science, 13*, 431–436. https://doi.org/10.1080/17461391.2012.738712.

Ottoboni, G., Russo, G., & Tessari, A. (2015). What boxing-related stimuli reveal about response behaviour. *Journal of Sports Sciences, 33*(10), 1019–1027. https://doi.org/10.1080/02640414.2014.977939.

Ripoll, H. (1988). Analysis of visual scanning patterns of volleyball players in a problem solving task. *International Journal of Sport and Exercise Psychology, 19*, 9–25.

Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror circuit: Interpretations and misinterpretations. *Nature Reviews Neuroscience, 11*(4), 264–274. https://doi.org/10.1038/nrn2805.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*, 207–231. https://doi.org/10.1037/0894-4105.20.6.675.

Rubinstein, J. S., Meyer, D. E., & Evans, J. E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology: General, 27*, 763–797. https://doi.org/10.1037//0096-1523.27.4.763.

Shim, J., Carlton, L. G., Chow, J. W., & Chae, W. S. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behavior, 37*, 164–175. https://doi.org/10.3200/JMBR.37.2.164-175.

Singer, R. N. (2000). Performance and human factors: Considerations about cognition and attention for self-paced and externally-paced events. *Ergonomics, 43*, 1661–1680. https://doi.org/10.1080/001401300750004078.

Starkes, J. L., & Allard, F. (1983). Perception in volleyball: The effects of competitive stress. *Journal of Sport Psychology, 5*, 189–196. https://doi.org/10.1123/jsp.5.2.189.

Starkes, J. L., & Deakin, J. (1984). Perception in sport: a cognitive approach to skilled performance. In W. F. Straub, & J. M. Williams (Eds.). *Cognitive sports psychology* (pp. 115–128). Lansing, NY: Sport Science Associates.

Stratton, G., Reilly, T., Williams, A. M., & Richardson, D. (2004). *Youth soccer: From science to performance*London: Routledge. https://doi.org/10.4324/9780203644133.

Tomeo, E., Cesari, P., Aglioti, S. M., & Urgesi, C. (2012). Fooling the kickers but not the goalkeepers: Behavioural and neurophysiological correlates of fake action detection in soccer. *Cerebral Cortex, 23*(11), 2765–2778. https://doi.org/10.1093/cercor/bhs279.

Urgesi, C., & Makris, S. (2016). Sport performance: Mental imagery and observational learning in sport. In S. Obhiand, & E. Cross (Eds.). *Shared representations:*

Sensorimotor foundations of social life. Cambridge social neuroscience (pp. 565–587). Cambridge University Press.
Verburgh, L., Scherder, E. J., van Lange, P. A., & Oosterlaan, J. (2014). Executive functioning in highly talented soccer players. *PLoS One, 9*(3), e91254. https://doi.org/10.1371/journal.pone.0091254.
Vestberg, T., Gustafson, R., Maurex, L., Ingvar, M., & Petrovic, P. (2012). Executive functions predict the success of top soccer players. *PLoS One, 7*, 1–5. https://doi.org/10.1371/journal.pone.0034731.
Vestberg, T., Reinebo, G., Maurex, L., Ingvar, M., & Petrovic, P. (2017). Core executive functions are associated with success in young elite soccer players. *PLoS One, 12*, e0170845. https://doi.org/10.1371/journal.pone.0170845.
Voss, M. W., Kramer, A. F., Basak, C., Prakash, R. S., & Roberts, B. (2010). Are expert athletes "expert" in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Applied Cognitive Psychology, 24*, 812–826. https://doi.org/10.1002/acp.1588.
Weinberg, R. S., & Gould, D. (2015). *Foundations of sport and exercise psychology* (6th ed.). Champaign, IL: Human Kinetics.
Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science, 24*, 283–307. https://doi.org/10.1016/j.humov.2005.06.002.
Yin, S., Wang, T., Pan, W., Liu, Y., & Chen, A. (2015). Task-switching cost and intrinsic functional connectivity in the human brain: Toward understanding individual differences in cognitive flexibility. *PLoS One, 10*(12), e0145826. https://doi.org/10.1371/journal.pone.0145826.