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PLAY THE BALL WITH YOUR COGNITIVE RESOURCES, STICK THE LANDING WITHOUT ANXIETY.
A Study On Cognition And Emotions In Youth Volleyball Players And Artistic Gymnasts.

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To all the researchers out there.

Just a reminder that it's hardly easy,
but it's always worth it.

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Some experiences in life are filled with nothing but joy and excitement, some others are very sad, but none is like writing a PhD thesis. It is a mental challenge and an emotional rollercoaster, it makes you feel both proud and desperate at the same time. At least, that's how I felt. I truly believe you can't "survive" this experience without the support of very special human beings, which I am lucky and proud to have by my side (and this manuscript is very concrete proof of it!). I, therefore, wish to express my deepest gratitude to all of you for your caring acts and thoughts during this extraordinary experience, they meant so much to me I can hardly express it. But I'll try.

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Here we are to my lifetime friends: where would I be without you? Without Ilaria and Giulia, we may not always be together, but you never made me feel lonely. Without Chiara, who grabbed my hand the very first day of University and is still not letting it go. Without Giada, who reminds me that certain bonds are eternal. Without Anna, Laura and Sam, being by my side during good and bad days (and also very good and very bad ones!). Without Sara and Lucrezia, always ready to provide me with girls chats and a glass of wine. Without Federico: no matter what, you have been there for me. Without Matteo and Marco: your clever and challenging minds and your emotional support meant more than ever during this stressful time. I deeply admire and look up to you both. And without each and any of you, my friends. Again: where would I be without you all?

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Last, but definitely not least, thank you to my parents, Margherita and Paolo. I may not be able to fully repay all the sacrifices you made for me in a lifetime, but this I want you to know: giving me the chance to get here, you made me very, truly, completely happy. You never asked me anything but to follow my dreams and I hope that I made you proud just 10% of what I am of being your daughter. I love you.

PLAY THE BALL WITH YOUR COGNITIVE RESOURCES, STICK THE LANDING WITHOUT ANXIETY.

A STUDY ON COGNITION AND EMOTIONS IN YOUTH VOLLEYBALL PLAYERS AND ARTISTIC GYMNASTS.

ABSTRACT

This study aims to address two shortcomings in sport psychology research: the scarcity of cognitive and developmental psychology studies in sports (Furley & Wood, 2016), and the lack of an integrated approach, i.e. comprising both cognition and emotion, to study sports performance. The aim of this research is to examine the role of general cognitive abilities, attentional style and emotions in predicting performance in different sports, namely volleyball and artistic gymnastics.

We tested 218 youth participants (104 artistic gymnasts and 114 volleyball players, aged between 11 and 17 years) with different measures of working memory capacity and executive functions (i.e. updating, shifting and inhibition). They completed two self-report measures, a Test of Attentional and Interpersonal Style and a questionnaire on the emotions experienced before a competition. For each participant, we collected the age and years of experience. The scores collected in 2017 competitions were the artistic gymnasts' performance measures. For each volleyball player, we computed an individual performance index, by asking two independent judges to rate their video-recorded performances in 2017-18 competitions. Then we derived, from our measures, ten predictors, namely a working memory-updating factor, an inhibition-shifting factor, four attentional style indicators and four groups of emotional states derived from the crossing of two dimensions, specifically the arousal (high activation or low activation) and the hedonic tone (pleasant or unpleasant). The regression analyses pointed to a clear dissociation. On the one hand, the working memory-updating factor was the only predictor (together with the experience) of the volleyball players' performance, with a moderation effect of emotional arousal on this relationship. On the other hand, experience and high-arousal unpleasant emotions (the latter with a negative coefficient) were the only predictors of artistic gymnasts' performance. This evidence underlines how performance in open-skills sports (volleyball), where athletes need to process a significant amount of information, mainly depends on working memory, while in closed-skills sports (artistic gymnastics), where gestures are highly automatized, it is affected by emotion regulation. Further differences between the sports sample are also described in the dissertation.

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PREFACE

When I was fourteen years old (quite late in development, I have to admit), I finally made my father happy by committing to a sport – volleyball, to be specific. I had always been the kind of girl who just wanted to read books and learn new things, I had never been interested in anything motor-related. This volleyball experience blew me away in many ways. First, I really enjoyed it. Second, I quickly discovered that it was much more than just repeating movements or gaining control over my body (even if this part was not so easy as well!), it was also dealing with a huge amount of information on how "to do" things. As a psychologist, I know now that all the information will at some point become procedural knowledge (Anderson, 1982; Tenenbaum & Eklund, 2007), but the process in between is a very interesting one.

When I was sixteen years old, I realized I actually loved volleyball and I started coaching. It gave me a different perspective: making other people (children) learn is actually even more difficult than learning yourself. And I was able to understand that, just like in my case, learning a new volleyball gesture was only partially a motor control problem. Indeed, very young children or volleyball *newbies* often seemed able to manage a task only partly, in the sense they could, for example, either throw the ball to the right distance or over the net, but not doing both things at the same time. This specific behaviour suggested that the key factor to understand the athlete's difficulty could be the amount of information the task required to handle.

What cognitive ability supports us in motor learning? That's the research I undertook during my Master's degree, finding that we heavily rely on general cognitive abilities, namely working memory, when we learn how to perform a certain motor gesture (Bisagno & Morra, 2018).

Then, the following question was: motor learning requires general cognition, but is this true for motor performance as well? Or is it all about automatic processes lead by expertise? In other words: in sports, do we rely on our cognitive abilities only while we are learning something new, or also when we provide skilled performance?

I tried to think of myself during a game and to the amount of information that, even when well technically and tactically prepared, I had to handle: the direction of the ball, the position of my teammates, the position of the opponents and so on. Sometimes, I had to rapidly change strategy in order to adapt to the opponent's game, some others I needed to inhibit an automatic response, not to perform an unfitting gesture. Given these considerations, it seemed to me that, even when "how to" perform a technical gesture is well automatized, still, the game itself posit a high cognitive load on the athlete.

Another aspect on which anyone who has practised competitive sport in his life has certainly questioned at least once is the relationship between performance and emotions. All athletes can describe a time in which they *chocked under pressure* (Hill, Hanton, Matthews, & Fleming, 2010) or they felt completely absorbed by their *peak performance* (Csikszentmihalyi, 2000) and they can all testify the importance of the emotional control during performance. However, a much less deepened question and under-researched topic is the relation between cognition and emotion in producing a performance outcome.

For this reason, investigating the role of general cognition and emotional control in motor performance in volleyball appeared to me both fascinating and worthy.

In order start formulating an appropriate research question, I started reading books on motor control (Nicoletti & Borghi, 2007), and, since the very beginning, another question arose: how about differences between sports? If volleyball, like many other sports, is played on a very unpredictable field (literally!), that can place a considerable cognitive load on the athlete. However, is it equally true for all disciplines? Indeed, in certain sports, like figure skating or artistic gymnastics, the athlete is not required to react to the unpredictable, but to perform, as closest to perfection as possible, a well-trained routine. This very simple consideration made me think that, in the same way in which they require different motor skills, sports possibly require diverse mental abilities as well. And knowing that is one step closer to know how to work and improve those mental abilities. Therefore, I decided to study cognition and emotional control not only in volleyball players but also in artistic gymnasts.

This is how my PhD topic was defined, and also how the little girl who loved to learn and the adolescent who discovered the beauty of sports met.

How is the mind of a champion made? How do cognition and emotions interact in affecting the athlete's performance? Do athletes practising different sports need to train different mental abilities?

These questions are, at present, of great applicative interest, but relatively little explored by scientific research in cognitive psychology and sport psychology. However, research in cognitive psychology has the potential to give an enormous contribution to performance studies, by identifying the most appropriate abilities to train in order to achieve optimal performance. This research aims to offer a contribution in this sense, by providing some aspects of novelty, as described below.

1. **OVERTURNING THE PERSPECTIVE IN THE RELATION BETWEEN COGNITION AND PERFORMANCE**. Cognitive research in sports studies is quite fragmentary. Most of the studies that link sports and cognitive processes, analyse the benefits of the relationship in the opposite direction (see Donnelly et al., 2017 and Verburgh, Königs, Scherder, & Oosterlaan, 2014 for reviews with children samples). For example, Moreau, Morrison, & Conway (2015) compared sports program with a computerized cognitive training, finding that the former were more beneficial not only from a physical point of view but also from a cognitive and executive point of view. Similar results are described by Diamond & Lee (2011) in a review that compares different types of interventions, including sports and exercise, on 4 to 12 years old children's cognitive abilities.

   Other studies highlight the benefits, in the short and medium term, of intense physical exercise on executive functioning (Chang, Tsai, Chen, & Hung, 2013; Tomporowski et al., 2005), on short-term memory (Roig, Nordbrandt, Geertsen, & Nielsen, 2013), long-term memory (Chang, Labban, Gapin, & Etnier, 2012; Pesce, Crova, Cereatti, Casella, & Bellucci, 2009) and on working memory (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009; Quelhas Martins, Kavussanu, Willoughby, & Ring, 2013; Sibley & Beilock, 2007) - in both adult (Tomporowski, 2003) and children populations (Ellemberg & St-Louis-Deschênes, 2010; Etnier, Labban, Piepmeier, Davis, & Henning, 2014). Taken together, these studies are aligned in emphasizing the beneficial role of exercise and sports on cognitive processes, especially during development.

Another branch of research that links cognition with sports is the so-called expertise studies. These researches compare adult athletes of different levels (i.e., elite athletes, amateurs, novices and non-athletes, see Piras, Lobietti, & Squatrito, 2014 for an example in volleyball) or athletes practicing different sports with respect to general cognitive functioning (Heppe, Kohler, Fleddermann, & Zentgraf, 2016; Jacobson & Matthaeus, 2014).

The *expert performance approach* studies the athlete under a sport-specific or ecologically valid context (Starkes & Ericsson, 2003). In these studies, the tasks that participants are asked to perform are specifically designed to match the athletes' field of expertise. Therefore, is not surprising that, in general, the expert performance approach has found that experts perform better than not-experts on sport-specific tests of many perceptual and cognitive abilities, namely declarative and spatial memory, attention, anticipation and decision-making skills (see Mann, Williams, Ward, & Janelle, 2007 for a meta-analytic review). The same review also compared athletes practising different sports, finding that those practising interceptive sports (i.e., sports that require coordination between the athletes' body or a held implement and an object in the environment, like tennis) also have faster response times than athletes who practice self-paced sports such as golf and swimming.

Differently, the *cognitive component skills approach* (Voss, Kramer, Basak, Prakash, & Roberts, 2010) examines the relationship between sports expertise and performance on measures of general cognition that are presumably involved in a certain sport, but without using sport-specific cues or tasks. Even if the results of these studies are less in agreement than the previous ones (see Voss et al., 2010 for a review), overall athletes practising different sports tend to outperform controls also in laboratory-based measures of cognition (namely processing speed and a category of varied attentional paradigms). Moreover, again, athletes from interceptive sports types show the largest effects. Further deepening sports differences, Wang et al. (2013) compared response inhibition across tennis players, swimmers and sedentary controls by using a Stop-Signal task and found, once again, an advantage of tennis players in response time over swimmers and sedentary controls. Based on their results, the authors suggested that inhibitory control was more developed in athletes engaged in interceptive (or, in general, open-skills) sports.

2. **OFFERING AN INTEGRATED APPROACH**. Conversely, the inverse relationship (i.e., the role of cognition in motor learning and/or performance), is still under-researched. Indeed, according to Furley & Wood (2016), until fairly recently athletes were typically described only with respect to their physical characteristics, so researchers hardly deepened the cognitive factors involved in sport performance, possibly because "the physical aspect of sports has far more intuitive appeal than the cognitive aspect" (Furley & Wood, 2016, p. 3).

   The few existing studies tend to focus on the relationship between performance and a single cognitive (for example, Furley & Memmert, 2012 studied the role of working memory in decision making) or emotional predictor (Hanin, 2000; Mccarthy, 2011; Robazza et al., 2008). To the best of my knowledge, no studies ever proposed a structured model of performance in sports or tried to predict sport performance in different sports by using together different cognitive and emotional predictors. The purpose of this research is precisely to provide an integrated overview of the psychological variables that predict performance in diverse sports (Raab, Lobinger, Hoffmann, Pizzera, & Laborde, 2015).

3. **TAKING A LOOK AT THE BIGGER PICTURE**. Indeed, in sport sciences, a classic categorization distinguishes sports according to the grade to which the environment they are played in is predictable (Poulton, 1957). Therefore, open-skills sports are those that occur in highly unpredictable environments, like those involving a direct opponent. Team sports (e.g. volleyball, football, basketball…) or individual sports (e.g., fight or combat sports) are in this sense prototypical. In these sports, the movement cannot be completely programmed in advance and the athlete's ability to adapt to the environment plays a fundamental role. In contrast, closed-skills sports are performed within a stable environment, in which the number of uncontrollable variables is reduced. This happens in disciplines such as gymnastics, shooting, bowling.

   Since this distinction appears to be substantial in research in sport sciences, two sports have been taken into consideration, belonging to the two different categories, namely volleyball as an open-skills sport and artistic gymnastics as a closed-skills one, with the hypothesis that such different disciplines would require not only different motor skills, but also psychological ones.

4. **ADOPTING A DEVELOPMENTAL PERSPECTIVE**. Another characteristic of cognitive research with respect to sport performance is that it is mainly focused

on adult athletes. Developmental studies investigating general cognitive functioning in children and adolescents are indeed quite rare and they generally highlight the importance of understanding cognitive functioning in the developing phase, in order to identify actual predictors of sport performance. For instance, Ishihara, Sugasawa, Matsuda, & Mizuno (2018) tested 6 to 12-years-old tennis players, finding a correlation between their flexibility and tennis experience. Other studies with young soccer players showed that, even during childhood and adolescence, experts are better than non-experts in inhibitory control, the orientation of attention (Verburgh, Scherder, Van Lange, & Oosterlaan, 2014) and shifting (Huijgen et al., 2015). Vesterberg, Reinebo, Maurex, Ingvar, & Petrovic (2017) found that 12 to 19-years-old soccer players performed better than the norm at the Delis-Kaplan Design Fluency and an N-Back task. Moreover, their performance on these tasks predicted the number of goals the players scored during the season. This study goes in a similar direction, involving young participants of different ages in order to guarantee a wide variability in cognitive measures and to analyse their predictiveness with respect to sport-specific performance.

On this basis, we decided to conduct a cross-sectional study with a group of athletes comprising two sports, namely volleyball and artistic gymnastics. Each sport's subsample included athletes equally distributed into three age groups. These sports were selected in order to match the differentiation between open and closed-skills sports, with the general hypothesis that cognitive processes are more involved in the first ones. For example, during a volleyball game, the athlete needs to rapidly react to changes in the environment (e.g. the opponents' tactics, the team-mates play and possibly mistakes) that place a great load on cognitive functioning (Claver, Jiménez, García-González, Fernández-Echeverría, & Moreno, 2016). Indeed, in their study with young volleyball players, Claver et al. (2016) found that among a set of cognitive and emotional predictors, the game action efficacy and classification were predicted only by cognitive variables (procedural knowledge and decision-making). Conversely, in closed-skills sports like artistic gymnastics, the exercise the athlete performs during a competition is highly automated. We, therefore, formulated the hypothesis that general cognition is less involved in this type of performance, while emotions play a decisive role in predicting it (Robazza et al., 2008; Robazza, Bortoli, & Hanin, 2006). Indeed, Cottyn, De Clercq, Crombez, & Matthieu (2012) measured self-reported emotions and heart rate during a balance beam acrobatic exercise performed at three different beam heights. The results showed that height affected the balance beam performance when the most difficult condition was presented as the first attempt, thus generating a higher amount of unpleasant and dysfunctional emotions according to the athletes' self-reports.

In the following chapter, all the predictors we took into consideration in this study are described in detail with respect to the main theoretical framework in which they have been researched.

CHAPTER 1. COGNITION AND EMOTIONS IN SPORTS: INTRODUCING THE ANALYSED PREDICTORS.

1.1 WORKING MEMORY

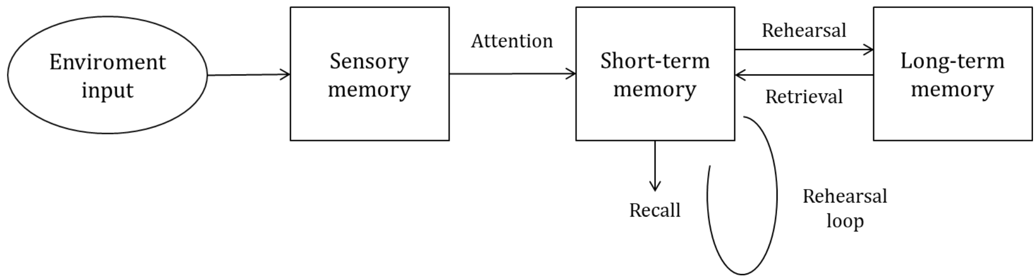
1.1.1 THEORIES AND DEFINITIONS

Working memory (WM) is often described as an "interface" between cognition and action (Baddeley, 2012) and it is associated with attention and executive functions (EFs). Like attention and EFs, indeed, working memory has a significant influence on cognitive efficiency, learning, and academic performance (Alloway et al., 2005; St Clair-Thompson & Gathercole, 2006).

The first definition of WM was given by Miller, Galanter, & Pribram (1960) who described it as the "memory we use for the execution of our plans as a kind of quick access", while Baddeley & Hitch (1974) defined it as the processes that maintain relevant information during the performance of a task (with a specific focus on storage capacity). Other definitions focus on both the concepts of storage capacity and information processing (Engle, Laughlin, Tuholski, & Conway, 1999), and on the storage capacity and retrieval of the information from long-term memory (Unsworth & Engle, 2007).

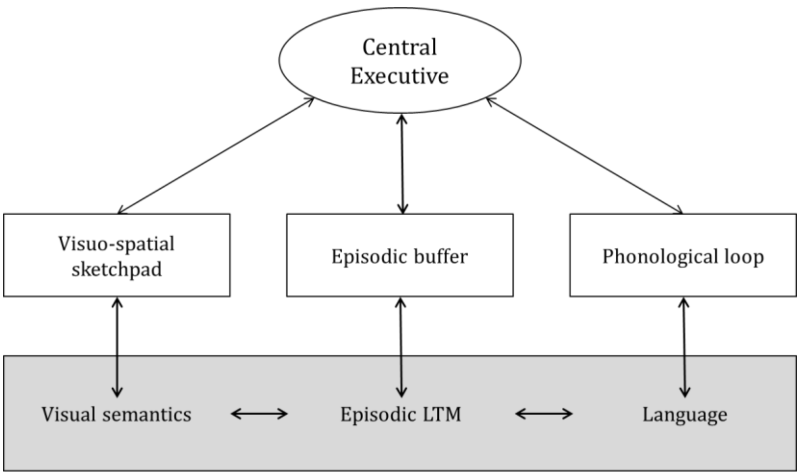
The "ancestor" of the concept of WM is the multistore model of memory (also known as the modal model) proposed by Atkinson and Shiffrin (1968). They proposed that memory is structured in three stores: the sensory registers, the short-term memory, and the long-term memory. In this model, information passes from one store to another in a serial way, like in a computer (input, process, and output). When information is detected by the sense organs, it enters the sensory memory, then, if the individual pays attention to it, the information is processed by the short-term memory. In the end, information is transferred to the long-term memory only if rehearsed (i.e., repeated), otherwise, it decays. Moreover, the recovery of information from the long-term memory to the short-term memory is also contemplated (see Figure 1). Even if not explicitly called working memory, the short-term store is defined as having sharply limited capacity and an attentional component is what allows the information to be processed.

FIGURE 1. THE MULTISTORE MODEL (ATKINSON & SHIFFRIN, 1968).



A model of working memory that for a long time enjoyed a broad consensus is the multicomponent model by Baddeley and Hitch (1974). The original model presents a tripartite structure: a central executive, a phonological loop, and a visuospatial sketchpad. The central executive is a multifunctional construct that employs and supervises a number of subsidiary slave systems, mediates the relation between short-term storage and retrieval from long-term memory, and controls cognitive processes (Baddeley, 2000; Baddeley, 1983; Baddeley & Hitch, 1974). The phonological loop and the visuospatial sketchpad are short-memory storage systems dedicated to a content domain (verbal or visuospatial, respectively). Later, Baddeley (2000) added to his model the episodic buffer, which holds representations that integrate different kinds of information (namely phonological, semantic, visual, and spatial). A schematic representation of Baddeley's (2000) model is shown in Figure 2. In this conceptualization, WM is described as a system of storage mechanisms, allowing to maintain and "work on" the representation of a terminated stimulus or to retrieve it from the long-term memory.

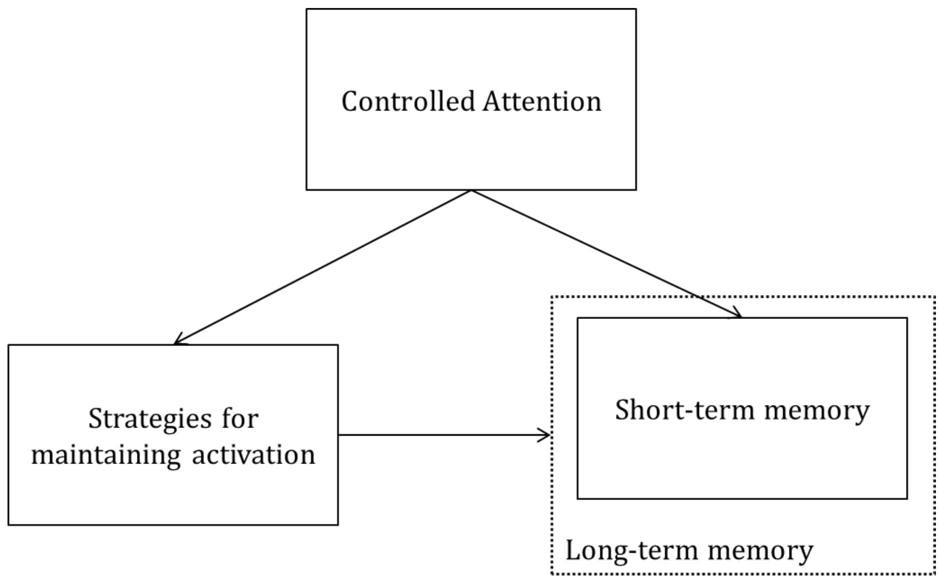
FIGURE 2. BADDELEY'S WORKING MEMORY MODEL (BADDELEY, 2000).



Differently from Baddeley, most current theories describe working memory not as a "storage mechanism" but with a "focus of attention" metaphor, therefore posing a central role of attentional resources in determining the capacity and functioning (Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; Barrouillet & Camos, 2012; Cowan et al., 2005; Engle, 2002).

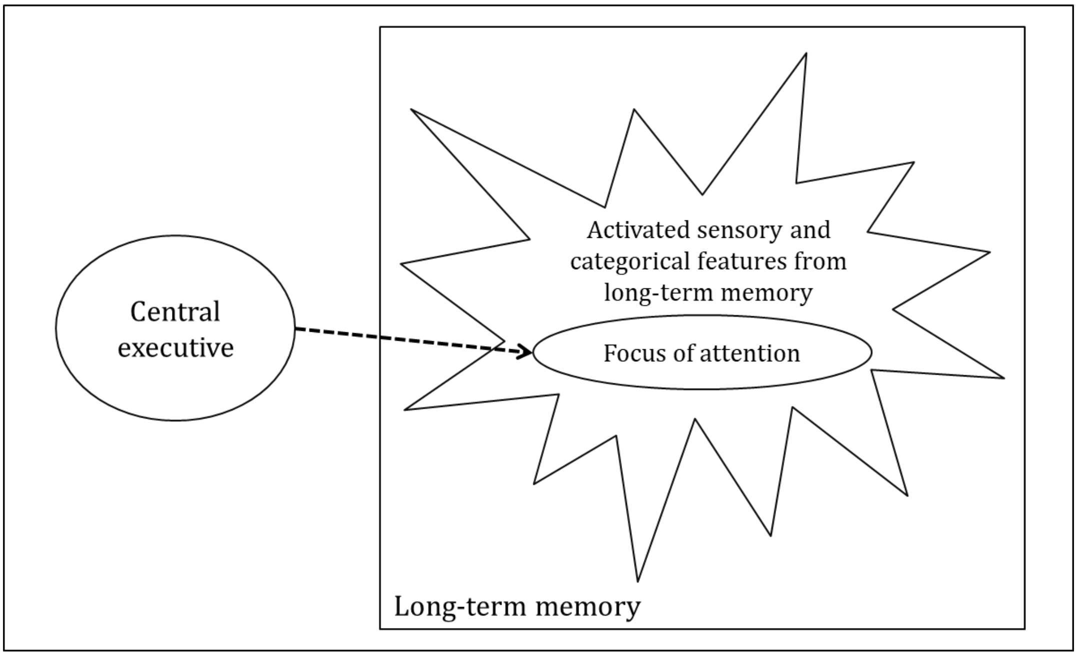
One influential theoretical account in this sense is the one proposed by Engle and colleagues (1999; 2002). Similarly to Baddeley and Hitch (1974), Engle's model refers to controlled attention. However, in Engle's model, the attentive component aims to inhibit irrelevant information and activate the relevant one, so (unlike the Baddeley's central executive) it plays a decisive role in maintaining information. Moreover, Engle never postulated specific storage mechanisms for verbal or visuospatial material but suggested that domain-specific processes are, instead, procedures or strategies. Short-term memory consists of traces that have exceeded an activation threshold and represent pointers to specific regions of long-term memory. Controlled attention, as a domain-general resource, intervenes on these traces by activating them through controlled retrieval, maintaining activation, and inhibiting possible distractors (see Figure 3).

FIGURE 3. ENGLE AND COLLEAGUES' MODEL OF WM (ENGLE ET AL., 1999).



Another attentional-based account of working memory function has been advanced by Cowan's (1999; Cowan et al., 2005) embedded process model (see Figure 4). According to this model, while a large part of long-term memory generally has a relatively low activation, a subset can be activated as a consequence of ongoing cognitive activities and perceptual experience. A smaller subset of this activated portion is included in the focus of attention. The focus of attention is controlled by voluntary processes of the executive system with limited capacity (typically between three and five chunks of information, see Cowan, 2001).

FIGURE 4. COWAN'S EMBEDDED MODEL OF WORKING MEMORY (COWAN ET AL., 2005)



Similarly to Cowan's, the Theory of Constructive Operators (TCO; Pascual-Leone, 1987; Pascual-Leone & Goodman, 1979) is consistent with the attention-based view of working memory and, in addition, provides a precise developmental model of capacity growth. Furthermore, the TCO assumes "schemes" as the units of cognition, which seems to be particularly suitable for sport abilities, because they involve different types of information (e.g., procedural and declarative; visual, motor, and conceptual), and the definition of "schemes" can apply to all of them (Bisagno & Morra, 2018). Therefore, the TCO was used as the framework for this study and it is subsequently described in depth in the following section.

The Theory of Constructive Operators by J. Pascual-Leone (1987; Pascual-Leone and Johnson, 2005; Morra, Gobbo, Marini e Sheese, 2008), arises from the integration between Piaget's theory of cognitive development and Witkin's studies (Witkin, Lewis, & Hertzman, 1954) on cognitive style.

Indeed, studies on cognitive style initially focused on perception (Witkin et al., 1954), distinguishing between so-called “field-dependent” individuals, i.e., those who are hardly able to isolate details and tend to remain anchored to the *gestalt*, and "field-independent" individuals, who process the various elements of the whole separately. Further studies (Witkin et al., 1974; Witkin, Goodenough, & Oltman, 1979) have shown that cognitive style is not only applicable to the perceptual domain, but also in cognition: field-independent individuals are therefore better able to solve problems that require cognitive restructuring, while the field-dependent individuals are more likely prone to functional fixedness (Duncker, 1945). Pascual-Leone refers to Witkin's studies to explain the results of some Piagetian tasks. Indeed, Witkin’s tasks resulted in a cognitive conflict, so that the perceptual characteristics of the stimulus or the previous knowledge of the subject lead to the activation of inappropriate strategies: the same would happen with the classic Piagetian conservation tasks.

Moreover, Pascual-Leone suggests that all these tasks require keeping in mind and integrating an amount of information that exceeds the possibilities of a child whose working memory is not sufficiently developed. So, instead of “logical gap”, as claimed by Piaget, according to Pascual-Leone, the child’s cognitive development depends on the ability to coordinate an increasing number of mental schemes.

The schemes Pascual-Leone refers to are the basic units of cognitive processes and can be described as mental representations of the constitutive elements of objects, events or people (Piaget, 1936; Piaget and Inhelder, 1966). Pascual-Leone classifies schemes according to three different criteria, as can be seen in Table 1.

TABLE 1. SCHEMES CLASSIFICATION CRITERIA ACCORDING TO THE TCO.

Criterion	Definition	Examples
Modality	It refers to the scheme content	Visual schemes, auditory schemes (for each sensory modality), linguistic schemes, affective schemes etc.
Abstraction Level	It refers to the scheme complexity since they are hierarchically organized	From basic schemes (e.g. cognitive functioning in daily life) to complex ones (e.g. personality schemes derive from the integration of many affective and cognitive schemes)
Type	Figurative schemes refer to states, while operative schemes refer to transformations	Figurative schemes: objects, contents, meanings etc. Operative schemes: actions, processes, operations

Each scheme consists of a series of components: a releasing component, which, if the conditions are met, allows the activation of the scheme itself, an effecting component, which consists of the effects of such implementation, and finally a terminal component, which is present if the scheme is organized according to a temporal sequence. When a scheme is activated, it tends to increase the probability of activating other schemes compatible with it and to decrease the probability of activating schemes that are incompatible with it. Moreover, according to the scheme's hierarchical nature, the activation of a scheme can also involve that of another higher level scheme, of which the first one is a condition of activation.

Next, to the construct of the schemes, Pascual-Leone defines the second-level operators or meta-subjective operators. Second level operators do not have their own information content, but they can be described as mechanisms that act on the schemes, increasing or reducing their activation, or even allowing the creation of new schemes. Meta-subjective operators are the following:

- the C operator (Content Learning) updates the schemes that have been violated by experience and creates new schemes by differentiating them from the old ones. It works similarly to the Piagetian concept of accommodation;
- the L operators (structural Learning) create new schemes through the simultaneous coordination of schemes the individual already possess.

- the LC operator generates complex schemes and allows gradual learning, based on the repeated co-activation of two or more schemes already formed by the operator C;
- the LM operator allows instead rapid learning, exploiting attentional resources and strategies and it generates hierarchical representations which are not bound to the context they have been learned in.

- the I (Interrupt) operator inhibits the interference created by disturbing stimuli, by operating with a top-down mechanism; it is particularly involved in selective attention tasks, like the Stroop test;
- the F operator (Field) refers to the "field" phenomena described by the Gestalt theory. In TCO it is not only about the simplest representation of a stimulus, but also about the simplest way of integrating activated schemes. It is also referred to as the tendency to give answers compatible with the structure of the situation (of stimuli);
- the S operator (Space) consists of a cognitive mechanism aimed at locating the objects, and the relations between them according to visuospatial coordinates;
- the A operator (Affect) determines the activation of schemes on an emotional basis;
- the operator M (Mental Energy) has the purpose to activate those schemes which, although being relevant for a task, are not sufficiently activated by the other operators. Therefore, the M operator can be considered as a central computing space and, according to Pascual-Leone, has its neurological substratum in the frontal and prefrontal cortex.

We speak of M capacity to define the maximum number of schemes that an individual is able to activate and coordinate at the same time. M capacity is expressed by the formula $e + k$, in which e represents the executive schemes and k is the number of operative and figurative schemes that can be activated simultaneously. The suggestion is that the amount of energy necessary for activation of the executive schemes is modest, given that these are well-automatized processes. M capacity develops during growth: many studies have shown that it increases by one unit (i.e., one more scheme that the individual is able to co-activate with the others) every two years, starting from 3 years of age. The development of M capacity described by Pascual-Leone is summarized in Table 2.

TABLE 2. DEVELOPMENT OF M CAPACITY ACCORDING TO THE TCO.

Age	M capacity
3-5 years	$e + 1$
5-7 years	$e + 2$
7-9	$e + 3$
9-11	$e + 4$
11-13	$e + 5$
13-15	$e + 6$
over 15 years	$e + 7$

In his theory, Pascual-Leone assumes that it is precisely the ability to coordinate an increasing amount of information that plays an important role in development. In other words, cognitive development would go hand in hand with the child's ability to coordinate an increasing number of mental schemes. Pascual-Leone (1970, 1978) tested his theory with an experiment involving a perceptual task called CSVI (Compound Stimuli Visual Information task) where the schemes were a priori constituted by stimulus-response pairs, e.g. "red-clap your hands", and so on. The participants were children aged between 5 and 11 years. They initially learned the pairs, afterwards, they were shown cards with composite stimuli, i.e., stimuli with more features among those they had learned to associate. Pascual-Leone's hypothesis was that the children would have recognized (and therefore responded appropriately) to one or more characteristics of the composite stimulus according to a two-parameter probabilistic model: the number of relevant characteristics in the design and the number of schemes they were able to integrate. As assumed, this number was two at 5 years of age and grew by one unit every two years. The same results were subsequently reproduced in other studies (De Ribaupierre & Bailleux, 1995; De Ribaupierre & Lecerf, 2006).

That M capacity plays a fundamental role in learning was not only verified with perceptual and attentive tasks such as the CSVI (Pascual-Leone , 1970), but also with reasoning tasks, such as the "horizontality of water level" problem (Morra, 2008), arithmetical problem solving (Agostino, Johnson, & Pascual-Leone, 2010) and problem solving in chemistry (Niaz, 1988). It has been also studied in the domain of language

(Balioussis, Johnson, & Pascual-Leone, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Morra & Camba, 2009) and of children's drawing (Panesi & Morra, 2016). Furthermore, the TCO was the framework for studies of moral reasoning (Stewart & Pascual-Leone, 1992), understanding of emotions in the presence of misleading or conflicting information (Morra, Parrella, & Camba, 2011), and theory of mind in adolescence (Im-Bolter, Agostino, & Owens-Jaffray, 2016).

Despite its applicability to many learning contexts, only rarely was the TCO used as a theoretical framework to study motor learning. However, performing complex motor gestures generates a high cognitive load (Furley & Memmert, 2010) and a recent study showed that M capacity is involved in the development of an early motor skill, such as scribbling (Morra & Panesi, 2017). The first experiments on motor skills, designed within the framework of the TCO, were carried out by Todor (1975, 1977, 1979; see also Pascual-Leone, 1987). In Todor's Rho Task, participants were asked to perform as quickly as possible a simple action, made of two basic hand movements, one circular and one linear. The M capacity was predictive of developmental improvements in the strategies by which the participants accomplished this task. Although the Rho Task is one of the few motor tasks for which an explicit TCO model was tested, it involves a very simple movement, hardly comparable to the complexity of the motor tasks that real-life situations and, particularly, a structured sport involve. A step in this direction was moved by Corbett and Pulos (1999), who conducted a longitudinal study on kindergartner's gross motor abilities, like hopping, skipping and jumping the rope. Their purpose was to analyse the relationship between gross motor development, cognitive development, and attentional skills. The ability that correlated most with M capacity was the rope jump. Indeed, in order to jump over the rope, children must coordinate arm and leg movements, thus coordinating several mental schemes. Corbett and Pulos also found correlations between cognitive measures (Piagetian tasks) and gross-motor abilities; these correlations, however, were drastically reduced when attentional capacity was controlled for, suggesting a causal role of attentional capacity in both cognitive and motor tasks. Despite its ecological framework, also this study investigated very simple motor tasks that cannot be compared to the amount of information an athlete has to coordinate when learning or performing a technical gesture. To address this question, a recent and sport-framed study, developed in the TCO theoretical framework, will be therefore discussed in the next section.

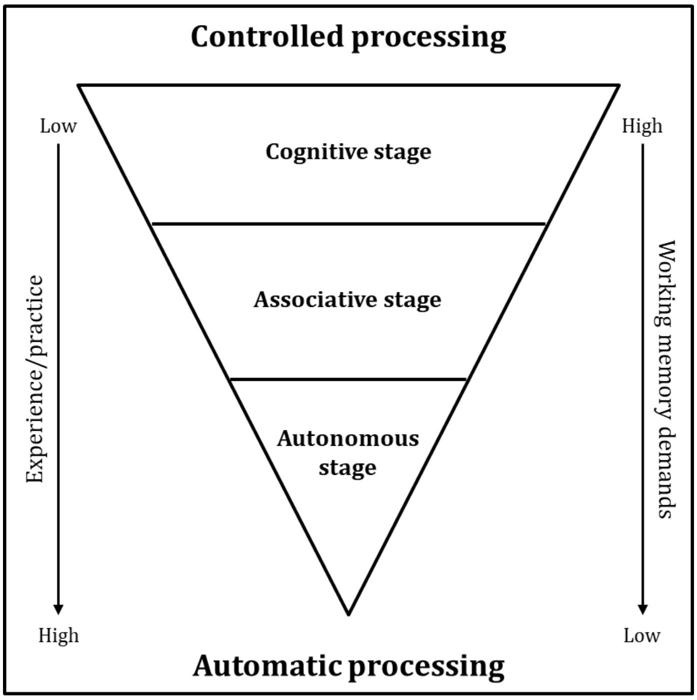
1.1.2 STUDIES ON WORKING MEMORY AND SPORT PERFORMANCE

Many of the studies investigating the relationship between working memory and physical activity focus on the effects of exercise on young adults' performance in working memory tests. Most of these studies aimed to investigate the immediate role of movement's physiological correlates, namely the release of neurotransmitters and the increased oxygenation of the brain, in enhancing performance in WM tasks (Pontifex et al., 2009; Quelhas Martins et al., 2013; Sibley & Beilock, 2007). A review by Best (2010) revealed similar patterns for children: aerobic exercise at a moderate to vigorous intensity was shown to enhance children's working memory, both after single bouts of exercise (Chen, Yan, Yin, Pan, & Chang, 2014; Pesce et al., 2009) and after chronic training (Koutsandréou, Wegner, Niemann, & Budde, 2016; Tomporowski, 2003). All these studies focused mainly on mere exercise. Conversely, Moreau, Morrison, and Conway (2015) conducted a study with 67 adults, randomly assigned to three conditions: aerobic exercise, working memory training or a designed sports intervention including both physical and cognitive demands. After training for eight weeks, the sports group showed the largest gains in the performance of working memory tests.

Recently, some authors have been interested in the role of working memory in motor learning or in sport performance (see Furley & Memmert, 2010 for a review). Some studies addressed the relation between working memory, decision making and the problem of choking under pressure (Beilock, 2007; Gimmig, Huguet, Caverni, & Cury, 2006; Hill et al., 2010; Ricks, Turley-Ames, & Wiley, 2007). Among these, Furley and Memmert (2012) conducted an experiment with young basketball players. By watching games footages, participants were asked to perform a time-constrained tactical decision-making task under auditory distraction conditions. Participants with higher WM were better able to focus their attention and produce creative solutions, blocking irrelevant auditory stimuli. In the second experiment with hockey players (Furley & Memmert, 2012), the same decision-making paradigm was used with a slight change. Half of the experimental trials included a team time-out simulation during which a virtual coach gave the players tactical information for the upcoming offensive play. Participants were asked to follow them only if the situation was appropriate. Low WM participants were significantly more likely to "blindly" follow the instructions of the coach even though they were not appropriate in that situation. These results suggest that athletes with higher WM are more capable of adapting their game to the situation, rather than using inappropriate impulsive responses.

Other studies focus on motor learning. Seidler and colleagues (2012) suggested that spatial working memory plays a fundamental role in the early stages of technical motor learning in sports. This hypothesis is indeed in line with a classic model (Fitts & Posner, 1967; Fitts, 1964) developed in sport sciences (see Figure 5). According to Fitts's model, an athlete would go through three distinct phases of learning, which are distinguished by virtue of the cognitive load they involve. During the first phase, called "cognitive phase", attentional resources and declarative knowledge (Anderson, 1982) are highly involved. The associative phase sees a decrease in the working memory involvement, as the associations between stimuli and responses strengthen; finally, in the automation phase, the execution of the motor task does not place any cognitive load on the athlete's WM, since it has become automated procedural knowledge (Anderson, 1982).

FIGURE 5. FITTS AND POSNER'S (1967) MODEL OF MOTOR SKILLS ACQUISITION (SEE FURLEY & MEMMERT, 2010).



To the best of our knowledge, the only research that studied motor learning in sports within the theoretical framework of TCO was conducted by Bisagno & Morra (2018, see the *Appendix*). This study involved 105 young female volleyball players, who were tested for M capacity with three neo-Piagetian tests (i.e., Mr Cucumber, Direction

Following Task and Figural Intersection Test). Moreover, the volleyball players' expertise measures, namely the years of practice in volleyball and the number of training per week, were collected. The participants were asked to perform a series of attack tasks, designed via a task analysis. In these increasingly difficult tasks (namely from a simple toss over the net to a spike against a block), the players were asked to send the ball to a certain court zone (zone 1) and, if they were able to, to score a direct hit into a hula-hoop ring, located in the same zone. The aim of the study was to study the role of the M capacity in predicting the volleyball players' performance in increasingly complex attack gestures. The results showed that M capacity was the main mechanism underlying the correct execution of the attack motor gesture (i.e., the athletes' M Capacity predicted their ability in correctly sending the ball to zone 1) while the expertise, namely the years of experience in volleyball, were the only significant predictor for the technical precision of the gesture itself (i.e., the ability of scoring into the hula-hoop ring). Given the results of this first study, M capacity has been included among the predictors of the model in order to better understand its role not only in motor learning but also in sport performance. Indeed, the main advantage of using this theoretical framework is that it offers a developmental model of capacity growth, thus enabling precise predictions on performance, as well as putting them in relation with a more general cognitive-developmental model.

1.2 EXECUTIVE FUNCTIONS

We can broadly define executive functions (EFs) as top-down processes that regulate planning and goal-directed, controlled behaviour (Espy, 2004), as well as the activation and modulation of cognitive schemes (Diamond, 2014). We rely on EFs when we have to concentrate, when we have to put an effortful control on what we are doing, or when we cannot rely on automatic responses (Diamond, 2014; Espy, 2004). From a neurological perspective, EFs are superior cortical functions and better performance on executive tasks is generally associated to larger prefrontal cortex (PFC) volume and to a greater PFC thickness (Miyake & Friedman, 2012; Yuan & Raz, 2014).

Even though many complex cognitive processes are defined as executive functioning, there is general agreement that there are three core EFs (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000): inhibition, which includes both behavioural inhibition (i.e., the ability of stopping an automatic response) and cognitive inhibition (i.e., interference control), working memory updating, and shifting (also called "cognitive flexibility" or "task switching"). From these three core EFs, higher-order EFs are built such as reasoning, problem-solving, and planning (Collins & Koechlin, 2012; Lunt et al., 2012). The most well-acknowledged model of EF (Miyake et al., 2000; Miyake & Friedman, 2012) will be described in the following section.

1.2.1 MIYAKE'S MODEL

The most prominent theoretical account of executive functioning is the one proposed by Miyake et al. (2000). Miyake et al. adopted a latent variable approach in order to minimize the task impurity problem and identified three distinct, but interrelated EFs (see Figure 6).

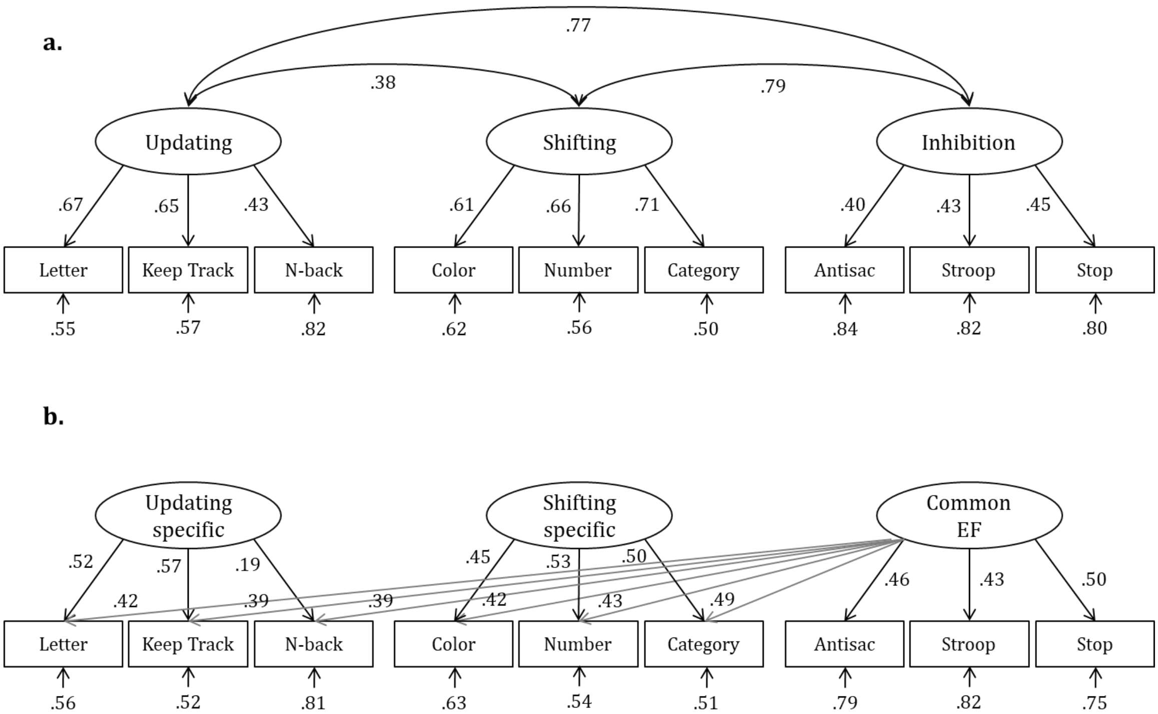
i. *Inhibition* concerns both the ability of the individual to suppress a preponderant or automatic response and the ability to suppress interfering mental representations and distracting stimuli. Diamond (2014) describes inhibition as the ability to control one's attention, behaviour, thoughts, and emotions. In this sense, inhibition can also be linked to self-control, conceived as the ability to control impulses (e.g., resisting the temptation of eating sweets while on a diet). Moreover, cognitive inhibition allows one to selectively focus, to voluntarily suppress irrelevant stimuli or automatic mental representations (e.g., resisting to unwanted memories). Despite having similar neural basis (Friedman & Miyake, 2004), these diverse types of inhibitory control of action and attention have been shown to be dissociable (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Engelhardt, Nigg, Carr, & Ferreira, 2008), even in toddlers (Gandolfi, Viterbori, Traverso, & Usai, 2014).

ii. *Updating* refers to the active updating and monitoring of the information in working memory.

iii. *Shifting* (or cognitive flexibility) is described as the ability to move from one task or mental set to another flexibly, and it is sometimes related to creativity (Diamond, 2014). We rely on shifting when we change perspective, or when we switch from a rule set to another in order to perform a task. This involves both inhibiting our previous response and updating a new one so that it is possible to say that shifting is built on the two other core EFs (Diamond, 2014). Evidence in this sense is that shifting comes later in development with respect to inhibition and updating (Davidson, Amsoa, Cruess Anderson, & Diamond, 2006).

Miyake et al. found these three executive functions to be separated but tapping some common underlying ability. Indeed, in the full three-factor model, the estimates of the correlations among the three latent variables were moderately high (from .42 to .63). This is what the authors defined as the "unity and diversity" of EFs (Friedman, Miyake, Robinson, & Hewitt, 2011).

FIGURE 6. MODELS OF EXECUTIVE FUNCTIONS.
PANEL (A): MIYAKE ET AL., 2000.
PANEL (B): MIYAKE & FRIEDMAN, 2012.



While factor analysis studies support the three EFs structure in adults (Friedman et al., 2008; Miyake et al., 2000), the latent structure of EF in lifespan is still a matter of discussion. The three-factor latent structure has been observed in children, preadolescents (Lehto et al., 2003; Rose, Feldman, & Jankowski, 2011), and elderly (Vaughan & Giovanello, 2010). However, focusing on developing individuals, some studies found a two-factor structure (Huizinga, Dolan, & van der Molen, 2006; Usai, Viterbori, Traverso, & De Franchis, 2014; van der Sluis, de Jong, & van der Leij, 2007) or a unitary EF construct in preschool children (Wiebe, Espy, & Charak, 2008). Referring to these evidences, we can easily argue that the development of EFs continues across childhood and adolescence (Best & Miller, 2010; Best, Miller, & Jones, 2009).

Even though there's still no agreement in developmental psychology about the latent structure of EF during childhood, the empirical evidence suggests that executive functioning emerges during the first few years of life (Diamond, 2014). Further, according to Best, Miller, and Jones (2009), significant improvements in EF tasks still occur during the school years, and distinct developmental trajectories can be identified for each EF component during middle childhood and adolescence.

1.2.2 STUDIES ON EXECUTIVE FUNCTIONS AND SPORT PERFORMANCE

Research on the role of executive functions in sport performance is rather limited and very recent. Moreover, there is scarce agreement on what executive Functioning is. Many studies that in sport psychology refer to EFs describe different constructs, not precisely referring to any model. In a study with young talented soccer players, Verburgh, Scherder, et al. (2014) found that the EFs are strongly involved in producing a winning performance, especially in team sports, which require rapid anticipation and adaptation to changing playing circumstances. Young professionals were significantly higher than the control group (amateur soccer players of the same average age) especially with respect to inhibitory mechanisms. Similar results were also observed with volleyball players (Lipoma, Corrado, Nuovo, & Perciavalle, 2006), where action planning skills are particularly relevant (Macquet, 2009), and other open-skills sports (Chang et al. , 2013). Nakamoto & Mori (2008) submitted to a Go/No-Go task three groups of participants: basketball players, baseball players -both further divided into low, medium and high levels- and controls; it was found that all the athletes were significantly faster than controls and that experience played a role in discriminating reaction times for basketball players only. This could suggest that inhibition is particularly well-trained in the open-skills disciplines. In this sense, more evidence is presented by Wang et al. (2013) who observed how tennis players have lower reaction times in a Stop-Signal task if compared with swimmers or non-athletes. These studies seem to suggest that, at least in open-skill sports, inhibition plays an important role in the production of sport performance. Regarding shifting and updating, there is no specific literature related to sport performance, although there are studies (Castiello & Umiltà, 1992; Pesce et al., 1998) which highlight an advantage of some types of athletes, such as the volleyball players, in rapidly re-orienting attention or having slightly better response time in N-back and Flanker tasks when compared to less strategic sports athletes (Krenn, Finkenzeller, Würth, & Amesberger, 2018).

Given this evidence, EFs are included among the possible predictors of sport performance in this study. Coherently with the existing literature, they are expected to be predictive of the performance to a greater extent for open-skills sports. Indeed, being more sensitive to the environmental variability, open-skills sports require a quick reorganization of the action that may rely on executive mechanisms. This hypothesis is supported by meta-analytic studies, showing that open-skills sports athletes achieve better results in cognitive tasks than those practising closed-skills sports (Mann, Dehghansai, & Baker, 2017; Voss et al., 2010).

1.3 ATTENTIONAL STYLE

The shape, capacity, and spatial distribution of attention have been widely studied (Cowan et al., 2005; Wiley & Jarosz, 2012) and many metaphors of its focus have been produced (e.g. Eriksen & St. James, 1986, proposed a zoom lens model, Posner, 1980, conceived the attentional spotlight metaphor). In general, individuals are different in their ability to distribute, orient and shift their attention (Heitz & Engle, 2007; Kane & Engle, 2002). Some authors refer to the individual's disposition to preferably adopt a certain attentional focus as his/her attentional style (Nideffer, 1976a). Since factors such as sustained alertness, a rapid orientation of attention, and freedom from distraction are considered vital ingredients for effective athletic performance, this construct has been considered of interest for the purpose of this research.

1.3.1 NIDEFFER'S MODEL

Attentional style refers to an individual's propensity to adopt a particular type of attentional focus (Nideffer, 1976a; Moran, 1998). The theory of Attentional and Interpersonal Style and the test derived from it (Test of Attentional and Interpersonal Style: TAIS, Nideffer, 1976b) were developed in order to provide a framework for understanding and possibly predicting the conditions under which individuals are able to perform at their full potential. The theory aims to examine, in a testable and performance relevant way, the relationship between cognitive processes, emotional arousal, and performance. It has relevance to both physical (execution of a motor skill) and mental (decision making, problem-solving) performance in virtually any performance arena. Even if not specifically designed for it, this theory was mainly used in the field of sport psychology (see, for example, Lipoma, Corrado, Nuovo, & Perciavalle, 2006), in order to understand the aspects of the individual that lead to the “choking under pressure” mechanism (see Hill et al., 2010, for a review) on the one hand, and entering the “flow” condition (Csikszentmihalyi, 2000) on the other hand. Indeed, also sport-specific versions of the TAIS questionnaire have been developed. In these versions, the items are given in a context pertinent to the specific sport being studied. Some examples can be found in tennis (Van Schoyck & Grasha, 1981), baseball and softball (Albrecht & Feltz, 1987) and basketball (Summers, Miller, & Ford, 1991).

According to Nideffer, individuals show a tendency to function within a narrow range along each of the two dimensions of attention: the width and the locus. This predisposition toward a certain kind of focus of attention is therefore defined as the individual’s attentional style. Nideffer (1976b) identifies four of them, determined by the crossing of two bi-polar dimensions: the amplitude (i.e., narrow or wide) and the direction, whereby the external focus will be turned towards the environment (for example, under the conditions of the game) and the internal one will be aimed at mental thoughts and/or patterns.

From the combination of the two aforementioned dimensions, the following styles emerge (see Figure 7 for a graphical representation):

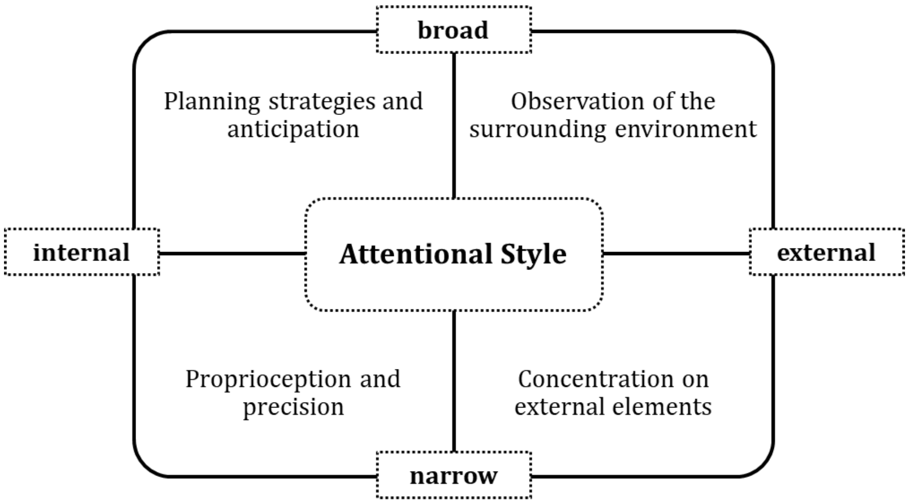
(i) *focused* or narrow external, such as that adopted by an archer who concentrates on the centre of the target before firing the arrow;

(ii) *aware* or wide external, adoptable - for example - by a player who scans the playing area in search of unmarked comrades;

(iii) *systematic* or narrow internal, used by athletes during mental imagery before a competition;

(iv) *strategic* or broad internal, necessary for the formulation of a game scheme or a tactic.

FIGURE 7. NIDEFFER'S MODEL OF ATTENTIONAL STYLE(NIDEFFER, 2002).



The dimension of width has been generally accepted by many researchers (Wachtel, 1967; Posner). These same researchers also support the idea that attention can be directed internally or externally: for example, Lacey (1967) suggested that a heart rate acceleration represents the shifting from an external to an internal focus of attention, while a heart rate deceleration indicates the adoption of an external focus, centred on the surrounding environment. Regarding the direction of attention, however, results are less clear. In a study with young basketball players (Summers et al., 1991), for example, while the dimension of width was supported, the validity of the direction dimension was inconclusive.

According to Nideffer, individuals who have a dominant attentional style will perform more easily in situations that are in line with it, although other mediating variables (e.g., arousal) will play a critical role in determining when individuals will and will not perform well. For instance, studies using the dual task paradigm showed empirical evidence of the narrowing of attention with increasing arousal. These studies show that as the importance of the primary task increases, sensitivity to peripheral cues decreases, thus indicating that the attentional focus narrows. Additional evidence comes from the relationship between measures of anxiety like the State-Trait Anxiety Inventory and the Taylor Manifest Anxiety Scale, and measures of attentional distractibility and excessive narrowing (Nideffer, 1976a).

Nideffer (Nideffer, 1976; 2007) also designed a measure to evaluate individual attentional style. The Test of Attentional and Interpersonal Style (TAIS) consists of 144 items that describe situations of daily life. The individual is asked to self-evaluate attention and interpersonal characteristics deemed important to predict performance.

In particular, the six attentional subscales evaluate the individual's ability to broaden his/her attentional focus (BET and BIT scales), to narrow it (NAR), or to adopt a dysfunctional focus (OET, OIT, RED). Studies with different populations showed that the six TAIS attentional scales result in two or three factors depending on the analysis, and/or the subject population (Nideffer, 2007; Vallerand, 1983; Van Schoyck & Grasha, 1981). The two-factor structure accounts for about 70% of the variance and shows a factor which includes the NAR, -OET and -OIT scales. It seems to reflect the ability to narrow attention not to get distracted; the second factor includes the BET, BIT and -RED scales and reflects the ability to develop a broad focus of concentration avoiding the tendency to make mistakes of under-inclusion. The three-factor solution, which is more common among athletes, accounts for 85% of the variance, pulling the RED scale away from factor two and combining it with the NAR – indicating a general tendency in narrowing the attentional focus both in an effective or ineffective way. In the end, studies that compared male and female athletes showed that, only in female samples, a strong correlation tend to appear between all measures of a dysfunctional focus, i.e., OIT, OET, RED (Lipoma et al., 2006).

Although there are studies (Nideffer, 1976a, 1993) in support of the theory of Attentional and Interpersonal style, the theory has undergone some criticism. For example, a limitation of the theory is that it does not take into account a distinction in the processing of the information which is relevant or irrelevant for sport performance and that it underestimates the modulation of attentional focus willingly adopted by athletes (Moran, 1998). For these reasons, research into attentional styles in sports suffered a setback after the 1990s. In the following section, the main studies that used the Theory of Attentional and Interpersonal Style as a framework are discussed.

1.3.2 STUDIES ON ATTENTIONAL STYLE AND SPORT PERFORMANCE

During a sport performance, the athletes modulate their attentional foci by virtue of environmental demands, for example, a volleyball player may need to narrow attention while serving the ball, while broadening it during the game action. Nevertheless, Nideffer (Nideffer, 1976, 1990) suggests that, according to the type of sport, a style may be preferred to the others. In particular, in open-skills sports like volleyball, a "broader and external" focus would be more useful in order to respond effectively to sudden stimuli (Bosel, 1998). Conversely, the athletes practising closed-skills sports would prefer a "narrow and internal" focus. In order to define this kind of focus, Nideffer describes an artistic gymnast who mentally visualizes the movements she has to perform on the beam before executing them. A graphical representation of the preferred focus of athletes from different kind of sports with data collected among 4,766 participants (Nideffer, 2007) can be seen in Figure 8.

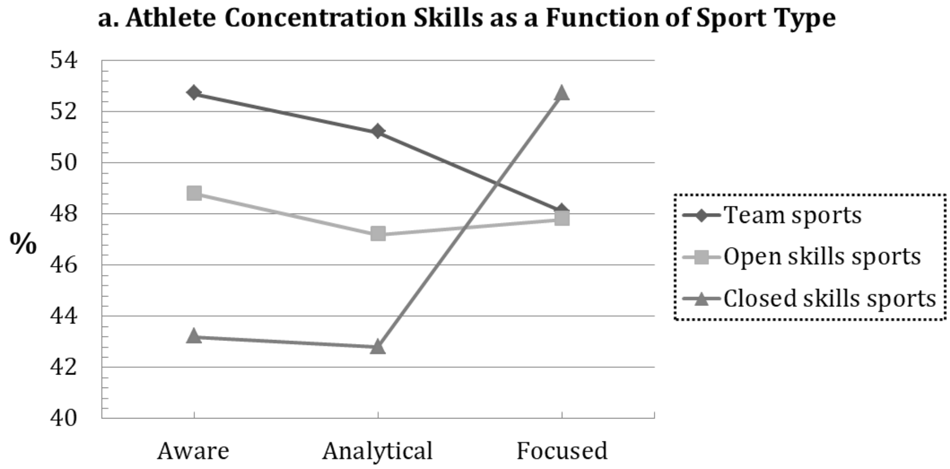
However, this distinction is not broadly supported. Recent research (Abdollahipour, Wulf, Psotta, & Palomo Nieto, 2015) identifies in the external focus the one preferred by young artistic gymnasts. In the same way, studies in golf found that elite athletes benefit from an external focus of attention while competing (Bell & Hardy, 2009). Moreover, golfers show a greater cardiac deceleration, which appears to be linked to the adoption of an external focus, prior to the execution of good rather than poor putting trials (Boutcher & Zinsser, 1990). An increase in alpha activity on the left side of the brain, and continued activation on the right side of the brain in expert shooters just prior to firing were found (Hatfield, Landers, & Ray, 1984). This evidence as well suggests both a narrowing of the athletes' attention and the adoption of an external focus. In the end, some studies suggest that an external focus is always better regardless of the type of sports (see Wulf, 2013 for a review). According to this review, both performance and learning would benefit from feedbacks inducing an external focus across different types of tasks, skill levels, and age groups. Benefits would be evident in movement precision (e.g., accuracy, consistency, balance) and efficiency (e.g., muscular activity, force production, cardiovascular responses).

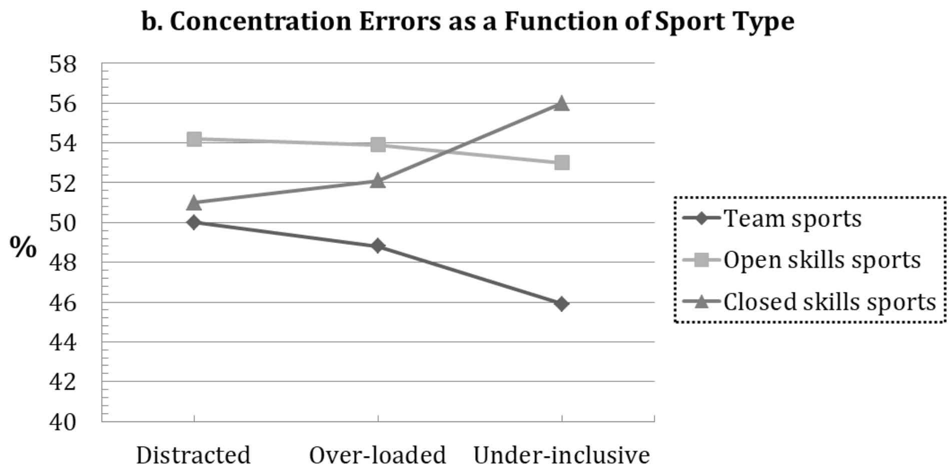
Nideffer's theory was widely tested in relation with performance in sport psychology research and a specific version of the Test of Attentional and Interpersonal Style, including only the attentional items, was designed for this very purpose (Nideffer, 1990). Significant relations between attentional styles, as measured by the TAIS, and performance have been found in sports such as swimming (Nideffer, 1976b), diving (Nideffer, 1987), archery (Landers, Boutcher, & Wang, 1986), squash (Kerr & Cox, 1990) and baseball (Albrecht & Feltz, 1987). In contrast, several other studies (e.g. Vallerand, 1983; Van Schoyck & Grasha, 1981) found no relationship between sport performance and TAIS attentional measures. In a study with basketball players, Summers et al. (1991) found empirical support for the width dimension only, although it appeared to be multidimensional (i.e., consisting of a scanning and a focusing component). Conversely, the validity of the direction dimension was not confirmed.

Despite the contrasting opinions with respect to Nideffer's theory, some recent studies have shown a renewed interest in the inter-sport differences in the management of the attentional focus. A study with footballers and volleyball players (Huttermann, Memmert, & Simons, 2014) showed that experienced footballers prefer a distribution of attention organized along the horizontal axis; in contrast, volleyball players showed a preference for the distribution of attention along the vertical axis.

Given its widely debated role in literature, the attentional style was tested as one of the predictors of sport performance in this research.

FIGURE 8. DATA COLLECTED ON 4766 ATHLETES AT THE TAIS (NIDEFFER, 2007).





Note: % on vertical axes represent the percentage scores on each TAIS style.

1.4 EMOTIONAL CORRELATES

Emotions are complex and organized response configurations, selected in the course of evolution to favour the organism's adaptation to the environment (Ekman, 1992). They are defined as multi-componential since they include a physiological response (e.g. an acceleration of the heartbeat), a cognitive appraisal (the evaluations we apply, i.e., "I'm reacting to something dangerous"), the experience of an affect (e.g. fear), an expressive reaction (i.e., a prototypical facial expression) and a behavioural one (e.g. a fight or flight response).

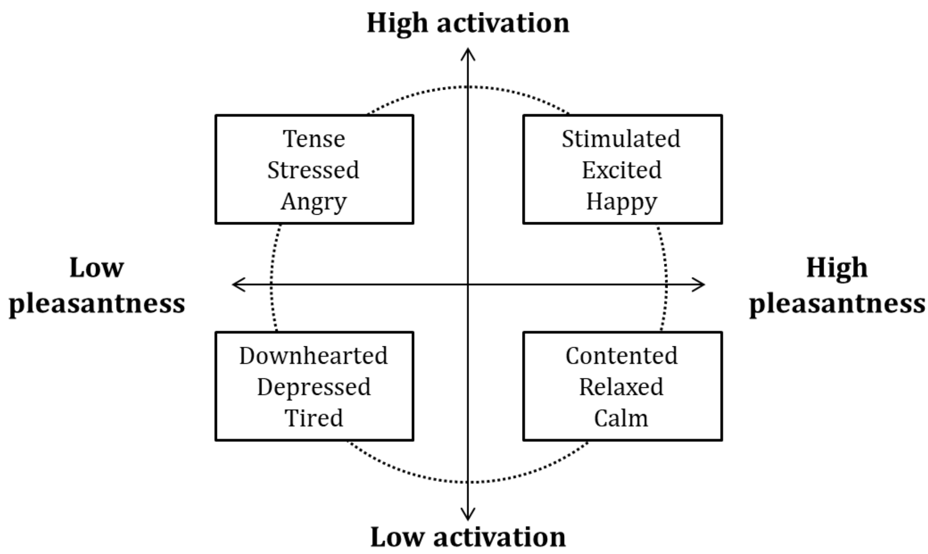
Many theories on emotions (Ekman, 1992; Panksepp, 2004) posit that they can be divided into discrete and independent categories, each with their own specific neural correlates and their prototypical facial expression, which would be cross-culturally recognisable. Other authors compared the human range of emotions to the spectrum of colour, without discrete borders to differentiate one from another (Russell, 1983; Watson, Wiese, & Vaidya, 1999). Among these theories, one of the most acknowledged is the Circumplex model of emotions developed by Russel and Posner (Posner & Russell, 2005; Russel, 1980).

1.4.1 THE CIRCUMPLEX MODEL OF EMOTIONS

The Circumplex model of emotions (Posner & Russell, 2005; Russel, 1980; Russell, 1983; Russell & Russell, 2016) stands in contrast to theories of basic emotions, which posit that a discrete and independent neural system underlies all emotions. It proposes that all affective states arise from cognitive interpretations of core neural sensations that are the product of two independent neuropsychological systems, namely arousal and hedonic tone. Indeed, Russel's conceptualization began with the assumption that emotions are often interrelated in a systematic fashion. Therefore, he suggested that the underlying structure of an affective experience is structured as an ordering of affective states on the circumference of a circle which is based on a classification of affective states based on the two dimensions cited before.

This approach is supported by numerous researches on verbal descriptions, facial expressions and self-reports with respect to affective states (Kring, Feldman Barrett, & Gard, 2003; Lang et al., 1998; Russel, 1980; Watson et al., 1999). These researches have consistently underlined the existence of two specific and independent dimensional systems: one that identifies the valence (or hedonic tone) of emotions, classifying them along a continuum of pleasantness-unpleasantness (Watson et al., 1999), and another one that determines the intensity (low or high) in terms of physiological activation, namely arousal. According to the authors of the model (Posner & Russell, 2005; Russel, 1980), the combination of these two dimensions, associated with the physiological response and cognitive appraisal, would thus give rise to the subjective emotional sensation. See Figure 9 for a graphical representation of the model, where emotions are distributed in four different quadrants accordingly with the combination of the two continua.

FIGURE 9. THE CIRCUMPLEX MODEL OF EMOTIONS (POSNER & RUSSELL, 2005; RUSSEL, 1980).



Describing emotions in terms of positive (pleasant) and negative (unpleasant) affects rather than the specific discrete emotions appears to be particularly functional with athletes, since they can easily express, even right before, immediately after or in certain cases (e.g. runners) even during how they feel with respect to the performance in a more immediate way (Vitali et al., 2019). Indeed, based on this model of emotions, a particular single-item questionnaire, namely the Affect Grid, has been designed and used in a sports setting. The Affect Grid is made up of a nine-by-nine matrix with emotion-adjectives (e.g., excited, relaxed, stressed) placed at the midpoints of each side of the grid and at the four corners. Participants can simply indicate one cell within the grid in order to communicate how they are/were feeling along the arousal and pleasantness dimensions.

Moreover, this theoretical framework is useful to distinguish between the two dimensions of emotions, and it allows to test specific hypotheses with respect to the effect of pleasant and unpleasant emotions with both high and low arousal on athletes' performance.

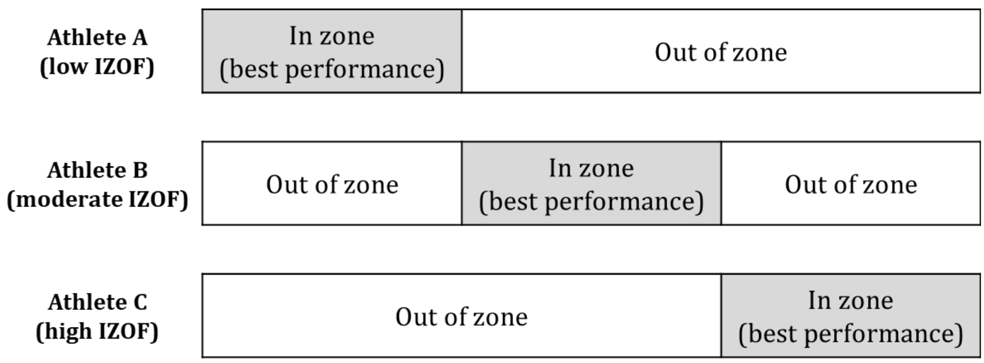
1.4.2 STUDIES ON EMOTIONS AND SPORT PERFORMANCE

Emotions have been studied in sport psychology research over the past fifty years. The very first topic of interest for most of the researchers was the anxiety-performance relation. Among the most widespread models, we can mention the inverted-U theory (Yerkes & Dodson, 1908), Hull's drive theory (1943) or the multidimensional anxiety theory (Martens, Burton, & Vealey, 1990) and the butterfly catastrophe model (Hardy, 1996): they all looked at emotions in sports as something to be controlled in order not to get too anxious. The implicit assumption of these theories was the detrimental effect of anxiety on sport performance. For this reason, at first, most researchers (Hanin, 2000; Vallerand, 1983) focused on negative (unpleasant) emotions, in order to provide athletes with training on how to reduce or control them.

Positive (pleasant) emotions became a promising field of research because of their influence on specific components of performance (e.g., attention) and general well-being. For instance, the studies on the flow condition (i.e., an optimal psychological state that occurs in case of a perfect balance between perceived challenges and skills of a specific activity such as sport) underline the importance of the enjoyment (Csikszentmihalyi, 2000). Positive (pleasant) emotions in sports are further associated with many attributes, characteristics, and behaviours such as personal traits (e.g., optimism, resilience, self-esteem), but also cognitive factors (e.g., concentration, attentional control decision making), motivational aspects (e.g., intrinsic motivation), and coping strategies (e.g., internal locus of control).

An interesting and relatively recent branch of studies focuses on the idea that, regardless having a pleasant or unpleasant hedonic tone, emotions in sports can be equally functional with respect to the athlete's individuality or the task request. The Individual Zone of Optimal Functioning (IZOF: Hanin, 2000, 2002, 2014) model, indeed, attempts to describe and explain emotions related to individually successful and poor performances (see Figure 10). This model has been conceptualized within the framework of four global emotional categories derived from two factors: hedonic tone (pleasure-displeasure) and functionality (functional-dysfunctional). The four emotional categories include therefore pleasant (positively toned) and functionally optimal emotions (P+), unpleasant (negatively toned) and functionally optimal emotions (N+), pleasant and dysfunctional emotions (P-), and unpleasant and dysfunctional emotions (N-). Research conducted within this theoretical framework showed how some emotions that are typically considered unpleasant and dysfunctional (e.g. anxiety) can possibly be predictive of a good performance for certain athletes (Ruiz, Hanin, & Robazza, 2016; Yao, 2016). For example, studies with team contact sports (Campo, Mellalieu, Ferrand, Martinent, & Rosnet, 2012) showed that anger, even if unpleasant, is actually a functional emotion for athletes practising combat sports since it usually appears to be predictive of more favourable outcomes. On the other hand, Mahoney & Avener (1977) observed that disciplines like artistic gymnastics, requiring a very high level of precision, are facilitated by low-arousal emotions. These studies could suggest that optimal functioning is not only person-related but could be linked to the practised sport as well. In this sense, it is possible that open-skills sports would benefit more of emotions characterized by a high-arousal level, even when unpleasant (e.g. anxiety) in order to better react to rapid environmental changes. Conversely, a gymnast could profit from low-arousal emotions, since he/she has to calmly focus on his/her own body's control.

FIGURE 10. THE IZOF MODEL (HANIN, 2000; RUIZ, RAGLIN, & HANIN, 2017)



Emotions in sports have been mainly studied as direct predictors of performance. However, another interesting aspect is related to their relationship with cognitive abilities and how they, combined, affect sport performance. With respect to the relationship between WM and emotional control, recent models of cognitive psychology applied to motor learning describe two modes of an athlete (i.e., two types of information processing that can guide the athlete's performance; Furley, Schweizer, & Bertrams, 2015). On the one hand, Type 1 mechanisms, independent of WM are more automatic, on the other hand, Type 2 mechanisms require the manipulation of a high cognitive load and therefore the intervention of working memory. Experienced athletes may benefit from Type 1 mechanisms, which give them greater fluidity during the performance and might cause less exploit of mental resources. However, when approaching new tasks or during development, unpredictable situations might occur, therefore the use of Type 2 mechanisms is could be still massive. Therefore, the literature emphasizes the role of a high WM in supporting athletic performance (Behmer & Fournier, 2014; Bijleveld & Veling, 2014; P. A. Furley & Memmert, 2012).

However, some studies suggest that, similarly to what happens with academic achievement (Ashcraft, 2001; Ashcraft, 2002; Passolunghi, Caviola, De Agostini, Perin, & Mammarella, 2016), also in sport performance, emotions with a high-arousal and a unpleasant hedonic tone (e.g. competitive anxiety) are experienced as debilitating (Hill et al., 2010; Hill, Hanton, Matthews, & Fleming, 2011). These emotions can possibly subtract cognitive resources from the athlete, by generating intrusive thoughts (Baumeister, 1984), or because the individual uses part of his/her cognitive resources in order to suppress unpleasant feelings (Klein & Boals, 2001). These theories refer to the athletes' effort to free themselves from the pressure as a real task, so that something similar to a double task is generated, i.e., keeping in memory the information and the patterns related to the correct execution of the performance and the thoughts related to anxiety (Hill et al., 2010).

A more complex level of explanation is proposed by Beilock (2007), who speaks of pressure's double whammy, because of which not only the athletes' resources are subtracted from working memory, but they are also re-invested on well-learned procedural knowledge (i.e., the athlete relies again on Type 1 mechanisms, as if the automatism had "jammed"), which in return subtracts resources itself. Evidence in this sense is also present at a physiological level. Indeed, the reinvestment process involves changes at the heartbeat level: Laborde, Furley, & Schempp (2015) observed that, in "high pressure" (e.g., with time constraints) decision-making tasks, low-reinvesters are more effective decision-makers. This evidence could suggest the existence of an effect of the unpleasant emotions (i.e., their hedonic tone) experienced by athletes before a competition moderating the relationship between M capacity and sport performance.

Moreover, the literature also suggests the existence of an inverse relationship, i.e., the one established during the so-called flow condition (Csikszentmihalyi, 2000), during which the athlete seems to perform extremely complex gestures without any physical or mental effort. This is another evidence supporting the idea of the hedonic tone of emotions as a moderator in the relation between M capacity and sport performance. Indeed, some studies (Osaka, Yaoi, Minamoto, & Osaka, 2013; Talarico, Berntsen, & Rubin, 2009) suggest a “boosting” role of pleasant emotions in various memory systems.

CHAPTER 2. RESEARCH QUESTIONS

2.1 RESEARCH STRATEGY

Driven by the interest in the role of general cognition and emotional control in sport performance, this study has examined two central research questions: First, how cognitive and emotional predictors are related to sport performance of young athletes. Second, if and how this relation is different with respect to the type of sport (i.e., open-skills or closed-skills sports).

Using an 11-17-year-olds sample we tried to offer a developmental perspective to a field, namely sport performance, that is usually focused on adult and/or elite athletes. Since our interest concerned sport performance in the developmental age, 11-17-years old seemed a feasible age-range to guarantee reliability on self-reports measures and a certain range of scores in the development of working memory. Indeed, an advantage of using a developmental perspective is that it allows testing theoretically-predicted developmental effects on cognitive functions which athletes require to perform in sports. From an applicative point of view, identifying which cognitive abilities are involved in different sports would allow designing sport-specific psychological skills training programmes and tailor them with respect to the athlete's cognitive development.

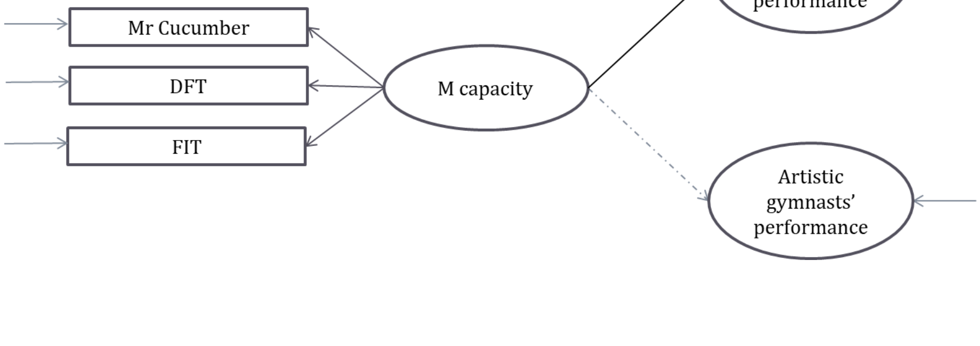
Given the lack of integration of findings in sport psychology and developmental psychology, the research strategy was to approach this topic in an interdisciplinary manner, by focusing on sport performance within a developmental sample. As the primary focus was on general cognitive abilities and emotional control as predictors of sport performance, we adopted a *cognitive component skills approach* (Voss et al., 2010), using measures of general cognition instead of sport-specific cues or tasks. Moreover, we used measures conceived within theoretical frameworks offering a developmental outlook and, therefore, particularly suitable for our age sample. Conversely with respect to performance, having an ecologically valid measure was really important to us, in order to find valid results, both theoretically and practically. For this reason, we collected measures derived from the actual sports competition the athletes participated in, and we manipulated them to obtain valid individual performance measures (i.e., dependent variables).

2.2 HYPOTHESES

With respect to the empirical state-of-the-art presented above, the hypotheses of this study on the role of cognition and emotions in sport performance were formulated. In particular, the role of each cognitive variable and of the emotional aspects were predicted, differentiating between the different type of sports (i.e., open-skills or closed skills), accordingly with Poulton's distinction (Poulton, 1957). Moreover, based on the theories that suggest a role of unpleasant emotions (Baumeister, 1984; Beilock, 2007; Hill et al., 2010) in regulating the relationship between working memory and performance, moderation effects were tested. Our hypotheses are summarized as follows.

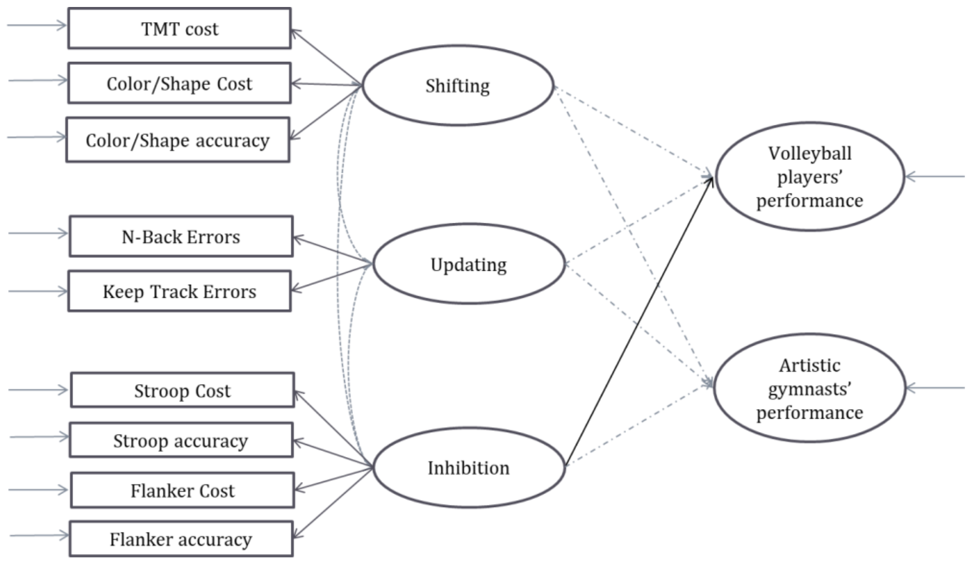
I. M capacity, being the general ability to integrate a developmentally increasing number of (motor) schemes, is expected to be predictive of better results in volleyball players, but not in artistic gymnasts. Indeed the very definition of "open-skills" sports being more influenced by unpredictable variables suggests that during a volleyball game the cognitive load (also placed by environmental stimuli) the athlete has to manipulate is greater, thus making the role of WM more predominant. Conversely, artistic gymnasts' performance consists of an automated motor repertoire which, by its very definition, is highly automated. (Paul M. Fitts, 1964). What is automated does not place any cognitive load on working memory. Therefore, working memory is not expected to be predictive of performance in artistic gymnastics. A graphical representation of the hypothesis is shown in Figure 11. For a description of the observed variables, see chapter 3, section 3.2.1.

FIGURE 11. HYPOTHESIS ON THE ROLE OF M CAPACITY AS A PREDICTOR.



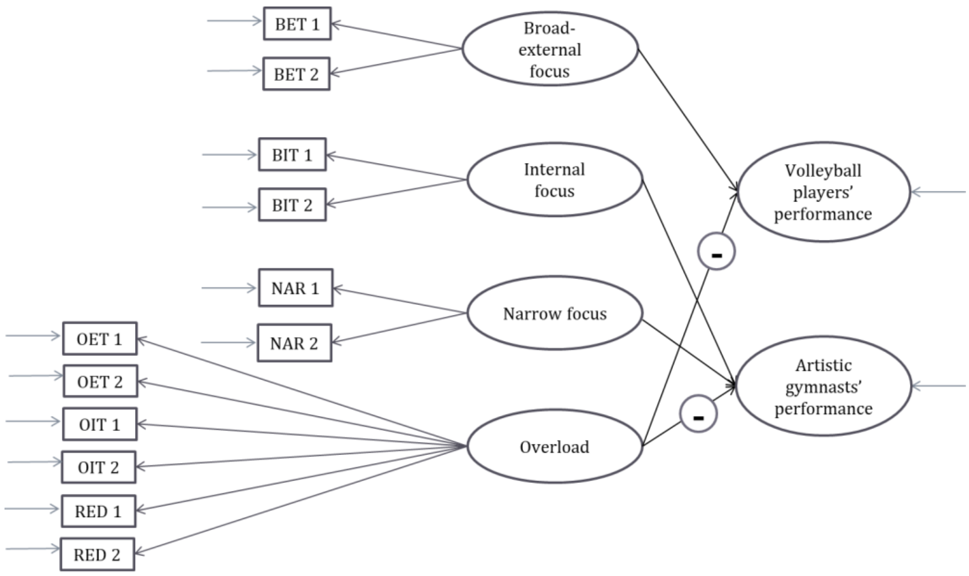
II. With respect to executive functions, the literature suggests that athletes practising open-skills sports are better than controls (i.e., non-athletes or athletes of closed-skills sports) in inhibitory tasks (Wang et al., 2013). Therefore, it is expected that inhibition will be predictive of the volleyball player's performance, but not of the artistic gymnasts' performance. Since there is not a sufficiently extensive corpus of literature in sports regarding the effect of shifting and updating mechanisms, their predictiveness of sport performance is studied in an exploratory fashion in both disciplines. A graphical representation of the hypothesis is shown in Figure 12. For a description of the observed variables, see chapter 3, section 3.2.2.

FIGURE 12. HYPOTHESIS ON THE ROLE OF EXECUTIVE FUNCTIONS AS PREDICTORS. THE DOT-DASH LINES REPRESENT THE RELATION NOT DOCUMENTED IN THE LITERATURE.



III. With respect to the attentional style, Nideffer's hypothesis (Nideffer, 2007) of a different style between open and closed-skills sports will be tested. According to the theoretical model (Nideffer, 1990), a broad-external attentional focus is expected to predict the volleyball players' performance, while a narrow and internal attentional focus is expected to be predictive of the artistic gymnasts' performance. We also predict an overloaded attentional focus to be detrimental for both sports. A graphical representation of the hypothesis is shown in Figure 13. For a description of the observed variables, see chapter 3, section 3.2.3.

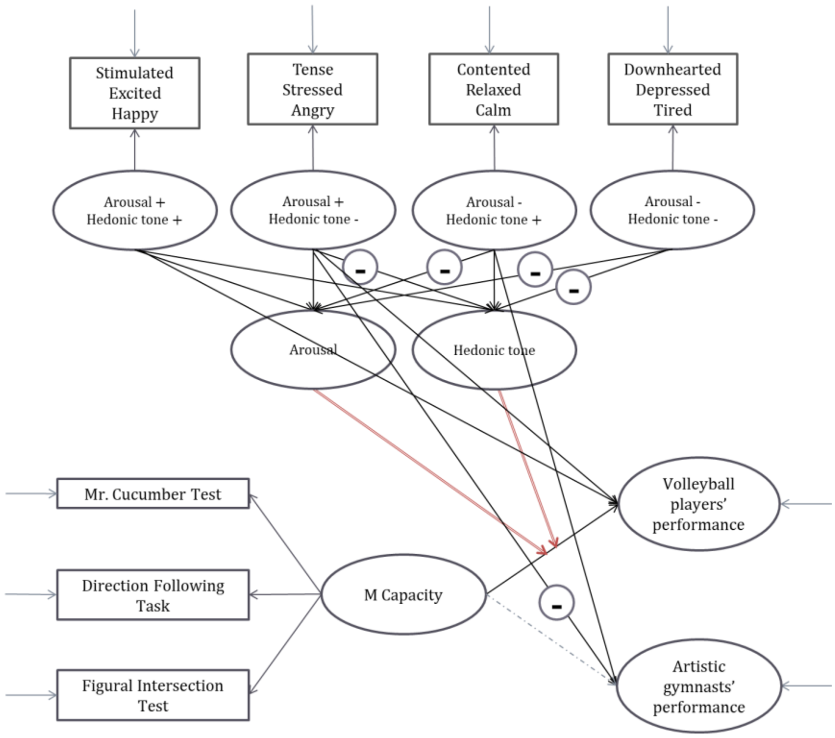
FIGURE 13. HYPOTHESIS ON THE ROLE OF ATTENTIONAL STYLE AS A PREDICTOR.



IV. We decided to adopt a nomothetic approach to study the emotional states, using the Circumplex model as a theoretical framework (Posner & Russell, 2005; Russel, 1980). This choice was motivated by the main aim of this study, i.e. to offer an integrated descriptive model of the predictors of sport performance and to compare two different types of sports. On this basis, it is expected that emotions attributable to different quadrants of the circumplex will predict the performance differently in the two sports. Specifically, it is expected that the artistic gymnasts' performance will be predicted by low arousal-pleasant hedonic tone emotions and high arousal-unpleasant hedonic tone emotions, respectively with positive and negative coefficients. High-arousal emotions, regardless of whether with the pleasant or unpleasant hedonic tone, are expected to have a direct positive effect on the volleyball players' performance (Ruiz et al., 2017), although to a lesser extent than in contact sports (Campo et al., 2012). Moreover, a moderation effect of the emotional hedonic tone on the relation between working memory and sport performance will be tested (Furley et al., 2015) in order to verify if unpleasant emotions actually have a detrimental moderating effect as suggested by the chocking-under-pressure theories (Baumeister, 1984; Beilock, 2007; Gimmig et al., 2006; Hill et al., 2010, 2011). A graphical representation of the hypothesis is shown in Figure 14. For a description of the observed variables, see chapter 3, section 3.2.4.

In this study, we decided to adopt a nomothetic approach, coherently with our main aim of offering a general model of the role of cognition and emotion in sports. Nevertheless, from a sport psychology perspective, we recognise that analysing the role of emotions merely with this approach can be limiting. Indeed, as suggested by the Individual Zone of Optimal Functioning model (IZOF: Hanin, 2000, 2002, 2014), emotions in sports can be equally pleasant or unpleasant, functional or dysfunctional with respect to the athlete's individuality. To better describe the role of emotions in sport performance, we also adopted an idiographic approach, by administering to part of the participants to this study the IZOF questionnaire as well. The data collected on this measure, however, will not be presented in this dissertation, but they will be the subject of a separate study.

FIGURE 14. HYPOTHESIS ON THE ROLE OF EMOTIONS AS PREDICTORS. THE DARK RED LINES REPRESENT THE MODERATION EFFECTS.



CHAPTER 3. METHODS

3.1 PARTICIPANTS

A total sample of youth 239 athletes, namely volleyball players (N = 127) and artistic gymnasts (N = 112), aged between 11 and 17 years, participated in this research (M = 168.77, SD = 20.80; M_V = 171.67, SD_V = 20.48; M_G = 165.95, SD_G = 20.84. Age is here expressed in months).

Volleyball players were recruited from seven different academies in Northern Italy (Genoa, Massa Carrara, Pietrasanta, Imperia, Verona). Similarly, artistic gymnasts were recruited from eight academies in Northern Italy (Genoa, Turin, Cuneo, Verona). Since both sports, artistic gymnastics in particular, are predominantly practised by girls, we preferred to include only female participants in the study, in order to avoid gender-related biases. We choose the age range according to two needs: on the one hand, we needed to guarantee a high developmental variability to detect a developmental trajectory in cognitive functioning, on the other hand, we had to include sufficiently meta-conscious participants for the compilation of self-report measures. Moreover, to ensure that all participants experienced a reasonable amount of practice and competitions, we enrolled athletes with at least three years of experience in the sports of interest. Three age-groups (namely 11-12 years old, 13-14 years old, and 15-17 years old) equally distributed in the two sports sub-samples were included in order to guarantee a sufficient variability of the M capacity (Bisagno & Morra, 2018; Morra, Gobbo, Marini, & Sheese, 2012; Pascual-Leone & Baillargeon, 1994) and EFs measures (Diamond, 2014; Lee, Bull, & Ho, 2013; Miyake et al., 2000).

Parents provided informed consent for participation. Among volleyball players, seven participants did not complete all tasks, while six didn't play any match during the sport season. Among artistic gymnasts, three participants didn't complete all tasks, while five got injured and were not able to compete during the sport season. This left us with 218 participants, namely 104 artistic gymnasts and 114 volleyball players. The participants are distributed in three age groups, as follows:

11-12 years (N = 70; M = 148.15 $\pm$ 5.56; M_v = 151.04, SD = 4.39; M_G = 146.00 $\pm$ 5.37);

13-14 years (N = 73; M = 166.70 $\pm$ 5.84; M_v = 167.24, SD = 4.67; M_G = 165.23 $\pm$ 7.24);

15-17 years (N = 75; M = 198.91 $\pm$ 12.23; M_v = 201.58, SD = 11.97; M_G = 196.39 $\pm$ 11.65).

The data relating to the final sample are shown in Table 3, for the volleyball players, and in Table 4 for the artistic gymnasts.

TABLE 3. VOLLEYBALL PLAYERS DATA

Club	City	Age group	*N*
Serteco Volley School	Genoa	11-12 years	15
		13-14 years	17
Spazio Sport Volley		15-17 years	15
Santa Sabina Volley		11-12 years	8
Maurina Volley	Imperia	11-12 years	5
		15-17 years	8
Libertas Montorio Volley	Verona	11-12 years	7
Pietrasanta Volley	Pietrasanta	13-14 years	10
		15-17 years	3
Nuova Robur Massa	Massa Carrara	13-14 years	10
		15-17 years	16
Total		**11-12 years**	**35**
		13-14 years	**37**
		15-17 years	**42**
		Total	**114**

TABLE 4. ARTISTIC GYMNASTS DATA

Club	City	Age group	*N*
Società Ginnastica Comunale Sampierdarenese	Genoa	11-12 years	1
		13-14 years	3
		15-17 years	4
PGS Auxilium A.S.D. – sez. Ginnastica Artistica		13-14 years	4
Società Ginnastica Artistica Andrea Doria		11-12 years	12
		13-14 years	8
		15-17 years	4
Ginnastica Rubattino		11-12 years	5
		13-14 years	3
		15-17 years	8
A.S.D. Tegliese – sez. Ginnastica		11-12 years	7
		13-14 years	4
		15-17 years	1
G.S.D. Regina Margherita Ginnastica		11-12 years	2
		13-14 years	3
OGAWA Ginnastica		15-17 years	6
G&A Academy	Turin	15-17 years	4
Ginnastica Artistica Est Veronese	Verona	11-12 years	7
		13-14 years	5
		15-17 years	3
Fondazione Marcantonio Bentegodi – sez. Ginnastica Artistica		13-14 years	5
Cuneo Ginnastica	Cuneo	11-12 years	1
		13-14 years	1
		15-17 years	3

Total	11-12 years	35
	13-14 years	36
	15-17 years	33
	Total	104

In order to compare the two sub-samples with respect to the control measures, we run an independent samples t-test. Results showed that the athletes of the two sports were comparable with respect to the Age (t=-1.72, *p* =.09; M_V = 174,45; M_G = 168,94). Regarding the years of experience, instead, the t-test showed a difference (t= 5.42, *p* <.001) between volleyball players (M = 5,66) and artistic gymnasts (M = 7,56). Indeed, even if the athletes of both sports were quite experienced, it is not surprising that the artistic gymnasts counted a higher experience than the volleyball players since artistic gymnastics is a particularly early sport.

3.2 MATERIALS

In order to assess the general cognitive abilities that we used as predictors, we administered three WM capacity tasks (Mr Cucumber Test, Figural Intersection Test and Direction Following Task, all designed within the theoretical framework of the TCO) – that have already been used in a research with young volleyball players (Bisagno & Morra, 2018), and six executive functions tasks -two inhibition tasks (a Stroop Task and an Arrow Flanker Task), two shifting tasks (Colour/Shape Task and Trail Making Test) and two updating tasks (Keep- Track Task and a N-Back Task). Moreover, to assess the attentional style, we administered the Test of Attentional and Interpersonal Style (TAIS) by Nideffer (1976) and, for the emotion-related variables, we used a questionnaire developed within the Circumflex model (Russel, 1980). All the tests are described below.

3.2.1 M CAPACITY MEASURES

MR CUCUMBER TEST (CASE, 1985; MORRA, 1994). This test is designed within the theoretical framework of the TCO; normative data for Italian children can be found in

Morra (1994) and Morra, Moizo, & Scopesi (1988). In this test, the participant is shown the outline of an extra-terrestrial figure called Mr Cucumber (or, in Italian, *Mr Nocciolina*), to which coloured stickers had been attached: the request is to remember the stickers' positions and point to them on a Mr Cucumber outline without any sticker on it. The number of coloured stickers to remember increases at each level, and the levels represent the M demand for the various tasks. There are seven levels with three items each, plus a level 8 including only one item. The items of levels 1 to 5 are presented to the participant for five seconds, while from level six the participant is allowed to look at Mr Cucumber for a number of seconds equal to the number of stickers on it. The administration of the test is discontinued when the participant fails all three items at a level. One point was given for each consecutive level on which a subject got at least two items correct, and one-third of a point for each correct item above that level. For the level 8 item, one point is given if level 7 has been assessed for one point as well; otherwise, the correct answer is given one-third of a point.

FIGURAL INTERSECTION TEST (FIT: PASCUAL-LEONE & BAILLARGEON, 1994). The FIT, whose convergent validity with four other working memory tests has also been verified on samples of Italian children (Morra, 1994b; Morra et al., 1988), consists of a booklet in which, in each item, some geometric forms are represented: on the right side of the sheet, they are scattered, while on the left one they are represented in a single configuration. On the left, in addition to the forms on the right (possibly rotated or changed in size), there can be an extra form (i.e. a distractor). The number of forms on the left configuration, in each item, represents the number of information units that the participant must integrate (i.e., the M demand). The items are divided into nine levels (not presented in order of difficulty) and each level comprehends four to six items, with the exception of the ninth, which has only one. The participant's task is to indicate, by placing a dot with a red pen, the intersection of all the forms in the configuration on the left side. An item is considered incorrect if: a) the space indicated as the intersection of the shapes is not the correct one; b) the item has been omitted; c) the dot was placed on a line instead of within a space; d) there is more than one sign. A level is failed if the participant commits two or more errors: the final score is given by the last consecutive level in which the participant has achieved the criterion, plus 1 for each additional level eventually matching the criterion. The ninth item accounts as 1 more, only if all eight previous items have been successfully passed.

DIRECTION FOLLOWING TASK (DFT: CUNNING, 2003; PASCUAL-LEONE & JOHNSON, 2005). The DFT involves oral commands of different complexity and in which the information load varies systematically. Materially, the test consists of an openable and re-sealable board, on whose side there are painted 10 square spaces, large and small, of different colours (white, yellow, green, blue and red); the other side is white. There are also 20 plastic tokens, squares or circles, also large or small, and of various colours (white, yellow, green, blue and red). The tokens are randomly scattered by the experimenter on the white half of the board: the participant is required to move them on the spaces, according to the experimenter's instructions. The instructions are given to the participant when the board is closed: when the experimenter opens it, the participant can proceed to arrange the tokens on the spaces. The DFT includes five practice items and forty-five test items, five for each of the nine levels of increasing syntactic complexity and information load. People over 12 years of age start from level 2 because success in the first level is taken for granted. The test ends when the participant scores 0 or 1 out of 5 on two consecutive levels. There are three types of syntactic constructions in the DFT, namely:

(i) Place [token] on [space], for example: "Put a blue square on a white space";

(ii) Place [token1] and [token2] on [space], for example: "Put a red square and a white circle on a small yellow space";

(iii) Place [token1] on [space1] and [token2] on [space2], for example: "Put a green circle on a yellow space and a blue square on a red space".

Spaces are described with one or two words (colour and/or size), and each shape can be described with a combination of three features at most, as in the case: "a small green circle". In this way, it is possible to increase the M demand that the participant has to elaborate both through the complexity of the sentence and through the number of features included. Pascual-Leone and Johnson (2011) assume that the meaning of the verb *place* and the noun *space* become automatized after the practice items and that two features (essentially, shape and colour) of the first token named in a sentence can be chunked together. No further chunking is assumed to occur beyond that. Thus, for example, the M demand of the item "Place a blue square on a white space" would be $e+2$, where *e* is a constant representing the processing load of the task executive, and 2 is the number of schemes that need to be kept activated, i.e., blue-square and white (Morra, Camba, Calvini, & Bracco, 2013). Pascual-Leone and Johnson (2005; 2010) reported results from Canadian participants, both children, and adults, which are fully consistent with this task analysis. Moreover, they also report experimental evidence that the DFT correlates with other measures of M capacity: this leads us to think that the DFT is a valid test of M capacity measurement. In this research, we used the Italian adaptation of the test (Morra et al., 2013).

3.2.2 EXECUTIVE FUNCTIONS MEASURES

3.2.2.i Inhibition

As regards the inhibition tasks, we decided to use not only a test of response inhibition but also a measure the athlete's ability to deal with cognitive interference, considering that, based on our hypotheses, this kind of inhibition could discriminate better closed from open-skills sports.

STROOP TEST (FRIEDMAN ET AL., 2008; STROOP, 1935). A Stroop Task was implemented in E-Prime, based on the procedure described by Friedman and colleagues, who used it with 17 years old participants. In this test, for each item, a white fixation cue is presented on a black screen for 500 milliseconds, then followed by the stimulus. The stimulus remains on the screen for 5000 ms. (or until the participant has responded), after which the screen turns black for 1000 ms. Participants are asked to verbally name, in a microphone connected to a response box, the colour of each stimulus as quickly and accurately as possible. We implemented three conditions: (a) 60 trials with a string of asterisks (of variable lengths corresponding to those of colour-words) printed in one of the colours (red, green, blue, orange, yellow or purple); (b) 60 incongruent trials, with colour-word printed in a different colour; (c) 60 filler trials, with a neutral word, also of length corresponding to one of the colour words, printed in one of the six colours. The order of tests was randomized and no word or colour was bound to the next word or colour. Furthermore, no more than three consecutive items belonged to the same condition. The trials were divided into three blocks and 18 practice trials were provided.

ARROW FLANKER TEST (ERIKSEN & SCHULTZ, 1979; RIDDERINKHOF, VAN DER MOLEN, BAND, & BASHORE, 1997). The task, as developed by Ridderinkhof and colleagues, was acquired from Inquisit 5 Lab by Millisecond. In each item of the test, a black rectangular box is presented in the middle of a white screen, as a cue. After 1000 ms., a horizontal matrix is presented, consisting of five identical arrows, which can point all to the same direction (congruent condition) or to different directions, namely the central arrow points to one direction, while the side-flanking ones to the opposite direction (incongruent condition). The subject is asked to indicate, by pressing on the keyboard ("Q" for left and "P" for right) as quickly and accurately as possible, the direction of the central arrow. The time between the target appears and the next cue is presented is 1750 ms (response timeout). When the participant responds, the next cue is presented after 750 ms. This version of the test was used by the authors both with children up to 12 years old and with university students, but it was also used to assess adolescents (Baumgartner, Weeda, van der Heijden, & Huizinga, 2014).

3.2.2.ii Shifting

COLOUR/SHAPE TASK (ADAPTED FROM MIYAKE, EMERSON, PADILLA, & AHN, 2004). This test was also administered via Inquisit 5 Lab, adapting its original version (Miyake et al., 2004) in order to reduce the number of conditions presented to the participant. In each trial of this task, the participant sees a shape (circle or triangle) superimposed on a square (red or green): they are asked to categorize the stimulus (pressing "A" or "K" on the keyboard) with respect to the shape or to the colour of the square below it, according to the cue presented to them (the word "SHAPE" or "COLOUR", which appear at the top of the screen, 350 ms. before the stimulus itself). The task provides, in the adapted version, 112 trials divided into two blocks, plus 24 practice trials. Furthermore, there are 24 trials for every single condition (shape or colour only), each one preceded by 12 practice trials. The test was validated with adolescents by Friedman et al. (2008, 2016).

TRAIL MAKING TEST (TMT: ARMITAGE, 1946; REITAN, 1958). The TMT is a paper-pencil test that can be easily administered and that consists of two versions: A and B. Within the TMT-A, the participants are asked to connect in ascending order 25 digits scattered on the sheet in pseudo-random order, while in the TMT-B the targets are both numbers and letters and the subject must alternate them in increasing order as well (1, A, 2, B, etc.), being as fast and accurate as possible. The participants are also required not to lift the pen from the sheet after they have started and, if they make a mistake, they are asked to correct it. Before the actual task was performed, it was explained to the participants, they practised and were given the possibility to ask any clarifying question. For both TMT-A and TMT-B completion time was recorded by the experimenter with a timer; the dependent variable is calculated as the difference between the completion time of parts B and A.

3.2.2.iii Updating

N-BACK TEST (ADAPTED FROM JAEGGI ET AL., 2010). Also, this test was administered via Inquisit 5 Lab, adapting it from Jaeggi et al., (2010). The test followed the administration method used in the original version, but the stimuli have been modified: the original task, which was administered to university students, used unnameable and hardly distinguishable spatial material, which we assumed would have placed an excessive cognitive load for our young participants. For this reason, these stimuli have been replaced with simpler ones, namely eight forms of three different colours: green, purple and blue. In two cases, the same shape could appear in two different colours, according to the scheme: [GREEN: A - B; BLUE: B - C - D; PURPLE: D - E - F]. In this way, the updating task is not complicated too much by the indistinguishability of the stimuli, but, at the same time, the stimuli are not either easily subjected to a verbal coding strategy. During the test, the participants are then shown the sequence of visual stimuli (shapes) and are asked to respond by pressing the letter "A" on the keyboard each time the current stimulus (the one they are looking at) is identical to the one presented *N* positions earlier; on the contrary, no response is required for non-targets. The stimuli are presented on a black background, each for 500 ms., with 2,500 ms inter-stimulus interval. There are three levels of increasing difficulty: in the 2-back, the current stimulus has to be compared with the one that appeared two positions earlier, in 3-back and 4-back the task is the same, but the comparison is made with the shape respectively three or four positions earlier. Each level consists of three blocks of 20 trials each (6 targets and 14 non-target) and it is preceded by a practice trial. We scored the total percentage of errors for each participant.

KEEP TRACK TEST (FRIEDMAN ET AL., 2008; YNTEMA, 1963). In the Keep Track task, participants are asked to keep track of some words that are shown to them in a list, namely remember the last one they have seen, among those belonging to given target categories. During the “learning phase”, six different categories (animals, colours, countries, fruits, metals and relatives) and forty-eight stimulus-words (for example: dog, red, France, apple, zinc, father) are shown on the computer screen: the participant was asked to read them aloud, in order to make sure she becomes familiar with the stimuli used in the experiment. During the actual task, fifteen words, 2 or 3 per each of the 6 categories are presented serially, in random order, in the middle of the screen for 1500 ms. each, while the target categories remain visible at the bottom of the screen. The participant's task is to remember the last word presented per each of the target categories. The task is made up of three levels of increasing difficulty, so that the participants have first to remember the words related to two categories, then to three, and then to four. Twelve trials are presented, i.e., four for each level of difficulty; they are preceded by a training phase of three trials (one per each level). We scored the total percentage of errors for each participant. The test was validated by Friedman et al. (2008), with a large sample of seventeen-year-olds.

3.2.3 ATTENTIONAL STYLE MEASURE

TEST OF ATTENTIONAL AND INTERPERSONAL STYLE (TAIS) (NIDEFFER, 2002; NIDEFFER, 1976; NIDEFFER, 2007). According to the framework of Nideffer's theory, data regarding the participants' attentional style were collected through the Italian version of the Test of Attentional and Interpersonal Style. In its full original version, this test consists of 144 items that describe situations of daily life, asking the individual to self-evaluate attention and interpersonal characteristics deemed important to predict performance. Responses are given on 0-4 Likert scales; the overall score on each scale is obtained by adding the values attributed to each item.

The test comprises twelve subscales, six regarding the individual's interpersonal style and six regarding the individual's attentional style. The internal consistency for the six attentional subscales averages 64.5 and ranged from .57 to .72. (Landers, 1981; Vallerand, 1983; Van Schoyck & Grasha, 1981). In order to examine the relationship between attention and athletic performance, most researchers have used only the six attentional subscales of the TAIS. Three of these subscales measure the effective use of attention, by assessing to what extent individuals can effectively broaden their attentional focus, either external (BET) and internal (BIT) and the extent to which they can effectively narrow their focus of attention (NAR). The other three subscales reflect an individual's tendency to adopt a dysfunctional attentional focus. Specifically, these subscales indicate the extent to which one has a reduced attentional focus (RED) and is overloaded by external (OET) and internal (OIT) stimuli (Summers et al., 1991).

The short version of the TAIS includes only twelve items regarding the attentional style and it is composed by six subscales (i.e. the same of the full version, namely BET, BIT, OET, OIT, NAR and RED) of two items each. This version has the same statistical properties of the full version (Nideffer, 2007) and is popular in sports studies because of its practicality. In this research, the Italian adaptation of the abbreviated form of the test (Lipoma et al., 2006) was used. A description of the scales can be seen in Table 5, while the complete measure can be seen in the *Appendix*.

TABLE 5. TAIS SCALES DESCRIPTION (SEE NIDEFFER, 1976)

Scale	Abbreviation	Description
Broad external attentional focus	BET	A measure of the ability to develop a broad external focus of concentration. People who score high on this scale describe themselves as capable to integrate many external stimuli at the same time.
Overloaded by external stimuli	OET	A measure of the tendency toward environmental distractibility or overload. A high score in this scale means the individual makes mistakes because he/she's overloaded with external stimuli.
Broad internal attentional focus	BIT	A measure of the ability to develop a broad-internal focus of concentration. High scores indicate that individuals see themselves as able to integrate information from several different areas.
Overloaded by internal stimuli	OIT	A measure of the tendency toward internal overload or distractibility. The higher the score, the more mistakes individuals are likely to make by thinking about too many things at once.
Narrow attentional focus	NAR	A measure of the ability to narrow the focus of concentration. The higher the score, the more effective individuals perceive themselves as being able to narrow their attention when needed.
Reduced attentional focus	RED	A measure of a tendency toward a reduced focus of concentration. A high score on this scale indicates that the individuals make mistakes because they excessively narrow their attention.

3.2.4 EMOTIONAL CORRELATES

"CIRCUMPLEX" QUESTIONNAIRE. In order to evaluate the athletes' emotional states with respect to the competition, a short twelve-items questionnaire was administered. The participants were asked to evaluate, on a Likert scale from 1 to 7, how often, before a competition, they felt: tense, stressed, angry (high-arousal, unpleasant hedonic tone); discouraged, depressed, tired (low-arousal, unpleasant hedonic tone); serene, relaxed, calm (low-arousal, pleasant hedonic tone); stimulated, excited, happy (high-arousal, pleasant hedonic tone). The twelve adjectives were chosen as the most recurrent in the literature, also with respect to the performance in sports studies (Russell, 1980, 2003, Posner et al., 2005). By choosing the adjectives, we assumed the dimensions of arousal (high and low) and hedonic tone (pleasant and unpleasant) in a nomothetic and “standardized” way, so that the adjectives could hypothetically be collocated in the four quadrants of the Circumplex model in groups of three. The factor analyses we performed on the data then confirmed the four-quadrants structure. The complete questionnaire can be seen in the *Appendix*.

3.2.5 PERFORMANCE MEASURES

The main purpose we aimed to with respect to the performance measures was for them to be as much ecological as possible. This because we wanted results to be related to real field performance, and not to an experimentally designed lab-task.

For these reasons, we focused on actual competitions the athletes participated in during a whole sports year.

- With respect to artistic gymnasts, we collected for each participant all the scores on all the apparatus in individual and team competitions in the regional and national championship during the sports year (January to September) 2017. We decided to refer to this only year because, after the Olympic Games in Rio 2016, the whole scores system in artistic gymnastics was renewed. For this reason, we decided not to include the athlete’s performance with respect to 2016 competitions because they would have been set on a different score system and, therefore, not comparable with the 2017 ones.

  The sports activities offered by the F.G.I. (*Federazione Ginnastica Italiana*, the Italian Gymnastics Federation) are differentiated between competitive and not-competitive. Among the competitive, there are two sports programmes. The Gold programme, which is a high elite programme meant for National-level athletes, imposes a pre-defined technical programme structured by age. Conversely, in the Silver programme, the technical difficulties of each exercise can be chosen regardless of age, even if the ranking is still divided per age. Both programmes impose both Team and Individual competitions.

Since our 104 artistic gymnasts sample includes both Gold and Silver athletes, whose score in competitions is computed with different rules and grids, we standardized all the scores in order to make them comparable. The procedure we used is described in the *Preliminary analyses* Chapter.

- Collecting a proper performance measure for the volleyball players sample was a harder task, because -this being an individual differences study- it required to derive an individual measure from team performance. In order to do so, I created a scoring system similar to the one used in scouting but focused on all the gestures a single athlete performs during a game.

  We video-recorded at least three matches for each athlete during the 2017-2018 regional championship. Two blinded raters, both volleyball coaches, independently evaluated each athlete's performance and calculated an individual performance index. To do so, every time that a participant (identified through her jersey number) touched (i.e., made contact with) the ball, her gesture was evaluated with the attribution of 0, 1 or .5 points. A point was attributed for every single contact a participant made with the ball, except for the block, which was not scored unless it ended the action (point gained for the team).

  The final raw individual score was computed on a grid (see Figure 15) for each *Set*[1] of the game by adding together all the points scored by the participant. The criteria by which the points were attributed by the raters are summed up in Table 6.

[1] Set: Each section in which the game is divided. In all there are 5, of which the first 4 of 25 points, the last of 15. In this thesis, in order to distinguish it from the set meant as a technical gesture, I will write it with the initial capital letter and in italic font.

TABLE 6. ATTRIBUTION CRITERIA OF THE RAW INDIVIDUAL SCORE CALCULATION.

Points	Criterion	Examples
0	The athlete causes the loss of the point for her team	1. The ball is lost; 2. Foul.
1	The athlete makes positive contact with the ball	1. Any gesture resulting in a point gained for the team; 2. A serve[2] reaches the opponents' court without touching the tape[3] / Ace (namely a serve that results directly in a point); 3. A pass[4] is played less than 1.5 meters away from the setter (or the auxiliary setter[5]); 4. A proper (i.e., easy to attack) set[6] played by the setter; 5. An attack reaches the opponents' court without touching the net; 6. A challenging dig[7], even when not precise; 7. A block[8], if resulting in a point gained for the team.
0.5	The athlete plays a ball which can still be played, but it is not precise	1. A serve reaches the opponents' court after touching the tape; 2. A defence is played more than 1.5 meters away from the setter (or the auxiliary setter), but the ball can still be played; 3. The setter set a ball that is hard-to-attack for the hitter; 4. An attack reaches the opponents' court after touching the tape. 5. An attack is "wasted" by setting an "easy" ball to the opponents' instead of spiking.

[2] Serve: One of the six basic skills; used to put the ball into play. It is the only skill controlled exclusively by one player.
[3] Tape: The top of the net.
[4] Pass: Receiving a serve or the first contact of the ball with the intent to control the ball to another player.
[5] Auxiliary setter: the player assigned to set when the designated setter cannot; usually the right-front player.
[6] Set: The tactical skill in which a ball is directed to a point where a player can spike it into the opponent's court. In this thesis it will be written in all lower case in order to disambiguate the term that refers to a fraction of the game.
[7] Dig: Passing a spiked or rapidly hit ball. Slang for the art of retrieving an attacked ball close to the floor.
[8] Block: A defensive play by one or more front row players meant to intercept a spiked ball. The combination of one, two or three players jumping in front of the opposing spiker and contacting the spiked ball with the hands.

FIGURE 15. PROTOTYPE OF OBSERVERS' GRID.

Volley team: ________					Rater: ____			Match date: ________				Result: 25-18					
S1	1	1	1	0	1	1	$^1/_2$	1	1	1	0						9/12
S2																	
S3																	
S4																	
S5																	

Even if the purpose of this procedure was to obtain an individual score, we could not ignore that volleyball is a team sport, in which the individual performance is highly influenced by the team and the opponents' behaviour. In order to control for this variable, we also collected, for each set, the final score and calculated the difference by which the participant's team won or lost. We, therefore, used this team performance measure to create a team-weighted individual performance index, as described below.

First of all, for each *Set*, we calculated the athlete's individual ratio (IR) between the total amount of touches[9] (T) and the individual score computed by adding all the points (IS). For example, in Figure 15: $(T = 12; IS = 9); IR = IS/T; IR = 9/12$. Secondly, we used the team performance index (i.e., the difference by which the participant's team won or lost; in Figure 15: $TPI = 25 - 18; TPI = +7$) in order to calculate a weighted game index (WG) of all the *Sets* the athlete played in. This index represents the team performance controlled for the total number of touches (TT, i.e., the "contribution" the athlete gave to the team) the athlete performed in all the *Sets* she played and it is computed as follows:

$$WG = \frac{(T_1 * TPI_1 + T_2 * TPI_2 + T_3 * TPI_3 \ldots + T_n * TPI_n)}{TT}$$

In the end, the final weighted individual index of performance (WIP) was calculated for each participant for both observers by saving the residuals of the regression of IR on WG. In order to derive the final performance measure for the volleyball players, we first conducted an interrater reliability analysis, which is described in the *Preliminary Analyses* section.

[9] Touch: A player contacting the ball.

3.3 PROCEDURE

In April 2016 sports clubs were first contacted in order to present the research project: the project was at first presented to the presidency and management of the clubs, then to the coaches and the athletes. Before the start of the study, parental informed consent was obtained. Data collection started in November 2016 and ended in June 2018 (see the Gantt in the *Appendix*). It took place through three sessions with each one of the participants:

- a first (where possible) collective session of 60 minutes, during which were administered, in order, (a) the TAIS (T1), (b) the "Circumplex" Questionnaire and (c) the Figural Intersection Test;
- a second individual session lasting about 50 minutes, with the administration of (a,) the TAIS (T2), (b) the TMT, (c) Mr Cucumber Test and (d) Direction Following Task;
- a third individual session of about 80 min, dedicated to the administration of computerized tests to evaluate the Executive Functions. The order of administration of the tests was the following for each participant: (a) Keep Track (about 20 min), (b) Stroop Test (about 10 min), a 10 mins break, then (c) N-Back Task (about 20 min), (d) Flanker Test (about 5 min) and (e) Colour-Shape Task (about 15 min). The order of the tests was designed not to excessively strain the participant, alternating more and less demanding tasks.

The participants were tested in a quiet room in the training facilities of their own academy or at the Department of Educational Sciences of the University of Genoa.

With respect to the performance measures, the artistic gymnasts' scores were derived from the official F.G.I. *website*, while the volleyball matches were mainly video-recorded by the author of this doctoral thesis or a Psychology student of the University of Genova involved in the project. When it was not able for either of them to be present to the competition, the team coach was instructed on how to take the video in a fashion the players were recognisable and the game actions clearly distinguishable. All videos (namely a total amount of 55 games and approximately 3895 min of game recorded), were then sent to the observers and scored as described in the section above.

Firstly, we run some preliminary analyses on the raw data. We used the trimmed mean (±3 Std. Dev.) to calculate the mean response time for the Stroop task, the Arrow Flanker task and the Colour/Shape task. The trimmed mean is a method of averaging that removes a small designated percentage of the largest and smallest values after removing the outliers and before calculating the mean. It is helpful to eliminate the influence of data on the tails that may unfairly affect the mean.

Afterwards, we checked for data outliers. The outliers were initially treated with univariate analysis and then with a multivariate one, namely Mahalanobis distance. The Mahalanobis distance is a multi-dimensional measure of the distance between a point and the distribution. Indeed, we used regression to determine if specific cases were outlier via the combination of two or more variable scores (i.e., multivariate outliers). We identified two univariate outliers and one multivariate outlier, but, even after eliminating them, the correlations between the cognitive raw measures remained the same. As a consequence, the outliers were reinserted into the sample being replaced with the sample mean.

Afterwards, descriptive statistics and zero-order (Pearson) correlations among all the cognitive measures were calculated. Correlations among cognitive measures with age partialled out were calculated as well. In order to verify the model of our latent cognitive predictors, we conducted a series of Confirmatory Factor Analysis (CFA), based on covariance matrices, using LISREL 8.80. Testing embedded models, we used the following fit indices: Chi-square (χ^2), the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Standardized Root Mean Square Residual (SRMR), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI) and the Akaike information criterion (AIC).

Chi-square is used to assess the overall fit of the CFA model. Non-significant values indicate a negligible discrepancy between the covariance matrix generated by the model and the observed matrix and therefore an acceptable fit. The RMSEA gives a standardized measure of the discrepancy between the specified model, with estimates of the optimal parameters, and the covariance matrix of the population. Acceptable values of RMSEA are considered those $<.08$, while optimal values those $<.05$. The CFI examines the discrepancy between the data and the hypothesised model (Bentler, 1990). Values of CFI $> .90$ are considered acceptable, while values $> .95$ are considered optimal.

The RMR and the SRMR are the square root and the standardized square root of the difference between the residuals of the sample covariance matrix and the hypothesised covariance model. Values for the SRMR range from zero to 1.0 with good-fitting models obtaining values less than .05 (Hooper et al., 2008), however values as high as .08 are considered acceptable (Hu & Bentler, 1999). An SRMR of 0 indicates perfect fit. The GFI represents the proportion of variance accounted for by the estimated population covariance. Values of ≥.95 are considered a good fit and ≥.90 an acceptable fit, respectively (Jöreskog & Sörbom, 1989; Schermelleh-Engel, Müller, & Moosbrugger, 2003). The AGFI favours parsimony and it is considered a good fit with values ≥.90 while values ≥.85 are considered as an acceptable fit (Jöreskog & Sörbom, 1989; Schermelleh-Engel et al., 2003).

The AIC is both a comparison and a parsimony index, which is used to compare at least 2 models that differ on a parameter. The model with the lowest AIC is considered the best fit.

We run a series of CFA for the Attentional Style indices as well, with the difference that, not including embedded models, we compared them indirectly through the Goodness of fit indices.

With respect to the Circumplex Questionnaire's data, we started with an exploratory Factor Analysis with principal axis extraction and both Varimax and Oblimin rotation using the SPSS 22 software. We also tested a hierarchical cluster analysis on a proximity matrix based on squared Euclidean distances. Since the first analysis suggested a three-factor model, while the second consisted of a four-factor one, we conducted again a series of Confirmatory Factor Analysis (CFA) using LISREL 8.80.

After finding the best model fit for the latent variables, we computed the predictors. Therefore, we calculated the inter-rater agreement with respect to the volleyball players' individual performance. The inter-rater agreement (also called inter-rater reliability or inter-observer reliability) represents how much homogeneity there is in the ratings given by various judges. Since we measured pairwise correlation among raters using a ratio scale, we used Pearson's r as inter-rater agreement statistic. Subsequently, we calculated a final performance measure. In order to make the Gold and Silver artistic gymnasts' scores comparable, we also manipulated and standardized their individual scores as described in the *Preliminary Analyses* section.

CHAPTER 4. RESULTS

4.1 PRELIMINARY ANALYSES

4.1.1 Raw Data Manipulation and Descriptive Statistics

Descriptive statistics for the complete sample for the three M capacity measures (i.e., Mr Cucumber test, Direction Following Task and Figural Intersection Test) are summarized in Table 7. Skewness and Kurtosis coefficients were relatively low, therefore all measures did not depart too much from normal distributions. According to the TCO, the score on M capacity tests is not merely an indicator but the actual number of mental schemes the individual is capable to simultaneously activate and integrate. Therefore, it directly represents the individual's M capacity. For this reason, the M capacity measures did not need to be standardized and were used without undergoing any further processing.

TABLE 7. DESCRIPTIVE STATISTICS FOR THE M CAPACITY MEASURES (N=218)

	Mean	St. Dev.	Min.	Max.	Skewness	Kurtosis
Mr Cucumber	6.01	1.18	3.33	8.00	-.14	-.62
DFT	5.26	1.30	3.00	9.00	.33	.20
FIT	6.09	1.34	3.00	9.00	.48	.10

With respect to the executive functions measures, we collected measures both of accuracy and response time, as follows:

- N-back Test and Keep-Track Test. For the updating tests, we collected the total percentage of errors in all trials.
- Stroop Test. We collected both a measure of accuracy, namely the total number of errors in the incongruent condition, and response times in all conditions (i.e., asterisks, filler and incongruent). In order to control for the outliers, we calculated the trimmed mean[10] in all conditions and used the difference

[10] The mean was calculated after discarding response times under 400 ms and over 2000 ms and, subsequently, discarding the response times over ± 3 standard deviations.

between the response time in the incongruent and the asterisks conditions as a cost measure.

- Arrow Flanker Test. We collected a measure of accuracy, namely the proportion of correct responses for all the incongruent trials and a measure of cost, namely the difference between the trimmed means of the reaction times in the incongruent and the congruent condition.
- Colour/Shape Task. We collected a measure of accuracy, namely the proportion of errors on the shift trials, and a measure of cost – given by the difference between the trimmed means of the reaction times in the shift and repeat conditions.
- Trail Making Test. We calculated the difference in the response time between the TMT-B and the TMT-A.

Descriptives for the EFs measures are summarized in Table 8.

TABLE 8. DESCRIPTIVE STATISTICS FOR THE EXECUTIVE FUNCTIONS MEASURES (N=218).

	Mean	St. Dev.	Min.	Max.	Skewness	Kurtosis
Keep Track total errors percentage	.35	.12	.11	.97	1.00	3.40
N-back total errors percentage	.27	.08	.10	.50	.56	.02
Stroop incongruent errors	3.07	2.64	.00	15.00	1.54	3.14
Stroop cost [milliseconds]	143.30	70.00	-41.00	406.00	.85	1.16
Flanker incongruent accuracy	.97	.04	.62	1.00	-4.06	29.06
Flanker cost [milliseconds]	55.33	36.91	-96.07	200.37	.63	2.46
Colour/Shape shift errors	.29	.12	.00	.69	.54	1.24

Colour/Shape cost [milliseconds]	123.32	114.06	-292.00	493.00	.31	1.63
TMT cost [seconds]	30.24	18.93	-1.11	143.79	2.08	7.44

Many variables presented skewed distributions and/or high Kurtosis coefficients. Specifically, some accuracy measures (i.e., meaning that in general, the participants made few errors) and the Trail Making test all exhibited a leptokurtic distribution. The Arrow Flanker measure of correctness, specifically, shows a very high kurtosis and negative skewness, since most of them responded with an accuracy rate of over 90%. In order to proceed with further analyses, we applied a square root transformation to the Stroop error measure, Colour/Shape and TMT cost variables, while for the Flanker, we transformed a measure of accuracy in a measure of error as follows: $\sqrt{1 - \text{the proportion of correct responses}}$. The descriptive statistics of the transformed variables are shown in Table 9.

TABLE 9. DESCRIPTIVE STATISTICS FOR THE TRANSFORMED EXECUTIVE FUNCTIONS MEASURES (N=218).

	Mean	**St. Dev.**	**Min.**	**Max.**	**Skewness**	**Kurtosis**
Stroop incongruent errors Sqrt	1.56	.80	.00	3.87	-.06	.18
Flanker errors Sqrt	.11	.12	.00	.62	.74	.26
Colour/Shape cost Sqrt	.29	.16	.00	.69	.54	1.24
TMT cost Sqrt [seconds]	5.27	1.59	.00	11.99	.65	1.95

Descriptive statistics for the complete sample for the six TAIS subscales at both T1 and T2 are summarized in Table 10. Skewness and Kurtosis coefficients were all close to 0, therefore, also in this case, the measures did not depart from normal distributions.

TABLE 10. DESCRIPTIVE STATISTICS FOR THE TAIS QUESTIONNAIRE'S SUBSCALES (N=218).

	Mean	St. Dev.	Min.	Max.	Skewness	Kurtosis
BET (T1)	4.76	1.44	.00	8.00	-.31	.21
OET (T1)	3.05	1.40	.00	7.00	-.03	-.38
BIT (T1)	4.96	1.45	1.00	8.00	-.32	.28
OIT (T1)	3.50	1.72	.00	8.00	.13	-.64
NAR (T1)	3.98	1.69	.00	8.00	-.06	-.39
RED (T1)	3.48	1.57	.00	7.00	-.06	-.42
BET (T2)	4.90	1.27	2.00	8.00	.13	-.34
OET (T2)	3.39	1.47	.00	8.00	.32	.02
BIT (T2)	4.91	1.36	.00	8.00	-.35	.52
OIT (T2)	3.56	1.73	.00	8.00	.15	-.36
NAR (T2)	3.87	1.66	.00	8.00	.02	-.14
RED (T2)	3.53	1.56	.00	8.00	.17	-.17

Finally, descriptive statistics for the complete sample for the Circumplex Questionnaire’s twelve items are summarized in Table 11. Skewness and Kurtosis coefficients were all close to 0, except for the “Angry” and “Depressed” items, which showed higher values on both indices, meaning that participants tended to assign rather low scores to these two adjectives. Namely, 66% of the whole sample rated the item “Depressed” with one, and another 18% with two. Similarly, 68% of the athletes rated her “Anger” before a competition with 1 or 2 on the Likert scale 1-7. Given these items’ specific distribution, in order to proceed with further analyses, we applied a square root transformation to these two variables. The statistics of the transformed variables can be seen at the bottom of Table 11.

TABLE 11. DESCRIPTIVE STATISTICS FOR THE CIRCUMPLEX QUESTIONNAIRE'S ITEMS (N=218).

	Mean	St. Dev.	Min.	Max.	Skewness	Kurtosis
Stressed	4.33	1.73	1.00	7.00	-.19	-.90
Relaxed	2.90	1.41	1.00	7.00	.49	-.51
Discouraged	2.66	1.31	1.00	7.00	.55	-.11
Happy	5.12	1.44	1.00	7.00	-.58	.05
Tense	5.27	1.64	1.00	7.00	-.62	-.69
Tired	2.76	1.44	1.00	7.00	.66	.09
Excited	4.55	1.54	1.00	7.00	-.40	-.54
Calm	2.81	1.66	1.00	7.00	.65	.50
Stimulated	4.91	1.41	1.00	7.00	-.23	-.52
Depressed	1.55	.90	1.00	5.00	1.65	2.06
Angry	2.27	1.42	1.00	7.00	1.25	1.21
Serene	3.92	1.71	1.00	7.00	-.02	-.99
Depressed Sqrt	1.20	.32	1.00	2.24	1.33	.63
Angry Sqrt	1.44	.44	1.00	2.65	.73	-.27

4.1.2 Measures of M Capacity and Executive Functions

4.1.2.i Correlations Among the Measures of M Capacity and Executive Functions

First, we looked at the correlations between the measures of general cognition.

It was verified that all test used to assess M capacity correlated among them: indeed all of the tests showed a highly significant correlation with one another (p <.001, see Table 12), even partialling out the effect of age: these results are consistent with the literature (e.g., Pascual-Leone & Johnson, 2011). Indeed, M capacity is assumed to be a general resource that grows due to maturation. A battery of tests that aims to measure it must, therefore, include tests with different content (e.g., both verbal and visual stimuli) and requiring different strategies. For this reason, the correlations among them, especially when age is partialled out, cannot be extremely high (Morra, 1994a; Morra & Camba, 2009). However, it remained highly significant.

The two Updating tasks (i.e., the Keep-Track and the N-back) significantly and positively correlated with each other (r = .26, p <.001 with age partialled out). Moreover, being measures of errors, they correlated negatively with all M capacity measures, especially with the DFT and the FIT (p <.001). This makes sense since we consider updating a function of working memory (Miyake et al., 2000). Indeed, Miyake et al. (2000) also tested participants on an operation span. The scores were highly related to updating skills, but not to measures of either shifting or inhibitory control. On this basis, they concluded that there is a common factor underlying operation span and updating.

With respect to the correlations among the other EFs measures, the results are less consistent. Indeed, the two inhibition tasks (i.e. Stroop Task and the Flanker task) appear not correlated in our sample. According to a widely shared distinction (Friedman, 2004; Nigg, 2000, 2001), there are different types of inhibitory control. Among these, prepotent response inhibition (i.e. Nigg's behavioural inhibition combined with oculomotor inhibition) is the ability to deliberately suppress dominant and/or automatic, responses and it is the most associated with executive functioning (Friedman, 2004). The Stroop task is one of the tasks commonly used to assess this function. However, the Flanker task is considered to measure another type of inhibitory control, namely resistance to distractor interference. Resistance to distractor Interference is similar to Nigg's interference control and describes the ability to resist or resolve interference from information in the external environment that is irrelevant to the task at hand. We decided to use this task to address different aspects of inhibition to offer a more complete image of this latent variable. However, this could be the reason the scores of the two measures are not correlated.

Regarding shifting, the TMT cost resulted to be associated only to the Colour/Shape accuracy (i.e. an error measure, r = .19, p <.001, with age partialled out), but not to the cost measure. However, this could be related to the error variance due to the nature of the measures, since the first one is a paper-pencil test, while the second one is a computerized task. The Colour/Shape error index showed to be highly and negatively related also to the M capacity measures (r = -.18 to r = -.36; all p <.01), positively related to the updating measures of error (r = .19 to r =.45; all p <.01) and the number of errors of inhibition the inhibition tests (r = -.30 to r = -.39; all p <.001). Similarly, the TMT cost is negatively related to the DFT (r = -.28, p <.001) and the FIT (r = -.30, p <.001).

Moreover, while the M capacity and the Updating measures scores increased with age, as we would expect in a developmental sample (respectively, r = .26 to r = .33; all p <.001 and , r = -.24 to r = -.32; all p <.001), this did not happen for the Inhibition and Shifting measures, except for the errors in the incongruent condition of the Stroop, i.e., older athletes were more accurate (r = -.18, p <.01) and in the TMT cost, i.e., older athletes showed a smaller difference in response time between the two conditions of the TMT (r = -.33, p <.001).

4.1.2.ii Factor Analyses of the Measures of M Capacity and Executive Functions

Considering that, in this study, M capacity measures were highly correlated with the Updating measures, while the other executive function measures showed an unusual correlation pattern, we tried to determine whether M capacity and executive functions can be grouped as factors similarly to the proposed theoretical models (i.e., for the M capacity see Pascual-Leone, 1987; Pascual-Leone and Johnson, 2005; Morra, Gobbo, Marini e Sheese, 2008; for the EFs see Miyake et al., 2000).

With the aim to clarify this issue, we performed an Exploratory Factor Analysis with Principal Axis Extraction and Varimax rotation. We considered all of the twelve measures described above: the Mr Cucumber test, the DFT and the FIT were assumed to index Working Memory, and the others the executive functions. Three factors accounted for 32% of the total variance. The first factor, accounting for the 17% of the variance on its own, included the Mr Cucumber test, DFT, and FIT (.51, .68, .63, respectively) together with the Keep-Track and the N-Back error measures (-.53, and -.49), the Stroop errors measure (-.31), the Stroop cost (-.26) and TMT cost (-.40). The Colour/Shape and the Flanker accuracy index loaded on the second factor (.63 and .62), while the Colour/Shape cost and the Flanker cost loaded on the third factor (.60 and .26). This model seemed to group in two specific factors the accuracy measures and the costs of the two computerized EF measures, including the Stroop and TMT measures in a factor with working memory and updating measures. For this reason, it didn't offer a clear grouping of the variables.

TABLE 12. PARTIAL CORRELATIONS BETWEEN M CAPACITY AND EXECUTIVE FUNCTIONS MEASURES CONTROLLED FOR AGE.

	[1] Cucumber	[2] DFT	[3] FIT	[4] Keep Track errs.	[5] NB err.	[6] Stroop errs.	[7] Stroop cost	[8] Flanker errs.	[9] Flanker cost	[10] C/S errs.	[11] C/S cost	[12] TMT cost	Age
[1]	1	.427***	.336***	-.258*	-.259**	-.194*	-.150	-.080	-.155	-.283*	-.117	-.164	.330***
[2]	.370***	1	.470***	-.389***	-.401***	-.222**	-.149*	-.170*	-.103	-.349***	.022	-.276***	.275***
[3]	.244***	.412***	1	-.380***	-.426***	-.238**	-.154*	-.171*	-.158*	-.393***	.018	-.302***	.370***
[4]	-.170*	-.330***	-.296***	1	.314***	.223**	.124	.073	.065	.243***	.089	.188*	-.322***
[5]	-.197**	-.359***	-.374***	.258***	1	.233**	.129	.293***	.072	.473***	-.047	.274***	-.240***
[6]	-.146*	-.183**	-.188**	.178**	.199**	1	.127	.143*	.059	.324***	.063	.172*	-.178**
[7]	-.117	-.121	-.117	.09	.104	.108	1	-.037	.033	.081	.091	-.016	-.122
[8]	-.073	-.167*	-.170*	.066	.293***	.14*	-.041	1	.189***	.385***	-.003	.116**	-.034
[9]	-.131	-.08	-.133	.036	.051	.043	.021	.186**	1	.171*	.149*	.119	-.096
[10]	-.183**	-.359***	-.347***	.191**	.446***	.298***	.057	.386***	.155*	1	.041	.243**	-.207
[11]	-.129	.019	.014	.099	-.044	.066	.094	-.002	.151*	.045	1	-.029	-.015
[12]	-.062	-.204**	-.205**	.091	.212**	.122	-.016	.111	.093	.189**	-.026	1	-.331***

Note: Zero-order (Pearson) correlations above diagonal. Partial correlations controlled for age below diagonal. * p <.05, ** p <.01, *** p <.001.

Fixing the factors at two, the explained variance was 27%. The first factor comprised the Mr Cucumber (.49), the DFT (.59), the FIT (.53), the Keep-Track error measure (-.50) and the Stroop cost (-.25). Conversely, the N-back error measure (-.55), the Stroop error measure (.31), the Flanker error measure (.59) and its cost (.23), the Colour/Shape error measure (-.66) and TMT cost (-.40) loaded higher on the second factor. The Colour/Shape cost didn't load on any factor. This second EFA showed a clearer pattern, by dividing the M capacity and one of the updating measures on one side and the Inhibition and Shifting measures on the other, although the N-back and the Stroop cost loaded counter-intuitively.

We, subsequently, proceeded with a set of Confirmatory Factor Analyses to examine more systematically this problem. This operation seemed appropriate to evaluate models more congruent with the theories and results present in the literature. We tested three embedded models. First, basing on the literature, we tested a four-factor model, similar to Miyake's model of EFs (2000) with a separate M capacity factor. The second model considered a three-factor structure, combining inhibition and shifting, that, in this sample, seemed to be correlated in a fragmentary but not clearly distinct way. Finally, a two-factor model assumed an M capacity-Updating factor and an Inhibition-Shifting one. This model combined the updating measures and those of M capacity, given their correlation and coherently with the relationship between the updating measures and the operation span found by Miyake et al. (2000). Table 13 summarizes the fit indices for these models. These fit indices are informative about the general fit of the models to the data. The models are ordered according to the number of factors extracted.

All fit indices were good or acceptable for all of the models. Indeed, all models showed an AGFI of .93 and differed in RMSEA, CFI and SRMR for just a few thousandths. The highest AIC was provided by Model C (the four factors one), which therefore appeared to be the least parsimonious.

The fit of nested models can be compared with a χ^2 difference test, by subtracting the χ^2 value of the less restricted model from the χ^2 value of the more restricted model. The difference of the χ^2 values of the two models is examined, as well as the difference of the degrees of freedom ($\chi^2_{diff} = \chi^2_s - \chi^2_l$ and $df_{diff} = df_s - df_l$, where s is the smaller model, i.e., the model with fewer parameters, while l is the larger model). In general, if the χ^2 diff-value is significant, the "larger" model fits the data better than the "smaller" one. If the χ^2 diff-value is not significant, both models fit equally well statistically, therefore, the parameters in question can be eliminated from the model (fixed to zero) and the "smaller" model can be accepted as well. If we compare the model A (two factors) and B (three factors), $\chi^2_{diff}(1) = 2{,}15$ is not significant . Similarly, if we compare the model A and C, $\chi^2_{diff}(2) = 5{,}40$. Therefore, using a larger model (i.e., three or four factors instead of two) did not offer a significantly better fit, so we decided to prefer a two-factorial structure, coherently with a parsimony criterion.

TABLE 13. FIT INDICES FOR THE COGNITIVE MEASURES MODELS IN ALL COMBINATIONS OF FACTOR STRUCTURES.

Model	Factors	χ^2	df	p	RMSEA	CFI	SRMR	GFI	AGFI	AIC
A	2	63.73	53	.13	.036	.98	.051	.95	.93	117.94
B	3	61.58	51	.15	.033	.99	.055	.95	.93	117.56
C	4	58.33	48	.15	.033	.99	.050	.96	.93	119.81

Note: In model A, the two factors are the following: (1) M capacity/Updating and (2) Inhibition/Shifting; in model B, the three factors are (1) M capacity, (2) Updating and (3) Inhibition/Shifting; in model C, the four factors are (1) M capacity, (2) Updating, (3) Inhibition and (4) Shifting.

In sum, given that the three models had similar fit indices and Chi-Square Difference Tests did not show any significant difference among the three tested models, using a parsimony criterion, we decided to use a two-factor model (see Table 14 for the Phi values and the Lambda-X matrix and Figure 16 for a graphical representation). Differently, from Miyake et al. (2000), we did not find three separated EFs (and a factor of M capacity), but a common "working memory" factor including M capacity and Updating, while inhibition and shifting loaded on another latent factor.

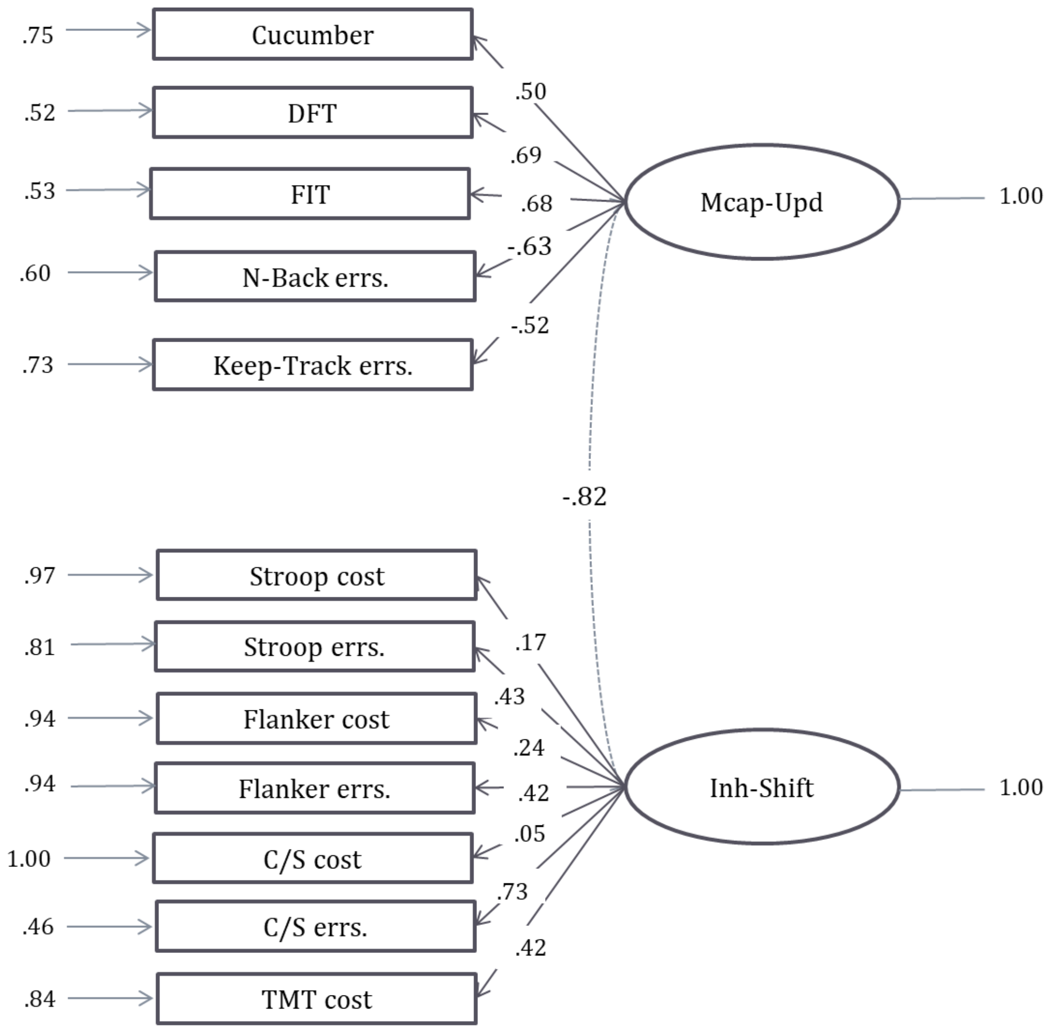
Therefore, from our twelve measures we derived two composite predictors: the first one, derived from the z scores of the Mr. Cucumber test, DFT, FIT, Keep-Track and N-back, will be from now on addressed as the M capacity-Updating (Mcap-Upd) factor, while the second one, derived from the z scores of the TMT cost and both the accuracy and cost measures of the Stroop, Flanker and Colour/Shape tasks will be addressed as the Inhibition-Shifting factor (Inh-Shift).

TABLE 14. LAMBDA-X MATRIX OF THE FACTOR LOADINGS FOR THE TWO-FACTOR MODEL OF GENERAL COGNITIVE MEASURES.

	M Cap-Upd	**Inh-Shift**
Cucumber	.50 (.07) 7.09	---
DFT	.69 (.07) 10.55	---
FIT	.68 (.07) 10.35	---
Keep-Track errs.	-.52 (.07) -7.41	---
N-Back errs.	-.63 (.07) -9.43	---
Stroop errs.	---	.43 (.07) 5.81
Stroop cost	---	.17 (.07) 2.20
Flanker errs.	---	.42 (.07) 5.59
Flanker cost	---	.24 (.08) 3.17
C/S errs.	---	.73 (.07) 10.10
C/S cost	---	.05 (.08) .68
TMT cost	---	.42 (.07) 5.30
Φ (PHI) = -.82 (0.06); -13.48		

Note: For each parameter, the Table shows that the estimated value, (the standard error) and the corresponding z. The C/S cost had a non-significant load on the Ihn-Shift factor. For this reason, we also computed a CFA with only eleven variables. The results did not differ and the C/S cost was, therefore, not excluded.

FIGURE 16. CFA OF THE TWO-FACTOR MODEL OF GENERAL COGNITIVE MEASURES WITH THE STANDARDIZED SOLUTION.



4.1.3 Measures of Attentional Style

4.1.3.i Correlations Among the TAIS Subscales

We analysed the correlations among the six subscales of the TAIS questionnaire that we administered to the athletes twice (T1 and T2), to have a more precise self-report index (see Table 15). We verified that all the subscales of the test had highly correlated scores with each other at the two waves of assessing ($r = -.47$ to $r = -.66$; all $p < .001$), meaning that participants were consistent in their answers. This is consistent with the construct of interest, which refers to a style and, therefore, undergoes little variation over time (Nideffer, 1976). Moreover, significant and positive correlations were found among the BET and BIT dimensions ($r = .20$ to $r = .29$; all $p < .01$), both indicating a broad attentional focus. Similarly, the same subscales were negatively correlated with the OET and OIT subscales (r = -.18 to r = -.24; all p <.01), which describe an overloaded attentional style. Finally, the subscale RED (reduced attentional focus), indicating a more dysfunctional attentional style, shows consistent correlations with both the subscale NAR (narrow attentional focus, r = -.20 to r = -.28; all p <.01) and the other scales (i.e., OET, r = .31 to r = .43; all p <.001 and OIT, r = .41 to r = .44; all p <.001).

4.1.3.ii Factor Analyses of the Measures of Attentional Style

In order to investigate the factor structure of the attentional style measure, we performed an Exploratory Factor Analysis with Principal Axis Extraction and Varimax rotation. We considered twelve measures, namely the six subscales of the TAIS questionnaire both at T1 and T2. Four factors were extracted and explained 53% of the total variance. The first factor, comprised the BET subscales at T1 and T2 (.68 and .87, respectively), thus being an external focus index. Similarly, BIT at T1 and at T2 loaded higher on the second factor (.76 and .81), constituting an index of internal focus of attention. A third factor was loaded by NAR at T1 (.62) and NAR at T2 (.68), describing a narrow focus of attention. Finally, the fourth factor included the OET subscales (.52 at T1 and .62 at T2), the OIT subscales (.75 both at T1 and T2) and the RED subscales (.60 at T1 and .64 at T2): This last factor appeared to describe an overloaded or, in general, dysfunctional attentional style. In order to compare these results with Nideffer's theoretical model (Nideffer, 1976), we performed again a CFA.

According to the author, the TAIS latent structure usually results in two or three factors depending on the analysis, and/or the population being studied (Nideffer, 2007).

Since we have a sample of athletes but our EFA suggested a four-factor solution, we tested two different CFA models. The first model assumed that the subscales loaded four different factors, i.e., an "External focus" factor (BET subscales), an "Internal focus" one (BIT subscales), a functional "Narrow focus" factor (NAR subscales) and a dysfunctional "Overloaded focus" one (OET, OIT and RED subscales). The second model, similarly to Nideffer's (2007) assumed the data are accounted for by three factors, all including both functional and dysfunctional aspects.

TABLE 15. ZERO-ORDER CORRELATIONS BETWEEN THE TAIS SUBSCALES.

	BET (T1)	OET (T1)	BIT (T1)	OIT (T1)	NAR (T1)	RED (T1)	BET (T2)	OET (T2)	BIT (T2)	OIT (T2)	NAR (T2)	RED (T2)
BET (T1)	1	-.216***	.248***	-.153*	.157*	-.163*	.662***	-.193**	.207**	-.098	.101	-.120
OET (T1)	-.216**	1	-.177**	.380***	-.186**	.308***	-.319***	.533***	-.198**	.331***	-.097	.355***
BIT (T1)	.248***	-.177**	1	-.232***	.150*	-.132*	.296***	-.076	.653***	-.231***	.161*	-.130
OIT (T1)	-.153*	.380***	-.232***	1	-.192**	.427***	-.135*	.434***	-.108	.696***	-.132*	.415***
NAR (T1)	.157*	-.186**	.150*	-.192**	1	-.211**	.195**	-.193**	.140*	-.149*	.466***	-.271***
RED (T1)	-.163*	.308***	-.132*	.427***	-.211***	1	-.220**	.344***	.008	.411***	-.123	.610***
BET (T2)	.662***	-.319***	.296***	-.135*	.195**	-.220**	1	-.238***	.277***	-.148*	.191**	-.175**
OET (T2)	-.193**	.533***	-.076	.434***	-.193**	.344***	-.238***	1	-.032	.438***	-.083	.416***
BIT (T2)	.207**	-.198**	.653***	-.108	.140*	.008	.277***	-.032	1	-.112	.104	.008
OIT (T2)	-.098	.331***	-.231***	.696***	-.149*	.411***	-.148*	.438***	-.112	1	-.108	.433***
NAR (T2)	.101	-.097	.161*	-.132*	.466***	-.123	.191**	-.083	.104	-.108	1	-.238***
RED (T2)	-.120	.355***	-.130	.415***	-.271***	.610***	-.175**	.416***	.008	.433***	-.238***	1

Note: * p <.05, ** p <.01, *** p <.001. Cells showing the correlations between T1 and T2 of the same subscale are highlighted.

Table 16 summarizes the fit indices for both models. As can be easily seen, the four-factorial model appears, in this case, a better fit for the data: all of the fit indices are not only better than those of model B but also optimal (AGFI = .93; CFI = .99). Moreover, it has a considerably lower AIC than Model B (the three factors one). The Phi matrix and the Lambda-X matrix for Model A can be seen, respectively, in Tables 17 and 18. A graphical representation of the model is presented in Figure 17.

TABLE 16. FIT INDICES FOR THE TAIS MODELS IN ALL COMBINATIONS OF FACTOR STRUCTURES.

Model	Factors	χ^2	df	*p*	RMSEA	CFI	SRMR	GFI	AGFI	AIC
A	4	55.76	45	.13	.03	.99	.044	.96	.93	119.78
B	3	405.78	51	<.001	.20	.70	.17	.78	.52	156.00

Note: In model A, the four factors are the following: (1) External focus; (2) Internal focus; (3) Narrow focus and (4) Overloaded focus. In model B, the three factors are (1) External focus; (2) Internal focus; (3) Reduced focus.

With respect to the better fit of Model A with the data, we decided to derive four predictors from our twelve measures (six subscales * two-time waves). The first one, derived from the mean between the T1 and T2 BET subscales, will be from now on addressed as “External Attentional Style Focus” (Ext. Focus), the second one, derived from the mean between the T1 and T2 BIT subscales will be addressed as “Internal Attentional Style Focus” (Int. Focus), the third one, including the two NAR subscales, will be referred to as “Narrow Attentional Style Focus”. In the end, the fourth factor, including both the overloading indices (i.e., the OET and OIT subscales) and the over-reduced focus (the RED subscales), will be addressed as the “Dysfunctional Attentional Style” (Dysfunctional). This fourth factor possibly appears because of a specific gender-related pattern, as suggested by Lipoma et al. (2006).

TABLE 17. PHI MATRIX WITH THE CORRELATIONS AMONG THE FOUR FACTORS.

	External Focus	Internal Focus	Narrow Focus	Dysfunctional Style
External Focus	1	---	---	---
Internal Focus	.37 (.07) 5.04	1	---	---
Narrow Focus	.29 (.07) 5.04	.24 (.07) 5.04	1	---
Dysfunctional Style	-.34 (.08) -4.43	-.25 (.08) -3.11	-.49 (.09) -4.49	1

Note: For each parameter, the Table shows that the estimated value, (the standard error) and the corresponding z.

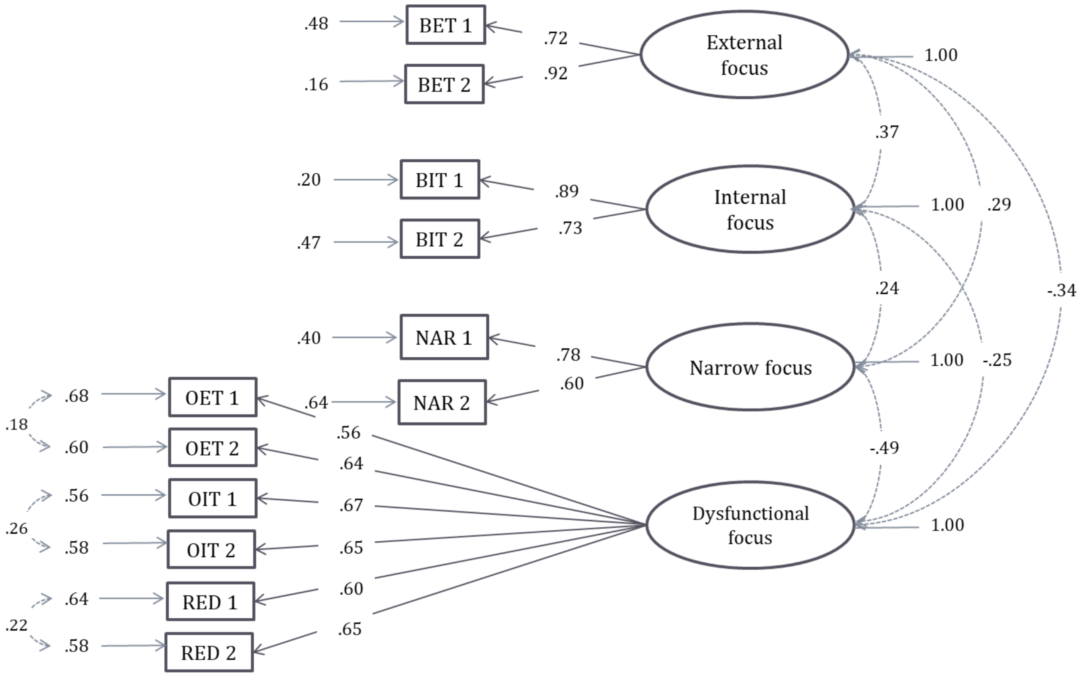
TABLE 18. LAMBDA-X MATRIX OF THE FACTOR LOADINGS FOR THE FOUR-FACTOR MODEL OF THE ATTENTIONAL STYLE PREDICTORS.

	External Focus	Internal Focus	Narrow Focus	Dysfunctional Style
BET T1	.72 (.08) 9.14	---	---	---
OET T1	---	---	---	.56 (.07) 7.63
BIT T1	---	.89 (.09) 9.56	---	---
OIT T1	---	---	---	.67 (.07) 9.32
NAR T1	---	----	.78 (.11) 6.59	---
RED T1	---	---	---	.60 (.07) 8.20
BET T2	.92 (.08) 9.14	---	---	---

OET T2	---	---	---	.64 (.07) 8.88
BIT T2	---	.73 (.09) 8.53	---	---
OIT T2	---	---	---	.65 (.07) 9.03
NAR T2	---	----	.60 (.10) 6.23	---
RED T2	---	---	---	.65 (.07) 9.11

Note: For each parameter, the Table shows that the estimated value, (the standard error) and the corresponding z.

FIGURE 17. CFA OF THE FOUR-FACTOR MODEL OF THE ATTENTIONAL STYLE PREDICTORS WITH THE STANDARDIZED SOLUTION.



4.1.4 Measures of Emotions

4.1.4.i Correlations Among the Measures of Emotions

Finally, we analysed the correlations among the twelve items of the Circumplex questionnaire (see Table 19). Using the Circumplex model as a framework, we can observe how the emotions theoretically belonging to the same quadrant of the model showed high positive correlations with one another. For example, the item "Happy" shows a positive correlation with the items "Excited" and "Stimulated" (respectively r = .37 and r = .44, both p <.001), which are both pleasant emotions with high arousal. Moreover, the same item shows a positive correlation also with "Relaxed" and "Serene", which have the same hedonic tone. Conversely, the item is negatively correlated with Stressed (r = -.35, p <.001) and Downhearted (r = -.30, p <.001). The only two items which exhibit an unusual correlational pattern are "Angry" and "Depressed". We could expect that "Angry" could be highly correlated with "Stressed" and "Tense" since they could have for the athletes an unpleasant hedonic tone and high arousal. However, the correlation between "Angry" and "Stressed" was not significant (r = .12). Interestingly, the item "Angry" shows a correlation only with "Downhearted" and "Tired". A possible explanation for this phenomenon is that the participants, especially the youngest ones, didn't interpret the "Angry" item as something related to competitiveness (Campo et al., 2012), but like a general feeling which could be interpreted as unpleasant. Similarly, the item "Depressed" is more correlated to "Stressed" (r = .32, p >.001) than, for example, to "Downhearted" (r = .29, p >.001). To explore the latent structure of the questionnaire, a series of EFAs and a hierarchical cluster analysis were performed.

4.1.4.ii Factor and Hierarchical Cluster Analyses of the Measures of Emotions

First, we performed an Exploratory Factor Analysis with Principal Axis Extraction and Varimax rotation. We considered the twelve items of the Circumplex Questionnaire, using the transformed scores for the "Angry" and "Depressed" items. Three factors were extracted and explained 45% of the total variance. The first factor included the following items: "Stressed" (.71), "Relaxed" (-.80), "Tense" (.74), "Calm" (-.80) and "Serene" (-.62). On this factor emotions with high (stressed and tense) and low (relaxed, calm, serene) arousal load with opposite coefficients, thus suggesting that Factor 1 represents the latent dimension of the "Arousal". "Happy" (.76), "Excited" (.46) and "Stimulated" (.55) loaded higher on the second factor, and "Downhearted" (.42), “Tired” (.58), “Depressed Sqrt” (.36) and “Angry Sqrt” (.51) on the third. These last two factors seemed to describe respectively a pleasant (happy, excited, stimulated) and an unpleasant (downhearted, tired, depressed, angry) hedonic tone. Therefore, differently, from what theoretically expected, in this first EFA with no fixed number of factors, the hedonic tone dimension seemed to split in two factors, while the Arousal dimension appeared as a single continuum. Similar results appeared applying a Direct Oblimin rotation, which assumes that the factors are correlated. In this case, the same three factors were extracted, with correlations from .23 to .32 with one another, meaning that the dimensions were indeed rather independent and pleasant and unpleasant emotions almost orthogonal.

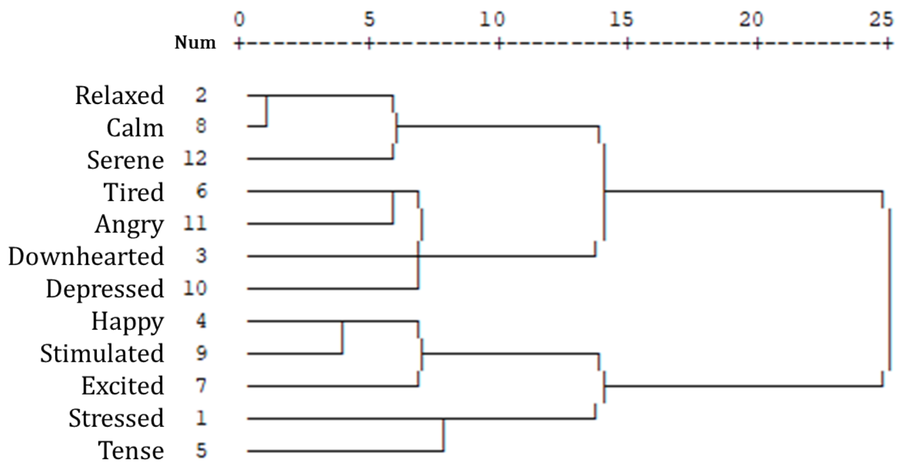
In order to better explore the data and to identify clusters of categories, a Hierarchical Cluster Analysis (HCA) was performed. A Cluster analysis enables to group a set of objects in such a way that objects in the same group (i.e., the same cluster) are more similar to each other than to those in other clusters. Specifically, HCA is a method of cluster analysis that seeks to build a hierarchy of clusters, based on their Euclidean distances (i.e., the straight-line distance between two points) or, as in this case, their squared Euclidean distances. The dendrogram in Figure 18 visualizes the similarity of category subgroups and suggests that the emotions rated by the participants can be split into four distinct clusters. In brief, this cluster analysis resulted in a model of four groups of emotions: (1) Relaxed – Calm – Serene (i.e., low arousal and pleasant hedonic tone emotions), (2) Tired – Angry – Downhearted – Depressed (i.e., low arousal and unpleasant hedonic tone emotion, with the exception of “Angry”, that has a high arousal), (3) Happy – Stimulated – Excited (i.e., high arousal and pleasant hedonic tone emotions), and (4) Stressed – Tense (i.e., high arousal and unpleasant hedonic tone emotions). This cluster analysis results in a model which is very similar to the Circumplex model.

TABLE 19. ZERO-ORDER CORRELATIONS AMONG THE ITEMS OF THE CIRCUMPLEX QUESTIONNAIRE.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
[1] Stressed	1	-.578***	.417***	-.349***	.587***	.135*	-.068	-.566***	-.185**	.323***	.325***	.117	.120	-.495***
[2] Relaxed	-.578***	1	-.223**	.300***	-.580***	-.090	.106	.702***	.135*	-.135*	-.125	-.110	-.105	.556***
[3] Downhearted	.417***	-.223**	1	-.271***	.227**	.228**	-.112	-.201**	-.320***	.287***	.295***	.206**	.202**	-.343***
[4] Happy	-.349***	.300***	-.271***	1	-.149*	-.173**	.372***	.273***	.444***	-.190**	-.190**	-.041	-.046	.449***
[5] Tense	.587***	-.580***	.227**	-.149*	1	.148*	.082	-.578***	-.006	.117	.108	.126	.121	-.428***
[6] Tired	.135*	-.090	.228**	-.173*	.148*	1	-.204**	-.010	-.281***	.175**	.184**	.352***	.359***	-.095
[7] Excited	-.068	.106	-.112	.372***	.082	-.204**	1	.048	.254***	-.039	-.035	-.055	-.049	.066
[8] Calm	-.566***	.702***	-.201**	.273***	-.578***	-.010	.048	1	.171*	-.093	-.087	-.100	-.090	.519***
[9] Stimulated	-.185**	.135*	-.320***	.444***	-.006	-.281***	.254***	.171*	1	-.093	-.105	-.129	-.132*	,250***
[10] Depressed	.323***	-.135*	.287***	-.190**	.117	.175**	-.039	-.093	-.093	1	.995***	.163*	.184**	-,187**
[11] Depressed Sqrt	.325***	-.125	.295***	-.190**	.108	.184**	-.035	-.087	-.105	.995***	1	.157*	.179**	-.179**
[12] Angry	.117	-.110	.206**	-.041	.126	.352***	-.055	-.100	-.129	.163*	.157*	1	.989***	-.110
[13] Angry Sqrt	.120	-.105	.202**	-.046	.121	.359***	-.049	-.090	-.132*	.184**	.179**	.989***	1	-.095
[14] Serene	-.495***	.556***	-.343***	.449***	-.428***	-.095	.066	.519***	.250***	-.187**	-.179**	-.110	-.095	1

Note: * p <.05, ** p <.01, *** p <.001.

FIGURE 18. DENDROGRAM USING AVERAGE LINKAGE (WITHIN GROUP).



At this point, we tested three different CFA models. The first model (A) assumed, as suggested by the EFA, that the subscales loaded three different factors, i.e., “Arousal”, “Hedonic Tone +” and “Hedonic Tone –“. The second (B) and third (C) models, driven by both the theory (Posner & Russell, 2005; Russel, 1980) and the HCA we performed, assumed four factors, coherently with the Circumplex model’s four quadrants. In model C, the parameter connecting Angry to the high-arousal unpleasant emotions is free, while the other three parameters are fixed to zero. In model B the parameter linking Angry to the low-arousal unpleasant emotions is free and the other three parameters are fixed to zero.

Table 20 summarizes the fit indices for all three models. In this case, none of the models fits the data in an optimal way, with GFIs ranging from .90 to .92. The three-factor model appears to have the worst fit, with the lowest CFI and the highest AIC. The four-factor models differ very little from each other. Model B, in which the item “Angry” loads the same factor as “Tired”, “Downhearted” and “Depressed”, appears to be slightly better (CFI = .94 instead of .93; AIC = .181.02 instead of 190.17). However, since the difference in the fit indices is minimal, we considered Model C preferable, being more consistent with the theoretical approach we used (Posner & Russell, 2005; Russel, 1980). The Phi matrix and the Lambda-X matrix for Model C can be seen, respectively, in Tables 21 and 22. A graphical representation of the model is presented in Figure 19.

TABLE 20. FIT INDICES FOR THE EMOTIONS MODELS IN POSSIBLE FACTOR STRUCTURES.

Model	Factors	χ^2	df	*p*	RMSEA	CFI	SRMR	GFI	AGFI	AIC
A	3	151.08	51	<.001	.075	.92	.075	.90	.85	197.06
B	4	126.42	48	<.001	.083	.94	.071	.92	.87	181.02
C	4	136.72	48	<.001	.088	.93	.077	.91	.86	190.17

Note: In model A, the three factors are the following: (1) Arousal; (2) Hedonic Tone +; (3) Hedonic Tone -. In model B and C, the four factors are (1) Low arousal and Hedonic Tone + emotions, (2) Low arousal and Hedonic Tone - emotions, (3) High arousal and Hedonic Tone + emotions, and (4) High arousal and Hedonic Tone - emotions.

We derived four predictors from our twelve items. The first one was given by the average score of the emotions with a low arousal and pleasant hedonic tone emotions (i.e., "Relaxed", "Calm" and "Serene"), the second one was computed as the mean of the emotions with low arousal and unpleasant hedonic tone emotion (i.e., "Tired", "Downhearted" and "Depressed"), the third emotion predictor was computed as the mean of the emotions with high arousal and pleasant hedonic tone (i.e., "Happy", "Stimulated" and "Excited". Finally, the fourth predictor was computed as the mean of all the emotions with high arousal and unpleasant hedonic tone (i.e., "Stressed", "Tense" and "Angry").

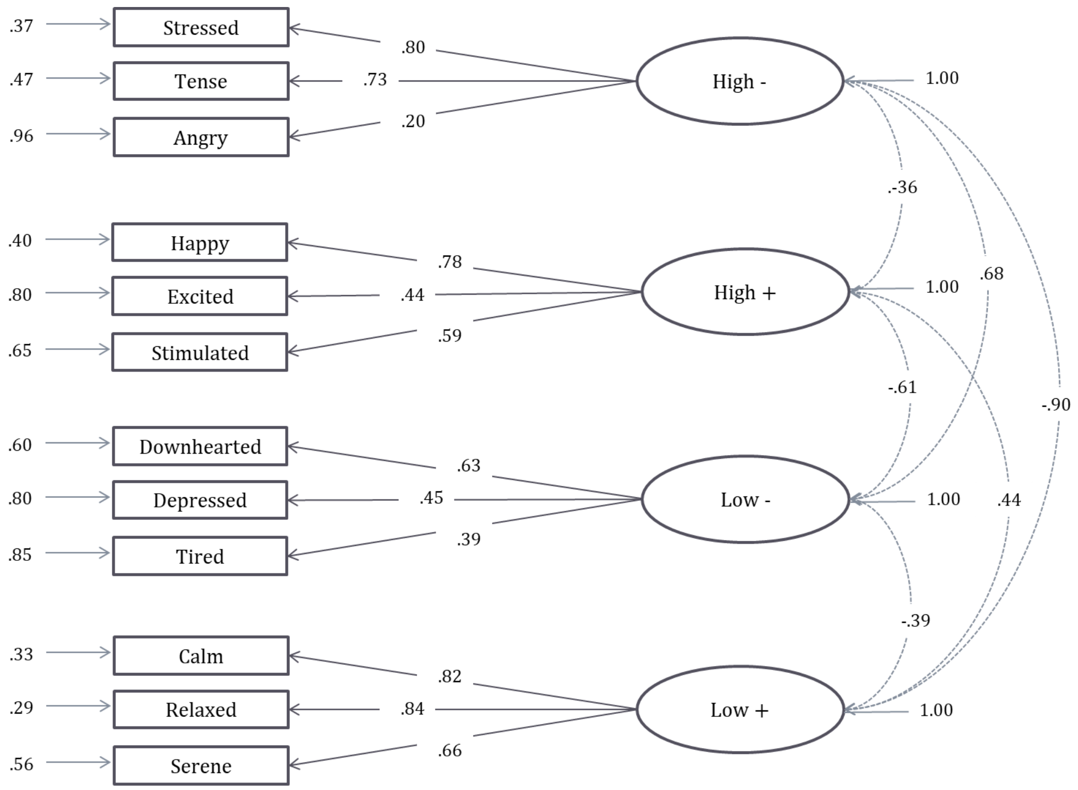
TABLE 21. PHI MATRIX OF THE CORRELATIONS AMONG THE FOUR FACTORS DERIVED FROM THE CIRCUMPLEX QUESTIONNAIRE.

	[1]	[2]	[3]	[4]
[1] High arousal Hedonic Tone -	1	---	---	---
[2] High arousal Hedonic Tone +	-0.36 (0.09) -4.13	1	---	---
[3] Low arousal Hedonic Tone -	.68 (.09) 7.67	-.61 (.10) -6.27	1	---
[4] Low arousal Hedonic Tone +	-.90 (.04) -23.33	-.44 (.08) -5.80	-.39 (.09) -4.17	1

TABLE 22. LAMBDA-X MATRIX OF THE FACTOR LOADINGS FOR THE FOUR-FACTOR MODEL OF THE EMOTIONS PREDICTORS.

	High arousal Hedonic Tone -	High arousal Hedonic Tone +	Low arousal Hedonic Tone -	Low arousal Hedonic Tone +
Stressed	.80 (.06) 13.04	---	---	---
Relaxed	---	---	---	.84 (.06) 14.64
Downhearted	---	---	.63 (.08) 7.65	---
Happy	---	.78 (.08) 9.92	---	---
Tense	.73 (.06) 11.73	----	---	---
Tired	---	---	.39 (.08) 4.96	---
Excited	---	.44 (.08) 5.85	---	---
Calm	---	---	---	.82 (.06) 14.14
Stimulated	---	.59 (.08) 7.85	---	---
Depressed	---	---	.45 (.08) 5.66	.---
Angry	.20 (.07) 2.78	----	---	---
Serene	---	---	---	.66 (.06) 10.58

FIGURE 19. CFA OF THE FOUR-FACTOR MODEL OF THE EMOTIONAL PREDICTORS WITH THE STANDARDIZED SOLUTION.



4.1.5 Performance Measures

ARTISTIC GYMNASTS' PERFORMANCE MEASURE. For each participant, we collected all scores on all of the apparatus in the competitions during the sport season 2017 (namely January to September). Since our sample (N = 104) comprised both *Gold* (N = 23) and *Silver* artistic gymnasts (N = 81), whose scores are attributed by using different rules and grids, after consulting with artistic gymnastics coaches and referees, we decided to adopt an "ecological" parameter to order the athlete's score on the one hand, and not to lose the quantitative data on the other hand. Given that all the *Gold* artistic gymnasts belong to a superior category, we computed an additive transformation in order for the lowest ranked *Gold* artistic gymnast to always score above the highest ranked *Silver* one.

$$Corrected\ Gold\ score = Gold\ score + S;\ S = [max_{Silver} - min_{Gold}]^{.01}$$

We will call these corrected variables simply "Corrected Vault", "Corrected Bars", "Corrected Beam" and "Corrected Floor", according to the apparatus. Second, we looked at the distribution of the competition scores on the different apparatus in the sample: 100 athletes had at least one vault competition (96,2%), 65 athletes competed at least once on the uneven bars (62,5%), 103 athletes had at least a competition on the balance beam (99,0%) and 100 competed on the floor (96,2%). We then analysed the athlete's scores (see the "Corrected" columns of Table 23) descriptives and noticed that, for most of the athletes, the vault represented the highest score, possibly because of a scoring bias (i.e., the scores on the vault are usually higher than on other apparatus). Therefore, to have a reliable measure of each athlete's leading apparatus, we then computed z-scores (see the "Z scores" columns of Table 23) for each apparatus. Finally, we calculated, for each artistic gymnast, the mean among the Corrected scores ("Gym Performance") and we isolated each athlete's leading apparatus, by selecting the maximum average score among all apparatus (Best Performance). These two measures were our dependent variables for the artistic gymnasts' sample.

VOLLEYBALL PLAYERS' PERFORMANCE MEASURE. As described in Section *3.2.5*, for each volleyball player, we calculated a weighted individual index of performance (WIP). For both observers, the WIP index was given by the residuals of the regression of the participant's individual ratio *points on ball touches* (IR) on the weighted game index (WG). This methodological procedure was meant to weight the individual performance on the team performance. At the first glance to these measures, both the IRs ($r = .899$, $p < .001$) and the WG ($r = .985$, $p < .001$) from the two observers showed a very high correlation. Moreover, the IR and the WIP (i.e. the "pure" individual score and the one weighted on the team performance) were highly correlated for both Observer 1 and 2 (respectively $r = .88$ and $r = .89$, both $p < .001$). Therefore, in order to compute a final performance variable, we assessed the inter-rater agreement between the two judges. Pearson correlation between observers' WIP was highly significant, namely $r = .841$, $p < .001$. Therefore, we computed a final performance measure for volleyball players using the mean WIP between Observer 1 and Observer 2. We will call this final index "Volley Performance".

TABLE 23. DESCRIPTIVES OF ARTISTIC GYMNASTS' CORRECTED AND Z-SCORES FOR EACH APPARATUS.

		Vault		Bars		Beam		Floor	
		Corrected	*Z score*	*Corrected*	*Z score*	*Corrected*	*Z score*	*Corrected*	*Z score*
Gold	Mean	24.256	1.647	22.155	1.306	22.395	1.645	21.215	1.722
	N	21		16		23		20	
	Std. Dev.	4.07	.879	6.156	1.185	3.315	.687	2.776	.755
	Minimum	19.35	.59	16.20	.16	19.05	.95	17.90	.82
	Maximum	33.34	3.61	34.14	3.61	31.04	3.44	28.11	3.60
Silver	Mean	14.590	-.438	13.160	-.425	12.183	-.472	13.297	-.433
	N	79		49		80		80	
	Std. Dev.	1.779	.383	1.955	.376	1.841	.382	1.553	.422
	Minimum	10.55	-1.31	8.03	-1.41	8.65	-1.20	9.45	-1.48
	Maximum	19.30	.58	16.15	.15	19.00	.94	17.85	.81
Total	Mean	16.620	.000	15.374	.000	14.463	.000	14.881	.000
	N	100		65		103		100	
	Std. Dev.	4.637	1.000	5.196	1.000	4.823	1.000	3.679	1.000
	Minimum	10.55	-1.31	8.03	-1.41	8.65	-1.20	9.45	-1.48
	Maximum	33.34	3.61	34.14	3.61	31.04	3.44	28.11	3.60

4.1.6 Predictors and Dependent Variables

To summarize, the following ten variables were considered as predictors.

I. Two general cognition variables, namely:

   a. A composite M capacity-Updating index (*Mcap-Upd*), computed as the mean of the z scores of the Mr Cucumber test, DFT and FIT and the proportion of correct responses in the Keep-Track and the N-Back.

   b. A composite Inhibition-Shifting index (Ihn-Shift), computed as the mean of the z scores of both the errors and the cost indices on the following tests: Stroop task, Flanker task, Colour/Shape test and Trail Making Test.

II. Four different attentional styles, namely:

   a. The "External Attentional Style Focus" (Ext. Focus), computed as the mean of the T1 and T2 BET subscales.

   b. The "Internal Attentional Style Focus" (Int. Focus), computed as the mean of the T1 and T2 BIT subscales.

   c. "Narrow Attentional Style Focus" (Narrow), computed as the mean of the two NAR subscales.

   d. The "Dysfunctional Attentional Style" (Dysfunctional), computed as the mean of the overloading indices (i.e., the OET and OIT subscales) and the over-reduced focus (the RED subscales).

III. Four different emotions variables, namely:

   a. The "High arousal and unpleasant hedonic tone" cluster of emotions (High -), given computed as the mean of the scores on the items *Stressed*, *Tense* and *Angry*.

   b. The "High arousal and pleasant hedonic tone" (High +), computed as the mean of the scores on the items *Happy*, *Excited* and *Stimulated*.

   c. The "Low arousal and unpleasant hedonic tone" (Low -), computed as the mean of the scores on the items *Downhearted*, *Depressed* and *Tired*.

d. The low arousal and pleasant hedonic Tone" (Low +), computed as the mean of the scores on the items *Relaxed*, *Calm* and *Serene*.

Two control variables, namely the athlete's Age in months and a measure of experience, namely the years of practice in her sport. These two variables have been included as predictors in certain analyses in order to control their influence.

The following dependent variables were considered in the following analyses; one for the volleyball players and two for the artistic gymnasts.

I. **Artistic gymnasts**. (A) The mean among the Corrected scores on all the apparatus ("Gym Performance") and (B) The mean score on each athlete's leading apparatus ("Best Performance").

II. **Volleyball players**. The "Volley Performance" variable is, for each athlete, the mean of the Weighted Individual Performance (i.e. the residuals of the regression of the athlete's individual ratio on the weighted game index) indices assigned by Observer 1 and Observer 2.

4.2 REGRESSION ANALYSES

4.2.1 VOLLEYBALL PLAYERS

As a preliminary analysis to verify the role of our cognitive and emotional measures as predictors of volleyball performance, we examined the correlations with both age and years of experience controlled for. Partial correlations only retain individual differences and statistically eliminate the age-related variance. Therefore, they ensure that a correlation between a performance measure and a predictor is not caused by the variance shared with other age-related variables. Moreover, we aimed at exploring the relations between predictors. As can be seen in Table 26, in the volleyball players sample, the two measures of general cognitive ability, namely the M capacity-Updating index and the Inhibition-Shifting index, were highly correlated, even controlling for age and experience ($r = -.58$, $p < .001$, the correlation is negative because the Inhibition-Shifting index is based on error and time cost measures). Moreover, both variables were highly correlated with age, that is coherent with being a cognitive function which develops during growth (Miyake et al., 2000; Pascual-Leone, 1970; 1978). The

Inhibition-Shifting index also appears to be slightly linked to the narrow focus of attention (r = -.21, p <.05). This can be explained because narrowing the attentional focus implies inhibiting the irrelevant information. The M capacity-Updating index is instead slightly related with all the attentional styles, especially with the broad internal focus of attention (r = . 27, p <.01). Updating factor instead was slightly related to all the attentional styles, especially the broad internal focus of attention (r = . 27, p <.01). Most important for our research goals, the M capacity-Updating index is the only one that was highly correlated with the volleyball players' performance: this correlation was not only maintained but even slightly increased when age and experience were partialled out (r = .33, p <.001)[11]. This finding is coherent with the idea of volleyball as a high cognitive load sport so that a good performance in volleyball is reasonably associated with higher scores on the M capacity and Updating tests.

With respect to emotions, all four predictors showed a clear correlational pattern with one another. Not surprisingly, the highest correlations are those between the variables describing opposite quadrants, namely the negative correlation between high arousal, unpleasant hedonic tone emotions and low arousal, pleasant hedonic tone emotions (r = -.73, p <.001). Moreover, the Low + emotions were negatively correlated with the dysfunctional attentional style (r = -.32, p <.01), while Low - and High - emotions were positively correlated with the dysfunctional attentional style (respectively r = .34, p <.001 and r = .29, p <.01) Surprisingly, there was no correlation between any of the attentional styles nor the emotions predictors and the volleyball players performance. Finally, no correlation was found between age and performance, but this could be explained because, in both sports, competition is organized within the same age group and this equals the difficulty in all groups.

In order to further explore the relation between volleyball performance and the predictors, a series of regression analyses were run. The first regression analysis we performed included all ten predictors (i.e. M capacity-Updating, Inhibition-Shifting, the four Attentional Style indicators and the four emotions predictors). We used a stepwise method with p <.05 as the inclusion criterion and p >.10 as the removal criterion. The results were surprisingly simple: only the M capacity-Updating predictor was included in the model (R^2 = .10; ß=.32, p <.001).

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[11] We noticed that our volleyball players subsample comprised two subjects with outlier scores, i.e. very low scores on both M Capacity-Updating and volley performance. In order to verify that the correlation between these two measures was not an artifact due to these outliers, we ran a correlation eliminating these two athletes. The correlation, albeit lower (r = .24, p <.01), was still significant and we therefore we did not exclude them from the following analyses.

We then ran a second regression analysis, also including the two control variables, namely the age and the years of experience in volleyball. The control variables were entered as a first block with the Enter method, while the ten cognitive and emotions predictors were entered in a second block with a stepwise method. Again, $p < .05$ was the inclusion criterion and $p < .10$ was the removal criterion. As can be seen in Table 24, this model accounted for 15% of the explained variance and, again, included the M capacity-Updating measure as the main predictor (ß=.35, $p < .001$). The years of experience had a ß of .30, $p < .02$. The effect of the age was nonsignificant, probably because of the high portion of variance shared with the years of experience which in this case are a more relevant predictor.

We then ran a third regression analysis entering all twelve variables (i.e. the ten predictors plus age and years of experience) at once. The results of this analysis are displayed in Table 25. The variance explained by this model was 23%, and the main predictor was, again, the M capacity-Updating (ß=.45, p =<.01), together with the years of experience (ß=.29, $p < .05$) and the high arousal and unpleasant hedonic tone emotions (ß=.30, $p < .05$). This predictor, which does not appear in the previous regression equations, became significant using the Enter method, i.e. when all predictors control for each other. This result is consistent with the idea that high-arousal emotions are predictive of better outcomes in open-skills sports.

In general, the pattern of results is consistent with our hypothesis that an adequate M capacity is required in volleyball not only to learn new motor gestures (Bisagno & Morra, 2018), but it is also a cognitive ability the athlete relies on during the competitive performance. Indeed, as general abilities to coordinate an increasing number of motor, perceptual, and cognitive schemes and to rapidly update them, M capacity and Updating are determinant for adequate performance in sports with much and rapidly changing information to handle. The prominent role of the M capacity-Updating measure as a predictor of performance in young volleyball players is the main finding with respect to this subsample.

However, contrary to our expectations, neither the Inhibition-Shifting factor nor the External attentional style explained a significant portion of the variance. With respect to emotions, in the last regression analysis, we identified a slight effect of the emotions with high arousal and unpleasant hedonic tone in predicting the volleyball players' performance. This result points towards the idea that emotions characterized by an unpleasant hedonic tone are not dysfunctional per se, but can be both functional or dysfunctional with respect to the individual's zone of optimal functioning and the environmental requests (Hanin, 2000; Robazza, 2006; Ruiz et al., 2017).

TABLE 24. STEPWISE REGRESSION ANALYSIS WITH THE VOLLEYBALL PERFORMANCE AS A DEPENDENT VARIABLE.

Predictors	*Volleyball Performance* $R^2 = .15$	
	β	*p*
Age	-.237	.083
Years of experience	.301	.020
M capacity-Updating	.352	<.001

Note: Age and Years of experience were entered as a first block with the Enter method, and the M capacity-Updating factor with a stepwise method.

TABLE 25. REGRESSION ANALYSIS WITH THE VOLLEYBALL PERFORMANCE AS THE DEPENDENT VARIABLE, AND ALL PREDICTORS AND CONTROL VARIABLE ENTERED IN THE EQUATION.

Predictors		*Volleyball Performance* $R^2 = .15$	
		β	*p*
General cognitive abilities	***M capacity-Updating***	.446	.001**
	Inhibition-Shifting	.115	.345
Attentional Style	***External***	.131	.182
	Internal	-.138	.150
	Narrow	-.084	.404
	Dysfunctional	.032	.758
Emotions	***High +***	-.167	.135
	High -	.302	.039*
	Low +	.209	.135

	Low -	-.175	.147
	Age	-.228	.106
	Years of experience	.291	.028*

Note: * p <.05, ** p <.01, *** p <.001

In order to explore our hypothesis regarding the role of emotions as moderators in the relationship between working memory and sports performance in open-skills sports, we performed a series of regression analyses including interaction effects. We were interested in testing a moderation effect of hedonic tone and arousal on the relation between working memory and sports performance (Furley et al., 2015) in order to verify a possible detrimental moderation effect of anxiety (Baumeister, 1984; Beilock, 2007; Gimmig et al., 2006; Hill et al., 2010, 2011). Moreover, we wanted to test whether a moderation effect is determined by either of the two dimensions (i.e. the hedonic tone or the arousal) or if it results as a specific combination of these dimensions.

First, we tested the "choking under pressure" hypothesis (Beilock, 2007; Gimmig et al., 2006), namely the hypothesis that emotions with an unpleasant hedonic tone and high arousal (i.e. stress) negatively moderate the relationship between working memory and performance. To do so, we created a new interaction factor M capacity*High -. We ran a regression analysis with a stepwise method (inclusion criterion p <.05, removal criterion p >.10) with the M capacity-Updating index, the "High -" emotions and their interaction as predictors. While again working memory was included as a predictor, (R^2 = 10; ß=.32, p <.001), neither the High – factor, nor the interaction accounted for any further variance (respectively, p =.22 and p =.61). Thus, we found no evidence of a detrimental effect of "High -" emotions on the relationship between working memory and performance.

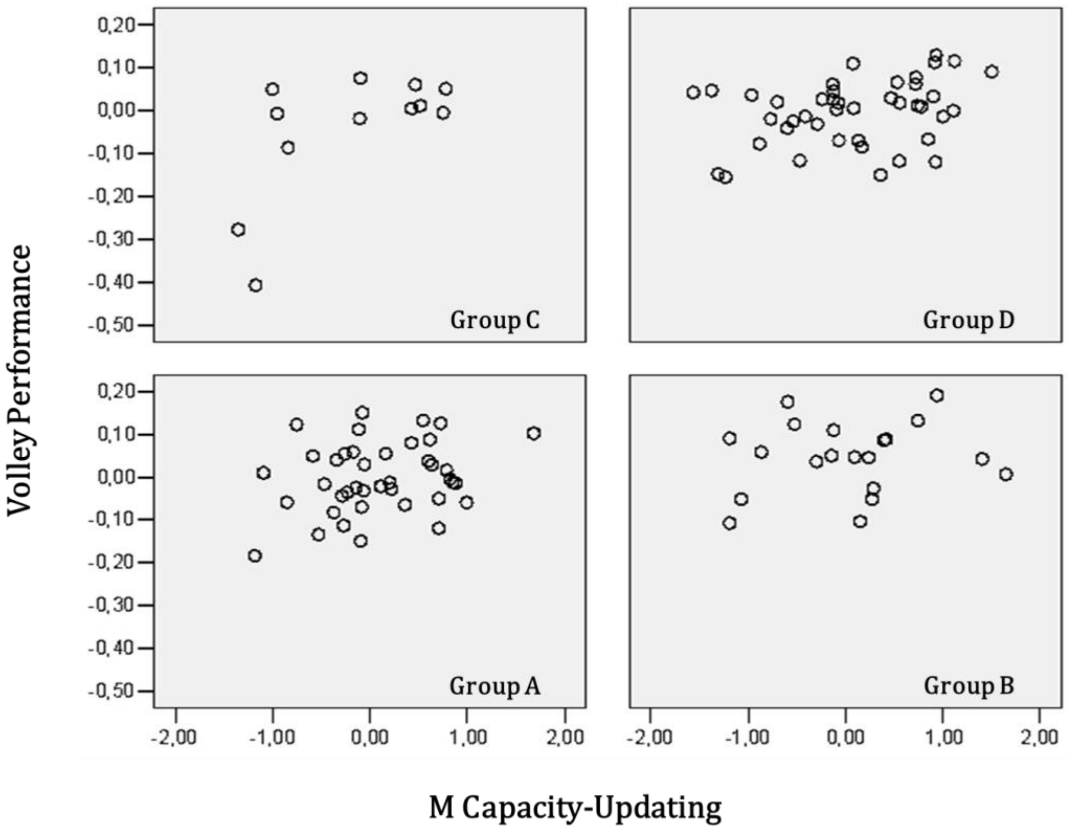
To clarify the role of the unpleasant hedonic tone of emotions with respect to the relation between working memory and performance, we then computed another "Hedonic tone –" variable by adding up all the items with unpleasant hedonic tone and subtracting those with a pleasant hedonic tone. Therefore, we computed the product between this new variable and the M capacity-Updating index as well. Again, we ran a regression analysis with a stepwise method (inclusion criterion p <.05, removal criterion p >.10) with the M capacity-Updating index and the two new variables as predictors, but the results were the same as in the previous regression. Working memory was included as a predictor, (R^2 = .10; ß=.32, p <.001), but the Hedonic tone – and the interaction (respectively, p =.52 and p =.92) were not. In these analyses, therefore, we did not find any moderation effect of the unpleasant emotions in general or of the high-arousal unpleasant emotions on the relationship between working memory and sport performance in volleyball. As an additional control, we also split our volleyball players sample in two, dividing the athletes with an average score on the "High –" items of the Circumplex Questionnaire mean (N = 62) from those who scored below the mean (N = 52). We then examined the correlation between the M capacity-Updating variable and the volley performance in both subsamples. The correlation was the same in both the subsample (respectively r =.320, p <.05 and r =.321, p <.05), indicating once again that there was no difference in the relation between working memory and volley performance with respect to the anxiety of the athlete or her self-reported unpleasant emotions.

Finally, we also looked at the effect of the arousal. In order to do so, we calculated two arousal indices: arousal in pleasant emotions (i.e., the scores on High + minus the scores on Low +) and arousal in unpleasant emotions (i.e., the scores on High - minus the scores on Low -). Then, for both measures, we split our sample according to a dichotomy criterion, namely if the subject scored above or below the mean of the sample. We derived four groups of subjects, namely:

- Group A (N = 40): participants who scored below the mean in the difference between high and low arousal emotions, in both pleasant and unpleasant emotions;
- Group B (N = 20): participants who scored below the mean in the difference between high and low arousal-emotions in pleasant but above the mean in the difference between unpleasant emotions;
- Group C (N = 12): participants who scored below the mean in the difference between high and low arousal-emotions in unpleasant but above the mean in the difference between pleasant emotions;
- Group D (N = 42): participants who scored above the mean in the difference between high and low arousal-emotions in both pleasant and unpleasant emotions.

Subsequently, for each group, we ran correlational analyses between the M capacity-Updating index and volleyball performance. The correlational pattern is graphically represented in Figure 20.

FIGURE 20. SCATTERPLOTS OF THE CORRELATIONS BETWEEN MCAP-UPD AND VOLLEYBALL PERFORMANCE IN THE FOUR GROUPS OF AROUSAL PATTERNS.



In group B, Mcap-Upd and volley performance were uncorrelated (r = .152, *p* =.52). In group C, even with a very small sample, the correlation was instead very strong (r = .635, *p* <.05). With respect to group A and D, group D it resulted significant (r = .318, *p* <.05), while in group A it did not (r = .257, *p* =.11), however, the correlations are similar. In general, a moderation effect of the arousal on the relationship between working memory and volleyball performance appears to exist when arousal itself is high on pleasant emotions, especially when it is also low in unpleasant emotions (i.e., group C). This finding suggests that emotions' arousal plays indeed a role in moderating the relationship between general cognition and volleyball performance, however not with a linear effect, but in a specific combination with the hedonic tone. Possible explanations for this phenomenon will be discussed in the final chapter.

TABLE 26. ZERO-ORDER AND PARTIAL CORRELATIONS BETWEEN PREDICTORS AND THE VOLLEYBALL PLAYERS' PERFORMANCE DEPENDENT VARIABLE.

	[1] Mcap-Upd	[2] Inh-Shift	[3] Ext. Focus	[4] Int. Focus	[5] Narrow Focus	[6] Dysfunc. Focus	[7] High + Emotions	[8] High - Emotions	[9] Low + Emotions	[10] Low - Emotions	[11] Volley Perf.	Age	Years Exp.
[1]	1	-.607***	.213*	.222*	.202*	-.167	.034	.018	.037	.039	.323***	.385***	.205*
[2]	-.575***	1	-.079	-.046	-.210*	-.010	.206*	-.108	-.008	-.157	-.179	-.256***	-.188*
[3]	.243*	-.081	1	.247**	.098	-.197*	.282**	-.106	.131	-.242**	.177	.001	.062
[4]	.267**	-.056	.242*	1	.238*	-.127	.108	-.094	.118	-.086	-.027	-.035	.028
[5]	.237*	-.227*	.098	.237*	1	-.354***	.129	-.184	.217*	-.264**	-.032	-.036	-.018
[6]	-.223*	.022	-.210*	-.133	-.356***	1	-.161	.295**	-.308**	.352***	-.014	.120	.156
[7]	.002	.238*	.283**	.110	.133	-.176	1	-.217*	.299**	-.466***	-.042	.087	.072
[8]	-.004	-.097	-.105	-.091	-.182	.294**	-.223*	1	-.729***	.487***	.117	.054	.030
[9]	.041	-.002	.125	.114	.218*	-.324***	.298**	-.732***	1	-.310**	-.002	.021	.071
[10]	-.021	-.125	-.244**	-.081	-.261**	.344***	-.485***	.485***	-.316**	1	-.009	.145	.091
[11]	.330***	-.157	.166	-.037	-.031	-.047	-.056	.115	-.019	-.024	1	.116	.203*

Note: Zero-order (Pearson) correlations above diagonal. Partial correlations controlled for age and years of experience below diagonal. * p <.05, ** p <.01, *** p <.001

4.2.2 ARTISTIC GYMNASTS

Similarly to volleyball players, as a preliminary analysis, we looked at the correlations between cognitive and emotional measures as predictors of artistic gymnastics performance, with both age and years of experience controlled for. As can be seen in Table 27, also in the artistic gymnasts sample, the two measures of general cognitive ability, namely the M capacity-Updating index and the Inhibition-Shifting index, are highly correlated, even controlling for age and years of experience (r = -.44, p <.001), although slightly less than in the volleyball players sample. Again, both variables were highly correlated with age, namely, the M capacity-Updating index showed a correlation of .46 (p <.001), while the Inhibition-Shifting index a correlation of -.40 (p <.001). Correlations between the predictors with both age and years of experience controlled for are here described. The M capacity-Updating index appears to be slightly related to a broad external focus of attention (r = . 20, p <.05).

Among the other variables, a dysfunctional attentional style (i.e., a tendency to be overloaded by environmental stimuli or to excessively reducing the attentional focus) is negatively correlated (-.24, p >.05) with the internal focus of attention which, in turn, appears to be positively related to the experience of high-arousal pleasant emotions (i.e., happiness, excitement) prior to a competition (.26, p >.05). A possible explanation for this relation is that having the tendency to direct attention to internal feelings and thoughts helps the athlete to inhibit the environmental stressors and to focus on the upcoming performance, similarly to what happens with imagery, which is usually associated to pleasant emotions (Munroe, Giacobbi, Hall, & Weinberg, 2000).

Also, in this case, all four emotional predictors showed a clear correlational pattern with one another. Again, the highest correlations were those between the variables belonging to opposite quadrants, namely the negative correlation between high arousal, unpleasant hedonic tone emotions and low arousal, pleasant hedonic tone emotions (r = -.53, p <.001). Moreover, the aforementioned emotion factors were the only variables that appear to be related to the artistic gymnasts' performance. Specifically, Low + emotions (i.e., calm, relaxed, serene) showed a slight positive correlation with the artistic gymnast' scores (.25, p <.05), while High – emotions (i.e., stressed, tense, angry) showed a highly significant negative correlation (-.33, p <.001). This result suggests that, indeed, emotional control plays an important role in closed-skills sports positive outcomes and, in particular, that for artistic gymnasts being calm and in control helps their performance (Mahoney & Avener, 1977) more than being highly aroused.

TABLE 27. ZERO-ORDER AND PARTIAL CORRELATIONS BETWEEN PREDICTORS AND THE ARTISTIC GYMNASTS' PERFORMANCE DEPENDENT VARIABLE.

	[1] Mcap-Upd	[2] Inh-Shift	[3] Ext. Focus	[4] Int. Focus	[5] Narrow Focus	[6] Dysfunc. Focus	[7] High + Emotions	[8] High - Emotions	[9] Low + Emotions	[10] Low - Emotions	[11] Gym Perf.	Age	Years Exp.
[1]	1	-.554***	.242*	.077	.007	-.072	.017	.142	-.082	-.044	.056	.463***	.352***
[2]	-.436***	1	-.237*	-.110	-.114	-.013	-.027	-.161	.032	.060	-.038	-.403***	-.410***
[3]	.202*	-.193	1	.378***	.352***	-.338	.192	-.029	.150	-.181	.018	.123	.135
[4]	.130	-.143	.391***	1	.156	-.247*	.258**	.012	.002	-.078	-.061	-.109	.047
[5]	.047	-.158	.365***	.145	1	-.184	-.194	-.054	.038	-.087	-.024	-.084	-.014
[6]	-.182	.072	-.371***	-.235*	-.172	1	-.075	.189	-.062	.276**	-.017	.182	.104
[7]	.028	-.033	.194	.255*	-.198*	-.072	1	-.090	.257**	-.235*	-.035	-.023	.015
[8]	-.026	-.010	-.082	.043	-.030	.138	-.090	1	-.556***	.369***	-.342***	.335**	.243*
[9]	-.008	-.031	.172	-.024	.021	-.032	.255*	-.543***	1	-.219*	.275**	-.175	-.052
[10]	-.122	.140	-.205*	-.075	-.081	.261**	-.237*	.349***	-.208*	1	-.124	.117	.120
[11]	.139	-.071	.023	-.121	-.052	.018	-.050	-.331***	.245*	-.125	1	-.192	.101

Note: Zero-order (Pearson) correlations above diagonal. Partial correlations controlled for age and years of experience below diagonal. * p <.05, ** p <.01, *** p <.00

In order to further explore these patterns, we ran also with the gymnasts the same series of regression as those we ran with the volleyball players' sample. The first regression analysis we performed considered the ten predictors and was performed with a stepwise method with $p < .05$ as the inclusion criterion and $p > .10$ as the removal criterion. Also in this case, the results were surprisingly neat and essential: only the high-arousal and unpleasant hedonic tone emotions were included in the model with a negative coefficient ($R^2 = .11$; ß=-.34, $p < .001$).

In the second regression analysis, we also considered the two control variables. Age and years of experience in artistic gymnastics were entered in the first block with the Enter method, while the ten cognitive and emotions predictors were entered in a second block with a stepwise method. As can be seen in Table 28, this model accounted for 20% of explained variance and, again, included the high-arousal and unpleasant emotions as the main predictor (ß=-.34, $p < .01$), followed by the years of experience (ß =.30, $p < .01$) and by age that entered the model with a negative coefficient. This could be due to the high portion of variance shared with the years of experience. However, in this case, age and years of experience showed a slightly negative correlation (r = -.19), meaning that younger artistic gymnasts either performed generally better than older ones (ß=-.25, $p < .05$) or were judged more favourably. We ran the same regression also with the athletes' best performance as the dependent variable (namely the each artistic gymnast's maximum z score on her leading apparatus). The results (see Table 28) were exactly the same, with age, years of experience and "High -" entering the model with respectively ß=-27 ($p < .05$), ß=.31 ($p < .01$) and ß=-.33 ($p < .01$). Also, the same results were obtained with the scores on any single apparatus as the dependent variable.

Again, we run a third regression analysis entering all twelve variables at once. The results of this analysis are displayed in Table 29. This model accounted for 25% of the variance, and the main predictor was, in this case, age (ß=-.36, p =<.01), followed by the years of experience (ß=.30, $p < .05$) and the high arousal and unpleasant hedonic tone emotions (ß=.30, $p < .05$).

In general, the pattern of results underlined the role of emotional correlates of performance in closed-skills sports (Hanin, 2000). Indeed, not only working memory did not play a significant role in predicting the artistic gymnasts' performance, which we expected being artistic gymnastics a discipline in which highly automatized routines are performed (Anderson, 1982; Fitts, 1964) but also no other variable of cognition or attentional style entered the model. As predicted, the best predictors of artistic gymnasts performance were high-arousal and unpleasant hedonic tone emotions, all of which entered the regression models with a negative coefficient. This result is consistent with previous research, suggesting that artistic gymnasts perform at their best when calm and in control (Cottyn et al., 2012).

TABLE 28. STEPWISE REGRESSION ANALYSIS WITH THE ARTISTIC GYMNASTS' OVERALL PERFORMANCE AND PERFORMANCE ON THEIR BEST APPARATUS AS A DEPENDENT VARIABLE.

Predictors	*Gym Performance* $R^2 = .20$		*Best Performance* $R^2 = .20$	
	β	*p*	β	*p*
Age	-.253	.023	-.271	.015
Years of experience	.320	.003	.307	.005
High -	-.335	.001	-.329	.001

Note: Age and Years of experience were entered as a first block with the Enter method, and the M capacity-Updating factor with a stepwise method.

TABLE 29. REGRESSION ANALYSIS WITH THE ARTISTIC GYMNASTICS PERFORMANCE AS THE DEPENDENT VARIABLE, AND ALL PREDICTORS AND CONTROL VARIABLE ENTERED IN THE EQUATION.

Predictors		*Gym Performance* $R^2 = .20$	
		β	*p*
General cognitive abilities	***M capacity-Updating***	.145	.220
	Inhibition-Shifting	-.035	.765
Attentional Style	***External***	.060	.605
	Internal	-.092	.384
	Narrow	-.093	.372
	Dysfunctional	.067	.519
Emotions	***High +***	-.113	.285

	High -	-.270	.030*
	Low +	.110	.344
	Low -	-.034	.742
	Age	-.360	.005**
	Years of experience	.296	.011*

Interestingly, not only the high-arousal unpleasant emotions were the only significant predictor of artistic gymnasts' performance, but they also distinguished between high and lower level athletes. We ran t-tests for independent samples in order to detect the differences between artistic gymnasts of different categories with respect to all of our predictors. As can be seen in Table 30, the only significant differences were found in the emotions, namely "Low +" ($t = 2.68$, $p <.05$) and "High –" ($t = -3.63$, $p <.001$). Indeed, with respect to competition, Silver athletes experience less low-arousal pleasant emotions ($M_G = 3.17$, $M_S = 2.40$) and more high-arousal unpleasant emotions ($M_G = 4.25$, $M_S = 5.20$). With respect to the previous regression analyses, this pattern could be interpreted as further proof that emotional control in artistic gymnasts is the main psychological prerequisite for success.

TABLE 30. INDEPENDENT SAMPLE T-TEST COMPARING GOLD (N = 23) AND SILVER (N = 81) ARTISTIC GYMNASTS.

	Category	Mean	Std. Dev.	t	*p*
M Cap-Upd	Gold	.048	.617	.649	.518
	Silver	-.056	.699		
Inh-Shift	Gold	-.189	.609	-1.060	.292
	Silver	-.047	.555		
External	Gold	4.814	1.167	.580	.563
	Silver	4.647	1.233		
Internal	Gold	4.754	1.477	-.154	.878
	Silver	4.798	1.109		
Narrow	Gold	3.962	1.319	.267	.790
	Silver	3.873	1.432		

Dysfunctional	Gold	3.507	1.219	-.148	.883
	Silver	3.544	1.000		
High +	Gold	4.543	.875	-.684	.495
	Silver	4.709	1.069		
High -	Gold	4.254	1.148	-3.630	.000
	Silver	5.204	1.097		
Low +	Gold	3.172	1.308	2.684	.012
	Silver	2.396	.865		
Low -	Gold	2.169	.770	-1.423	.158
	Silver	2.459	.885		

4.2.3 COMPARISONS AMONG SPORTS

In the end, we explored the differences between the athletes of our two samples. In this analysis are included all the participants with complete data on the psychological measures, regardless of performance. Therefore, we were able to include six more volleyball players in the sample (N = 120).

Based on this first attempt to identifying the latent structure of our emotional predictors, we derived three variables by computing the mean of the scores of the items loading on each scale and taking care of changing sign when needed. We, therefore, computed the variables "Arousal", "Hedonic tone +" and "Hedonic tone –". Therefore, we ran an independent samples t-test, to compare the general arousal and the two dimensions of the hedonic tone of emotions between artistic gymnasts and volleyball players. The results are shown in Table 31.

TABLE 31. INDEPENDENT SAMPLE TEST COMPARING ARTISTIC GYMNASTS (N = 104) AND VOLLEYBALL PLAYERS (N = 120) ON EMOTIONS REPORTED BEFORE THE COMPETITION.

	Sports	Mean	Std. Dev.	t	*p*
Arousal	Gymnastics	.425	.711	7.272	<.001
	Volleyball	-.376	.940		
Hedonic tone +	Gymnastics	-.158	.796	-2.668	<.01
	Volleyball	.140	.870		
Hedonic tone -	Gymnastics	-.030	.747	-.555	.587
	Volleyball	.027	.778		

Significant differences were found among the two groups in the arousal (t = 7.27, *p* <.001) and the pleasant hedonic tone (t = -2.69, *p* <.01). Differently from what expected being a closed-skills sport (Ruiz et al., 2017), the arousal appeared to be significantly higher in the artistic gymnasts' sample. Even if it doesn't inform us about its relationship with the sport performance, this result is surprising and can be possibly read with respect to the other difference found among these indicators. Indeed, even if they don't differ in the intensity of unpleasant emotions experienced in relation to the competition, volleyball players appear to live more pleasant emotions regarding their agonistic activity. From this analysis, we could argue that feeling low pleasant emotions in relation to competition, artistic gymnasts also experience more performance-related stress and, therefore, score higher on the arousal index.

In order to obtain a more fine-grained comparison, we ran t-tests for independent samples with respect to all our predictors. As can be seen in Table 32, significant differences between artistic gymnasts and volleyball players are mainly related to the emotions they experience prior to a competition, namely "High +" (t = -3.27, *p* <.01), "High –" (t = 5.54, *p* <.001) and "Low +" (t = -6.85, *p* <.01). Indeed, as described above, volleyball players experience less high-arousal unpleasant emotions (M_G = 4.99, M_V = 4.04), meaning they are less stressed and tense before competing. This could be read in a social psychology key and referred to diffusion of responsibility (Latané & Darley, 1968) and perceived social support (Rosenfeld & Richman, 1997), which are more related to the nature of team sports and, therefore, mediate with the experience of pleasant sports-related emotions (Nixdorf, Frank, & Beckmann, 2016). Similarly, volleyball players also experience more pleasant emotions, both with high arousal, namely happiness and excitement (M_G = 4.67, M_V = 5.12) and with low arousal, namely calm and relaxation (M_G = 2.57, M_V = 3.68).

TABLE 32. INDEPENDENT SAMPLE TEST COMPARING ARTISTIC GYMNASTS (N = 104) AND VOLLEYBALL PLAYERS (N = 120) ON ALL THE PREDICTORS.

	Sports	Mean	Std. Dev.	t	*p*
M Cap-Upd	Gymnastics	-.033	.680	-.649	.517
	Volleyball	.029	.735		
Inh-Shift	**Gymnastics**	**-.078**	**.568**	**-1.845**	**.066**
	Volleyball	**.068**	**.612**		
External	**Gymnastics**	**4.684**	**1.216**	**-1.786**	**.075**
	Volleyball	**4.977**	**1.228**		
Internal	Gymnastics	4.788	1.192	-1.598	.111
	Volleyball	5.062	1.351		
Narrow	Gymnastics	3.893	1.402	-.374	.709
	Volleyball	3.965	1.474		
Dysfunctional	Gymnastics	3.535	1.046	1.301	.195
	Volleyball	3.334	1.245		
High +	Gymnastics	4.672	1.028	-3.266	.001
	Volleyball	5.148	1.135		
High -	Gymnastics	4.994	1.171	5.543	.000
	Volleyball	4.043	1.369		
Low +	Gymnastics	2.568	1.025	-6.850	.000
	Volleyball	3.682	1.400		
Low -	Gymnastics	2.395	.866	.919	.359
	Volleyball	2.288	.876		

Although the emotional patterns were the only significant ones, the scores on the Inhibition-Shifting index and those of the external focus of attention as preferred attentional style are close to .05. Therefore, we decided to run two Analysis of Covariance with the Inhibition-Shifting index first and the External Attentional Style secondly as the dependent variable, in order to detect any sports-related difference.

Firstly, we run an ANCOVA with Sport as a fixed factor, Inhibition-Shifting as dependent variable and age as a covariate. Results showed a significant effect of both age ($F_{(1;221)} = 23.115$, $p < .001$, $\eta^2 = .10$) and Sport type ($F_{(1;221)} = 6,088$, $p < .05$, $\eta^2 = .03$). Although no significant differences in age were found between the artistic gymnasts and the volleyball players, apparently the artistic gymnasts being about 6 months younger was enough to make the effect significant, once the age has been controlled for. Looking at the means of the two groups of athletes for the composite Inhibition-Shifting measure (i.e., a measure of error), we can observe that the volleyball players' have a higher score than the artistic gymnasts (M_G = -.078, M_V = .068). This result is in contrast with the literature suggesting that athletes of open-skills sports are better at inhibitory control (Wang et al., 2013). The effect of the type of sport is no longer present (F (1;220) =1.418, *p* =.25, η^2 =.01) if both age (F (1;220) =6.383, *p* <.05, η^2 =.03) and experience (F (1;220) =6.383, *p* <.05, η^2 =.02) are inserted as control variables. A possible explanation for this is that the experience reduces the differences between diverse sports similarly to how it reduces the differences on some cognitive tasks between male and female athletes (Voss et al., 2010).

We ran an ANCOVA with Sport as a fixed factor, the External attentional style as dependent variable and experience as a covariate. We did not put the age as a covariate because, differently from EFs, the attentional style is not a measure that develops with age. The results showed no effect of experience (F (1;221) =2.330, *p* =.128, η^2 =.01), but the type of sport was significant, albeit small, with η^2 =.02 (F (1;221) =4.890, *p* <.05). Indeed, volleyball players (M = 4.98) scored higher than artistic gymnasts (M = 4.68) on the External focus of attention measure. This result suggest, coherently with what proposed by Nideffer (Nideffer, 1990; Summers et al., 1991; Van Schoyck & Grasha, 1981), that open-skills sports athletes have a general preference for directing their attention towards environmental stimuli if compared to other disciplines.

5 DISCUSSION

5.1 GENERAL DISCUSSION

In this dissertation, the role of general cognition (i.e., working memory, executive functions), attentional style and emotions in predicting sport performance was analysed by means of a cross-sectional study with volleyball players and artistic gymnasts, designed within a developmental framework. This study provides innovation in research both because it applies a cognitive and developmental perspective to a sport psychology research question, and because, it tries to offer an integrated view of many mental abilities that are considered involved in sport performance (Raab, Lobinger, Hoffmann, Pizzera, & Laborde, 2015).

In this study, we considered (a) Working Memory (more specifically M capacity) as a general limited-capacity resource that allows the activation of schemes that are relevant for task performance (Pascual-Leone, 1987; Pascual-Leone and Johnson, 2005; Morra et al., 2008); (b) executive functions as top-down processes that regulate controlled behaviour and cognition (Diamond, 2014; Espy, 2004); (c) attentional style as the athlete's propensity to adopt a particular type of attentional focus, namely directing attention preferably to external, or internal stimuli and adopting a narrow or broader focus (Nideffer, 1976a; Moran, 1998); (d) emotions as the product of two independent neuropsychological systems, namely arousal and hedonic tone (Posner & Russell, 2005; Russel, 1980; Russell, 2009; Russell & Russell, 2016).

The general purpose of this study was to identify cognitive and emotion-related predictors of performance in different types of sports, namely open-skills (i.e., volleyball) sports and closed-skills sports (i.e., artistic gymnastics). Specifically, the aims of our study were (a) testing the hypothesis that M capacity represents a predictor not only of motor learning (Bisagno & Morra, 2018; Buszard et al., 2017), but also of performance in volleyball, but not in artistic gymnastics; (b) testing the hypothesis that Inhibition represents a predictor of performance in volleyball, but not in artistic gymnastics and verifying the role of both Updating and Shifting as a predictors of performance in both sports; (c) testing the hypothesis that volleyball players and artistic gymnasts differ in their attentional style and that a broad external focus of attention is more predictive of volleyball players' performance, whereas a narrow internal one is more predictive of artistic gymnasts' performance; (d) testing the hypothesis that volleyball players and artistic gymnasts differ in the emotional patterns they experience before a competition and verifying the role of arousal and hedonic tone in predicting performance in both sports; (e) testing the hypothesis of a moderation role of arousal and hedonic tone with respect to the relationship between M capacity and sport performance. We found that the results supported the first hypothesis of this research, while the others were only partly confirmed.

After running a series of CFAs including all cognitive task measures, we computed a composite M capacity-Updating index by combining the scores on the three M capacity tests and the two measures of updating. Similarly, we computed an Inhibition-Shifting predictor, by combining the error and cost measures in both the inhibition and the shifting tasks. Therefore, we tested two models of attentional style and we derived four predictors: external, internal, narrow and dysfunctional.

Finally, accordingly with the theoretical model, we derived four predictors from the items of the circumplex questionnaire as well: High +, High -, Low + and Low - emotions.

In order to test the role of these variables in predicting performance in both sports, we ran a series of regression analyses. The M capacity-Updating index emerged (together with the years of experience) as the only predictive variable for successful performance in volleyball. Conversely, the only predictor that emerged (together with age and the years of experience) in the regression for the artistic gymnasts' performance was given by the emotions with high arousal and an unpleasant hedonic tone, which entered the model with a negative beta. This dichotomy between volleyball players' performance, for which the main predictor was represented by a general cognitive construct, and artistic gymnastics, in which the main predictor was basically given by emotion regulation, was substantially in agreement with our hypothesis.

THE ROLE OF M CAPACITY AND UPDATING IN SPORT PERFORMANCE. Based on Poulton's (1957) categorization of sports according to the predictability of the environment they are played in, volleyball, as an open-skills sport, is characterized by the impossibility to fully rely on automatisms, since the surrounding environment (i.e., teammates, opponents) changes constantly and the athlete is forced to rapidly adapt to new stimuli. In this sense, the ability to coordinate and integrate mental schemes becomes fundamental, as well as the ability to update them when needed. We can imagine the case of a hitter who, while she is approaching the ball in order to attack, needs to activate (at least) a scheme of her own position in space, one of the ball's trajectory (i.e., to hit it with the right timing), a scheme of the opponent's block disposition, not to be stopped by it, a scheme of the position of the rest of the opponent team, in order to decide which kind of attack to perform and in which zone of the court. This decision process happens under very limiting time constraints and, even though many motor schemes the athlete needs to activate in order to perform a motor gesture are completely automated and, therefore, do not load on M capacity any longer (Shiffrin & Schneider, 1977), still – due to this unpredictability of the environment, several cognitive, perceptual, and motor schemes require controlled processing and demand attentional resources. Therefore, the role of M capacity and updating in volleyball performance appears particularly relevant. This result is coherent with the few other researches that explored the role of working memory in sports, showing how individual differences in working memory represent good predictors of motor learning (Behmer & Fournier, 2014; Bisagno & Morra, 2018; Buszard et al., 2017; Seidler, Bo, & Anguera, 2012) and decision making in sport performance (Furley & Memmert, 2010, 2012; Gimmig et al., 2006).

Moreover, an explanation of the different role that working memory plays in predicting performance in volleyball and artistic gymnastics is offered by dual-process theories (Evans & Stanovich, 2013; Furley, Schweizer, & Bertrams, 2015; Kahneman, 2011; Schneider & Shiffrin, 1977). According to dual-processes theories, Type 1 processes are "both initiated and completed in the presence of relevant triggering conditions" (Furley et al., 2015), therefore they are called autonomous and do not heavily rely on working memory to be successfully accomplished. These processes can be distinguished from Type 2 processes by the assumption that the response to the trigger has become part of its cognitive representation, thus it is automatized (Thompson, 2013). In contrast, Type 2 processes require working memory in order to produce an appropriate response to environmental stimuli (Evans & Stanovich, 2013). Although dual-processes theories have undergone some criticism (Keren & Schul, 2009), Furley et al. (2015) consider them a fruitful meta-theoretical framework for understanding behaviour in sports.

We can say that, in general, all athletes need to rely on Type 2 processes, for example when they are learning a new gesture or facing a new task. This experience is common to athletes of both open and closed-skills sports and it is indeed described by Fitts's theory as the progress from a cognitive to an autonomous stage of motor learning (Fitts & Posner, 1967; Fitts, 1964). On the other hand, experienced athletes benefit from Type 1 mechanisms, which allow them to perform fluently and to execute very polished gestures, causing less expenditure of mental resources.

To summarize, we can say that Type 1 processing will "get the job done" in many circumstances, but in some situations, Type 2 processing is required. What makes a difference between closed and open-skills sports is then the number of situations in which Type 2 processes need to be activated. For example, Furley et al. (2015) highlight the role of Type 2 processes in carrying out action plans, e.g., passing the ball to a certain receiver in American football, focusing indeed on the amount of information that one needs to integrate into this task. These situations are more common in open-skills sports, due to the presence of teammates and/or opponents on field, since 'we do influence ourselves in action, at different time scales and in different contexts, both as individuals and in groups, especially small groups engaged in joint action' (Sutton, McIlwain, Christensen, & Geeves, 2011).

In contrast, closed-skills sports summon Type 2 processes during motor learning but, typically, expert athletes perform within a stable environment, in which the number of uncontrollable variables is minimized. Moreover, in sports like artistic gymnastics, the performance consists in a highly trained and automatized routine that does not require attentional control to be performed; on the contrary, this might even disrupt fluent execution as stated by the "paralysis by analysis" hypothesis (Baumeister, 1984)(e.g., Baumeister, 1984; Beilock & Carr, 2001; Hardy, Mullen, & Jones, 1996; Masters, 1992).

To conclude, generally speaking, in open-skills sports the cognitive load the athlete has to manipulate is greater, thus making the role of working memory more predominant. Conversely, artistic gymnasts' performance consists of an automated motor repertoire. Therefore, our results pointing to a role of M capacity and Updating in predicting performance in volleyball but not in artistic gymnastics are coherent with the idea of a major cognitive load determined by situational aspects of open-skills sports.

THE ROLE OF INHIBITION AND SHIFTING IN SPORT PERFORMANCE. Formulating a precise hypothesis on the role of inhibitory and shifting mechanism in volleyball and artistic gymnastics was not an easy task. Indeed, the literature on this topic is rather limited and lacks agreement on how to define EFs. After performing a series of CFAs, we found that the best fitting model included a factor that comprised the athlete's score on the measures of both inhibition and shifting. However, when we performed the regression analyses this index did not predict either the artistic gymnasts' performance or -as we would have expected- for the volleyball players' performance.

This result is in contrast with other studies, suggesting not only that athletes practising open-skills sports are better than controls (including athletes of closed-skills sports) in inhibitory tasks (Nakamoto & Mori, 2008; Wang et al., 2013), but also that their inhibition abilities are predictive of their sport performance (Verburgh et al., 2014). A possible explanation for this discrepancy relies on the factor structure that emerged from the tasks we used. Indeed, all the previous studies just looked at inhibition, while we used a composite inhibition-shifting index. Another possible methodological explanation depends on the measures we used to test inhibition itself. Indeed, Verburgh et al. (2014) tested young soccer players on a Stop-signal task, similarly to Wang (2013), who found an advantage of tennis players over swimmers in response time. Nakamoto & Mori (2008) tested their participants (i.e., basketball players, baseball players and controls) with a Go-No go task. According to an aforementioned distinction (Friedman, 2004; Nigg, 2000, 2001) of types of inhibitory control, the Stop-Signal task and the Go-No go task are specifically designed as prepotent response inhibition tasks, and the same is true for the Stroop task that we used in our study. However, we also used an arrow Flanker task, which is considered to measure resistance to distractor interference. As described in section 4.2.1, we decided to use this task to address different aspects of inhibition. However, this methodological choice could as well be the reason for the different results between previous studies and ours with respect to the role of inhibition and shifting in predicting performance in open and closed-skills sports. It is indeed possible that only pure response inhibition is somehow predictive of performance in sports, while interference control and shifting are not related to it.

With the aim to better explore potential differences between the two sports, we ran an ANCOVA with Sport as a fixed factor and age as a covariate from which observed that the composite inhibition-Shifting measure (i.e., a measure of error) was higher for the volleyball players than for the artistic gymnasts. Again, this result is in contrast with the studies described above, especially with Wang et al. (2013), who suggest superiority of open-skills sports athletes in inhibitory control. However, in a recent study, Jacobson & Matthaeus (2014) compared athletes of sports mainly comprising self-paced skills to athletes of sports mainly comprising externally-paced skills and to non-athletes on their performance at the Stroop task. Self-paced skills are those in which the athlete controls the rate at which the performance is executed and require high levels of focus and discipline. This is more common in closed-skills sports since there are no external factors forcing the athletes into performing a skill before being ready (Singer, 2000). In contrast, externally paced skills are forced by the environment (i.e., a footballer being forced into passing due to the pressure exerted from an opposition player) and they are very common in open-skills sports. Similarly to our study, Jacobson and Matthaeus (2014) found that self-paced athletes performed better than externally-paced athletes on the Stroop task. Offering a reversal of perspective in comparison with the aforementioned studies, they suggest that is because self-paced athletes' performance mainly depends on their ability to suppress external (i.e., the audience, in order to concentrate) and internal (i.e., pain, fatigue, anxiety) distractors to maximize performance (Singer, 2000).

ATTENTIONAL STYLE IN SPORTS. With respect to the attentional style, Nideffer's hypothesis (Nideffer, 2007) of a different style between open and closed-skills sports was tested, together with their predictivity of performance. Also in this case, after performing a series of CFAs, we found the best fit not for a three-factor model, as usually reported by Nideffer, but a four-factor model, describing four different focuses of attention, namely external, internal, narrow and dysfunctional (i.e. a tendency to overload and/or excessively reduce the attentional focus). Also in this case, when we performed the regression analyses none of these factors predicted either the artistic gymnasts' performance or -as we would have expected- the volleyball players' performance.

With respect to the theoretical model (Nideffer, 1990), we would have expected a broad-external attentional focus to predict the volleyball players' performance, and a narrow and internal focus to be predictive of the artistic gymnasts' performance. However, it is also true that neither Nideffer nor following studies ever tested a causal model but always focused on between sports differences. It is conceivable that the relation between attentional style and sport performance is reversed: a certain attentional style would not predict sport performance, rather, using an *expertise* approach we could argue that practising a certain sport would favour the adoption of a peculiar attentional focus.

Indeed, the ANCOVA with the external attentional style as the dependent variable and experience as a covariate showed an effect of the sport. Coherently with Nideffer's model (Nideffer, 1990; Summers et al., 1991; Van Schoyck & Grasha, 1981), volleyball players scored higher than artistic gymnasts on the external focus of attention measure, albeit the effect size of the difference was small. This result is in line with Nideffer's (2007), who compared 2535 professional athletes involved in team sports like hockey, soccer and baseball with 767 athletes involved in closed-skill sports like diving, archery, shooting, and 1464 athletes involved in open-skill (but not team) sports like tennis, judo, and karate, finding that closed-skill sports participants were characterized by a narrow focus of concentration, while those competing in open-skills and especially team sports tended to adopt a broad external focus of attention. Taken together, these results could lead us to think that it is indeed the sport which shapes the athlete's attentional focus. In this case, we should observe an effect of experience as well, meaning that the longer an athlete practices a sport, the more his/her attentional style becomes stable. However, our results showed no effect for the experience or for the interaction experience*sport. Therefore, either also this explanation is misleading, or a qualitative stable difference between sports can only be seen at a very high elite level. In a developmental sample only a slight tendency, with no clear trajectory can be detected. Since we have no adults elite athletes in this sample, these results remain partially unclear.

Another meaningful aspect is that, even though only the External focus reaches the significance level, the volleyball players score higher than the artistic gymnasts on the internal factor as well. These results seem to document the ability of these athletes to allocate their attention to external or internal stimuli in relation to the different game situations, suggesting that the main characteristic of open-skills sports athletes may not be a preference for an external focus, but flexibility in adaptively re-orienting attention when needed. Evidence in this sense is presented by many studies on attention orienting with volleyball players (Bosel, 1998; Castiello & Umiltà, 1990; Nougier, Rossi, Alain, & Taddei, 1996). In general, we can affirm that results regarding attentional style measures lend themselves to multiple interpretations and are potentially subject to debate.

THE ROLE OF EMOTIONS IN SPORT PERFORMANCE. Antithetically compared to volleyball players', artistic gymnasts performance resulted to be predicted by no cognitive factor. Instead, the best predictor of artistic gymnasts performance, together with experience and age (included in the model with a negative beta – meaning that younger athletes performed better than the older ones) were high-arousal and unpleasant hedonic tone emotions, which entered all the regression models with a negative coefficient. This result suggests that what makes the difference in artistic gymnasts performance is indeed the ability to control unpleasant emotions and not to get excessively (dis)stressed before a competition. Another hint in this direction emerged from the comparison between categories, showing that not only emotions were the only significant predictor of artistic gymnasts' performance, but they also distinguished between *Silver* and *Gold* athletes. Indeed, the first ones appeared to experience less low-arousal pleasant emotions (calm, relaxation, serenity) and more high-arousal unpleasant emotions (stress, tension, anger). Since *Gold* athletes are those competing at a higher level, this difference can be interpreted as further proof that controlling unpleasant emotions is a fundamental prerequisite for artistic gymnasts to succeed. This result is consistent with previous research showing that high levels of stress are detrimental for artistic gymnasts performance (Cottyn et al., 2012; Mahoney & Avener, 1977), while pre-competitive routines to cope with anxiety have a beneficial effect on performance itself (Faggiani, McRobert, & Knowles, 2012; Gröpel & Beckmann, 2017).

In contrast with the artistic gymnasts' model, emotional aspects were not included among the significant predictors of volleyball players' performance in the stepwise regression analyses. However, High - emotions became significant when all the predictors were entered in the regression at the same time, thus controlling each other. In this case, the coefficient was positive, meaning that emotions like stress and tension actually predict a good performance in volleyball. This result could be understood in connection with an IZOF perspective (Hanin, 2000, 2002, 2014), because emotions that are typically considered unpleasant and dysfunctional (e.g., anxiety) can be indeed predictive of positive performance for certain athletes (Ruiz et al., 2016; Yao, 2016). Moreover, sports based on the athlete's rapid reaction (or collision sports, such as wrestling, American football and rugby) can benefit from unpleasant emotions like anger and anxiety (Campo et al., 2012). Here we suggest that optimal functioning is not only individual but could be derived by the fit between the athlete's personal characteristics and the environmental requests placed by the sport itself. In this sense, we could argue that open-skills sport can benefit to a higher extent from emotions with a high arousal level, even when unpleasant, because, net of individual differences, they facilitate the athlete in rapidly reacting to environmental changes. Conversely, closed-skills sports could profit from a lower level of High- emotions, to better maintain control.

If in a regression analysis we found a direct positive effect of High- emotions in predicting volleyball players' performance, comparing volleyball players and artistic gymnasts we also found that the former actually experience less high-arousal unpleasant emotions and more pleasant emotions, both with high arousal (happiness and excitement) and with low arousal (calm and relaxation). Similarly, in a study with 116 collegiate non-professional athletes (Aufenanger, 2005), open-skills athletes were found to be higher in self-confidence intensity and lower in somatic anxiety intensity than closed-skills athletes. If read in a performance perspective, these results could be considered counterintuitive, however, they can also be read from a social psychology point of view, considering that we are comparing non-professional developing athletes. Indeed, we could suppose that, in general, team sports benefit of perceived social support (Rosenfeld & Richman, 1997) more than individual sports such as artistic gymnastics. Moreover, some research suggested that team sports offer to the athlete an opportunity to diffuse responsibility among teammates, thus minimizing the identifiability of an individual's performance contributions and therefore reducing pre-competitive anxiety (Scanlan, 1984). So, if on the one hand, experiencing pre-competitive anxiety could facilitate volleyball players' performance, on the other hand, sharing the experience with teammates makes volleyball players happier and less (dis)stressed than artistic gymnasts before a competition (Freeman & Rees, 2010).

Finally, considering the theories that suggest a role of unpleasant (Baumeister, 1984; Beilock, 2007; Hill et al., 2010) emotions in regulating the relationship between working memory and performance, we also looked for moderation effects of the unpleasant hedonic tone on the relationship between Mcap-Upd and performance in the volleyball players' sample. However, neither the "Hedonic tone -" variable (computed by adding up all the items with unpleasant hedonic tone and subtracting those with a pleasant hedonic tone), nor the interaction between the same variable and M capacity-Updating index entered a new stepwise regression. Therefore, we did not find any moderation effect of hedonic tone on the relationship between working memory and sport performance in volleyball. A possible explanation for this non-significant result is that the hedonic tone dimension alone is not sufficient in order to capture the negative moderation effect described above.

We, therefore, looked at the effect of arousal in combination with the hedonic tone. In order to do so, we calculated two arousal indices, one in pleasant and one in unpleasant emotions. After splitting our sample according to a dichotomy criterion, we derived four groups of participants, namely: (a) participants who scored below the mean in the difference between high and low arousal emotions, in both pleasant and unpleasant emotions, (b) participants who scored below the mean in the difference between high and low arousal-emotions in pleasant but above the mean in the difference between unpleasant emotions, (c) participants who scored below the mean in the difference between high and low arousal-emotions in unpleasant but above the mean in the difference between pleasant emotions and (d) participants who scored above the mean in the difference between high and low arousal-emotions in both pleasant and unpleasant emotions. We then tested the correlation between the M capacity-Updating index and sport performance in each of the four groups, finding a significant correlation in the group (c) of athletes, i.e., those who, before a competition, feel more excited and less calm, while being less stressed and perhaps a bit discouraged, and in group (d) of athletes, i.e., those who tend to be both more excited and stressed. These results suggest indeed a combined moderating role of emotions on the relationship between working memory and performance. Specifically, volleyball players' tendency to experience more high-arousal emotions with respect to low arousal emotions, especially pleasant ones (i.e., excitement) would endorse the relationship between working memory and sport performance, and to a larger extent if the arousal on the unpleasant emotions is lower. A possible explanation for this result, especially if combined with the results of the regression analyses, is that, even if they do not show or only marginally show a direct effect on performance in volleyball, high arousal emotions do actually moderate the role of working memory in sports, but they are in return moderated by the athletes' general feeling towards the competition. In other words, if an athlete is generally happy and excited to compete, unpleasant emotions will not make him or her choke under pressure.

A better outlook on the interaction between emotions could be offered by the IZOF model, according to which the total impact of emotions on the task is derived from the interaction of enhancing and impairing emotion effects. Therefore, an athlete performs at his/hers best when his/hers personal functional emotions (regardless if pleasant or unpleasant) are in his/hers individual zone of optimal functioning while dysfunctional (pleasant and unpleasant) emotion intensities are outside the non-optimal zone. (Hanin, 2000; Robazza, 2006). An idiographic approach could better inform us with respect to the interaction between different emotions in influencing the performance and, possibly, also in influencing the relation between the performance itself and cognitive predictors.

5.2 LIMITATIONS AND FUTURE DIRECTIONS

Being a relatively new typology in sports study, this research presents some limitations.

From a methodological point of view, the first one is related to the sample. Being an only-female sample, our findings are only generalizable to female volleyball and artistic gymnastics athletes. We cannot exclude that with male athletes, the same predictors could have a different role and load, especially with respect to attentional style (Lipoma et al., 2006) and emotional aspects (Nicholls, Polman, Levy, & Backhouse, 2009; Robazza, Bortoli, & Nougier, 1998), regarding which evidence of gender-related differences is documented in literature. In order to verify this, it would be interesting to repeat this study with both a male and a female subsample.

Other limitations pertain the measures we used to asses our predictors. While M capacity measures had already been successfully used in another research with athletes (Bisagno & Morra, 2018) and showed very good correlations with each other, some of the EFs measures, namely the ones testing inhibition and shifting were not always correlated with each other. This could have made the composite measure we derived less reliable, given the correlations between the variables on the basis of which they were built were not always significant. Such low or nil correlations denote a certain heterogeneity of the construct. With respect to inhibition measures, this could be due to the fact that we used a measure of response inhibition (i.e., the Stroop task) and a measure of interference control (i.e., the Flanker task). We specifically made this choice in order to capture different aspects of inhibition, however, this resulted in a methodological limitation. Future research aiming to study the role of inhibition in predicting sport performance should use tests assessing the same aspect of inhibition or, in order to study both aspects, at least two measures for each type of inhibitory control (Friedman, 2004; Miyake et al., 2000). As regards to the shifting measures, a possible explanation for their not being correlated could be due to differences in the measures themselves (i.e., the TMT is a paper-pencil test, while the Colour/Shape is a computerized measure). Also in this case, similarly to the choice of using two EF measures instead of three for each of the EFs described by Miyake, we were driven by "economic" reasons. Indeed, athletes undertook long assessment sessions and we could not use additional measures that would be even more time-consuming. In order to avoid this methodological problem, future research might prefer to use more similar measures, in order to reduce measure-related error variance.

Another critical aspect is related to the artistic gymnasts' performance measure, for two different reasons. On the one hand, the score attribution system itself, in artistic gymnastics, is based on a subjective component (i.e., the judges). For this reason, using measures from different competitions and, therefore, scores derived from diverse raters, we could not guarantee that the same parameters were used to assess them all. However, we wanted to use the most ecological measure of performance as possible, and using real competition scores was the best option in this sense. Secondly, we included in our sample both *Gold* and *Silver* artistic gymnasts, whose scores are attributed according to different criteria and rating grids, and we then had to create and compute a method to combine them on a single scale. Future research could consider to include either *Gold* or *Silver* artistic gymnasts, and, if possible, video-record the actual competitions in order for them to be at least re-scored by new independent judges.

More importantly, from a sport psychology perspective, another limitation could be found in the use of a nomothetic approach with respect to the study of emotions. This approach was mirrored in the choice of an ad-hoc assessment measure. We could also have used the Affect Grid, which has its theoretical foundation in the Circumplex model as well, however, the Affect Grid is meant to capture the athlete's individual feeling along with the arousal and hedonic tone dimensions with respect to the present situation. Since we wanted to assess how participants felt, in general, before a competition, we decided to use a list of descriptors. Future research might use the Affect Grid to offer better insight into the athlete's emotions even right before or during the competition.

Plus, although the "Circumplex" questionnaire was useful for our purpose of studying the dimensions of arousal and hedonic tone of emotions in relation with cognitive predictors, we certainly missed an idiographic component that could have offered us a clearer pattern of results by focusing on the functional/dysfunctional impact of emotions on performance (Robazza, 2006; Ruiz et al., 2017). For this reason, a very close future direction of our study will be to analyse the data we collected framed on the IZOF perspective administering the Individualized Profiling of Psychobiosocial States questionnaire (Ruiz et al., 2016) with the aim of better understanding the effect of functional and dysfunctional emotions in influencing the volleyball players and the artistic gymnasts' performance.

In general, our study was ambitious in putting together many elements of novelty and, therefore, given these first results, it could be useful to take a step back and examine more in depth the relationship between the predictors that resulted significant in this study and sport performance.
Specifically, the relationship between high-arousal unpleasant emotions and artistic gymnasts' performance could be studied with respect to other possible moderators. For example, Jones, Swain, & Hardy (1993) conducted a study with artistic gymnasts on the relationship between anxiety and performance on the balance beam. In this research, forty-eight female artistic gymnasts were divided into poor performance and good performance groups based on their previous competition scores. The results indicated that the two groups did not differ in the intensity of their anxiety, but in the interpretation, the athletes themselves gave to this emotional state. Specifically, the good performance group considered anxiety as facilitative towards performance, while the poor performance group considered it debilitative. This result suggests to further analyse the relationship between emotions and performance in artistic gymnastics within an IZOF theoretical framework (Hanin, 2000; Robazza et al., 2008, 2006). Moreover, the authors measured each athlete's self-confidence level. The intensity of self-confidence positively correlated with the facilitative interpretation of anxiety, suggesting a moderation role of self-confidence in the relationship between anxiety and performance.

With respect to volleyball performance, future studies could further explore the moderating role of emotions on the relation between working memory and performance. One possibility is to combine and compare different measures of general cognitive functioning, Moreover, a very promising line of research theorizes about the relations between general cognitive functions and sport-specific measures of cognition, such as decision making or anticipation, and, in turn, the relations between the latter and performance. Indeed, some interesting studies link working memory capacity with sport-specific decision making (Furley & Memmert, 2010, 2012), while some others studied the relationship between decision making and performance (Musculus, 2018). Exploring the relationships between all these variables would be a promising research field, and possibly one could find a mediating role of sport-specific decision making in the relationship between working memory and field performance. Moreover, in order to clarify the relation between general and sport-specific cognitive factors, a developmental perspective is promising, since it allows to address the (causal) relations while they are developing. Also in this case, a similar approach could also have important applicative implications, since it would be a useful perspective for identifying talented athletes in professional sports at an early age (Mann et al., 2017).

Finally, of course, a complete representation of which factors determine sport performance cannot avoid taking the physical component into consideration. For this reason, in future researches on the predictors of sport performance a multi-disciplinary approach that includes both psychology and sport sciences expertise would be desirable.

5.3 ELEMENTS OF NOVELTY AND PRACTICAL APPLICATIONS

Despite the aforementioned limitations, this study has the merit of having introduced many elements of novelty with respect to cognitive research in sports studies. First of all, to the best of our knowledge, this is the first study that offers an integrated approach to the study of cognitive and emotional predictors in sports, taking into account the difference between open and closed-skills sports with respect to all these variables in a developmental sample.

Specifically, taking into account many predictors and two different types of sports together gave us the opportunity to shed light on the different demands that sports place on the athletes according to their characteristics. Indeed, even though not all of our hypotheses have found confirmation in the data, this research has outlined a clear dissociation between the prerequisites necessary for effective performance in an open and a closed-skills sport. Specifically, it has been pointed out that general cognitive skills, such as M capacity and working memory updating, represent a fundamental predictor of performance in volleyball, being a sport in which the athletes need to manage a high load of information. On the other hand, given that none of the cognitive variables entered the regression model with the artistic gymnasts' performance as the dependent variable, this study offered a unique insight on how the level of automatization given by training allows artistic gymnasts to reduce the cognitive load of their performance. In this way, the outcome of the competition, for artistic gymnasts, seems to depend mostly on the ability to regulate their emotions and manage pre-competitive anxiety. From a practical point of view, this evidence could result in customized mental training curricula. Indeed, identifying which cognitive abilities and which emotional patterns are more involved in performing a certain sport, could allow to specifically tailor psychological skills training interventions in order to match the sport's mental requests – similarly to what happens with physical training. In this sense, we could propose a working memory training to volleyball players or possibly other interceptive sports athletes, while in training athletes engaged in closed-skills sports we would mainly focus on emotion regulation strategies.

Another element of novelty in this research is that, feeding into a rather small research line (Huizinga et al., 2006; Ishihara et al., 2018; Verburgh, Scherder, et al., 2014; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012; Vesterberg et al., 2017), it offers a developmental perspective. Developmental studies investigating general cognitive functioning with respect to performance are indeed quite rare. However, they all underline the importance of understanding cognitive functioning in its development, to identify actual predictors of sport performance. Indeed, testing athletes of different age groups and different sports allowed us to provide insights into the relation of complex cognitive functions, motor learning and performance in different sports.

Finally, our study distinguishes itself for a specific ecological approach to the study of sport performance. Indeed, as dependent variables, we used the scores of the actual competitions the athletes participated in during their sport seasons. In sport studies, this approach is more likely to be used in individual sports since scores are easier to gather. Conversely, in team sports, research usually focuses on comparing different sports or levels of experience with respect to the athletes' cognitive abilities, tested without using sport-specific cues or tasks, like in the cognitive component skills approach (Voss et al., 2010; Wang et al., 2013) or within an ecologically valid context (Starkes & Ericsson, 2003), like in the expert performance approach (Mann et al., 2007). Researches that study individual differences in team sports, hardly focus on the actual "on-field" performance (Vestberg et al., 2012) , mainly using "off-line" decision making paradigms (Furley & Memmert, 2012; Philip Furley & Memmert, 2015; Musculus, 2018), which are of course valid outcome measures, but they do not completely mirror the real "on-line" game situation.

Driven by the specific desire to use real competition results as our dependent variable for volleyball performance as well, we ideated and tested a scoring system similar to the one used in scouting, but designed to take into account all of the gestures that an athlete performs during a game. Based on the rules of volleyball according to FIPAV and on my personal experience as a volleyball coach, we defined a series of criteria in order to score the athletes' gestures, and we submitted the video-recordings of our participants' volleyball matches to two independent raters. Moreover, well aware of aiming to derive an individual performance measure from the performance, by its nature, of a group, we devised and calculated a control index that takes into account the –indeed- “open” component of volleyball. This index, calculated through the score difference in each *Set* played by the athlete and weighed on the actual participation of the athlete herself to the game, has allowed us to definitely calculate an individual performance measure (i.e., the residuals of the regression of the “individual index” on the “team” one). This measure proved to be reliable, showing a high degree of agreement between the two independent observers.

The calculation of this dependent variable is, therefore, a significant example of how an expertise-based methodological approach can be used in order to acquire a performance measure that is as much as possible "cleaned up" from error variance while maintaining an ecological approach.

6 POSTFACE

In conclusion, I think that this study represents a first attempt to offer a more complete image of which psychological abilities are involved in different sports. We also think that, despite its limits, this research lays the foundations and emphasizes the importance of a greater dialogue between cognition, emotion and sports - in order to develop increasingly precise models of athletes' mental functioning and, consequently, offer them more and more refined intervention programmes in order to support them enhancing performance.

Now, looking back at the very first questions that motivated my research, I have some more answers. I know, now, with scientific data and not only by personal experience, that motor performance requires general cognition, albeit to a lesser extent with respect to motor learning (Bisagno & Morra, 2018; Fitts, 1964), and that this is true specifically for sports that require to process a substantial amount of information (i.e., open-skills sports or, at least, volleyball).

I know that, despite the importance of general cognition, emotions still play a role in moderating the relationship between cognition and sport performance, which is another aspect that was both well acknowledged in other performance contexts, such as the academic one (Ashcraft, 2001; Ashcraft, 2002; Passolunghi, Caviola, De Agostini, Perin, & Mammarella, 2016).

I also know that, in sports like artistic gymnastics, in which highly trained routines are performed during competition, expertise and emotional control are the most important prerequisite for a skilled performance (given this information, I also know why I played volleyball instead of practising artistic gymnastics, since I'm the most anxious human being I know).

Most of all, I know that this research is just a tiny drop in the ocean but, hopefully, it will be the beginning of many more studies on this fascinating topic, and the first of many more answers I will keep looking for. In the end…

If we knew what it was we were doing, it would not be called research, would it?
(Albert Einstein)

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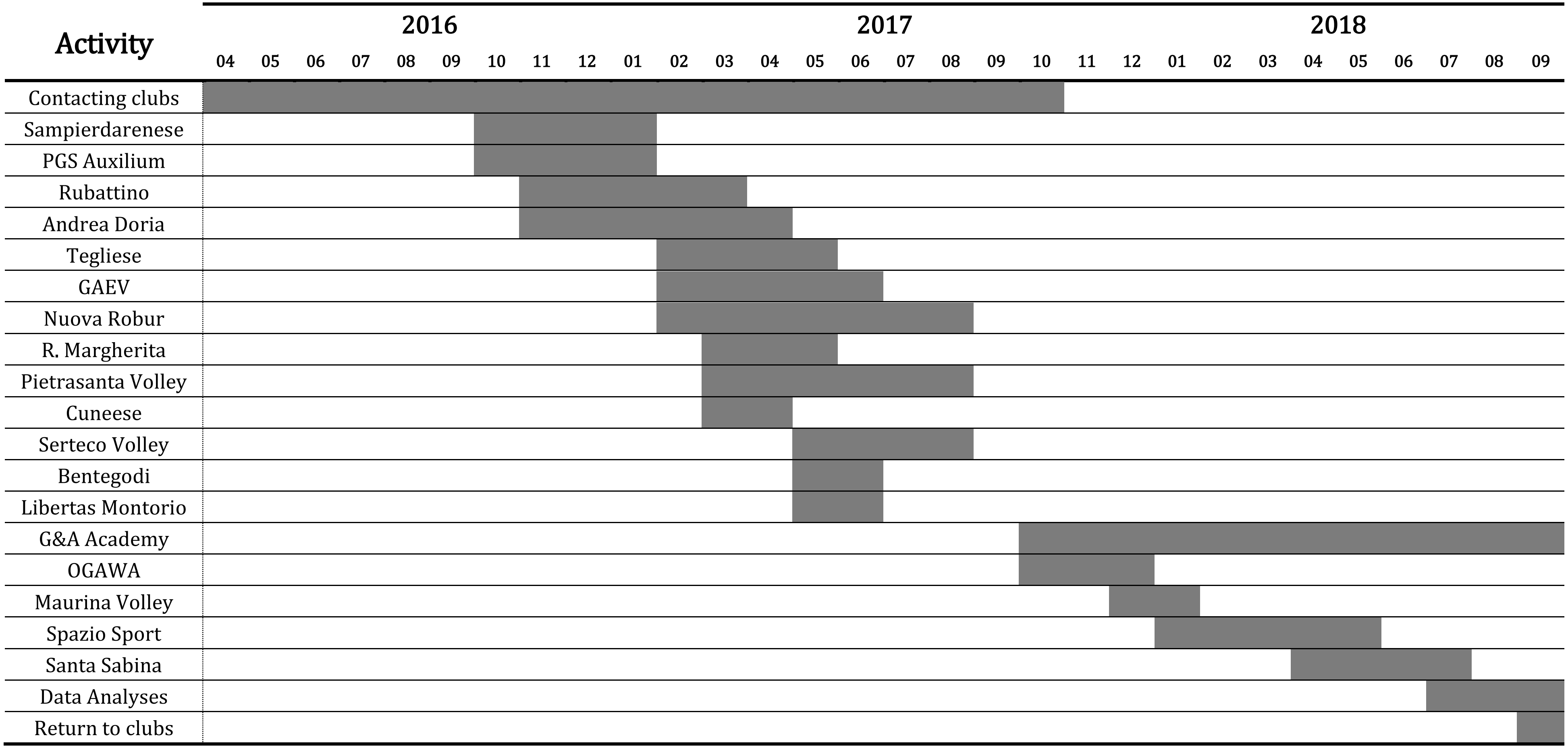
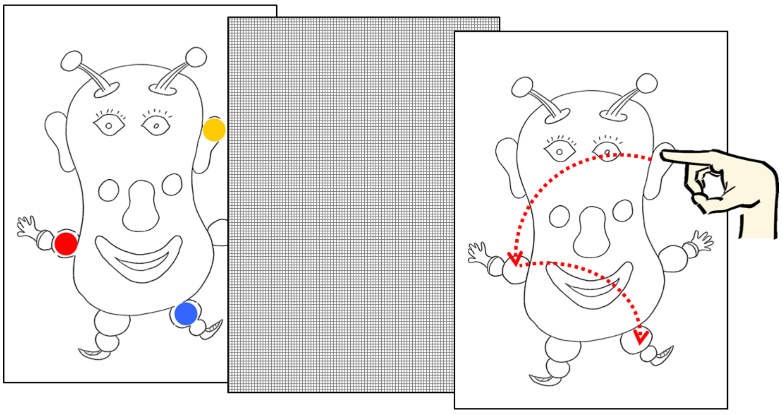
APPENDIX A. PROJECT SCHEDULE FOR THIS RESEARCH

FIGURE A.21. 2016-18 GANTT.

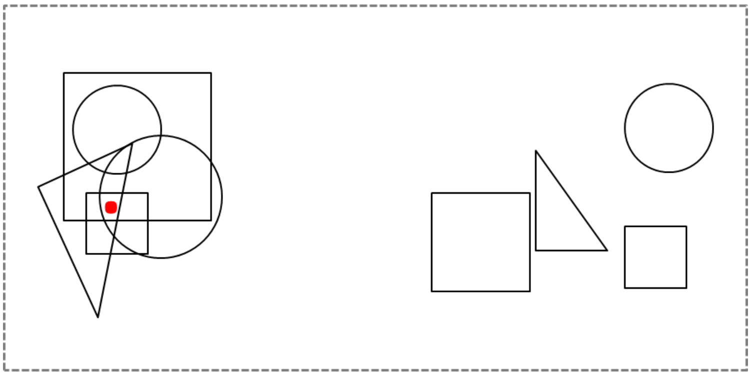


M capacity measures

Mr Cucumber Test
(Case, 1985; Morra, 1994)

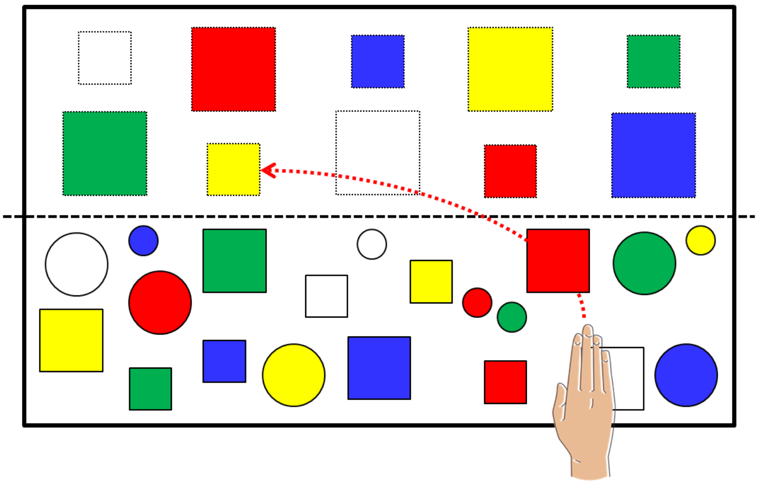


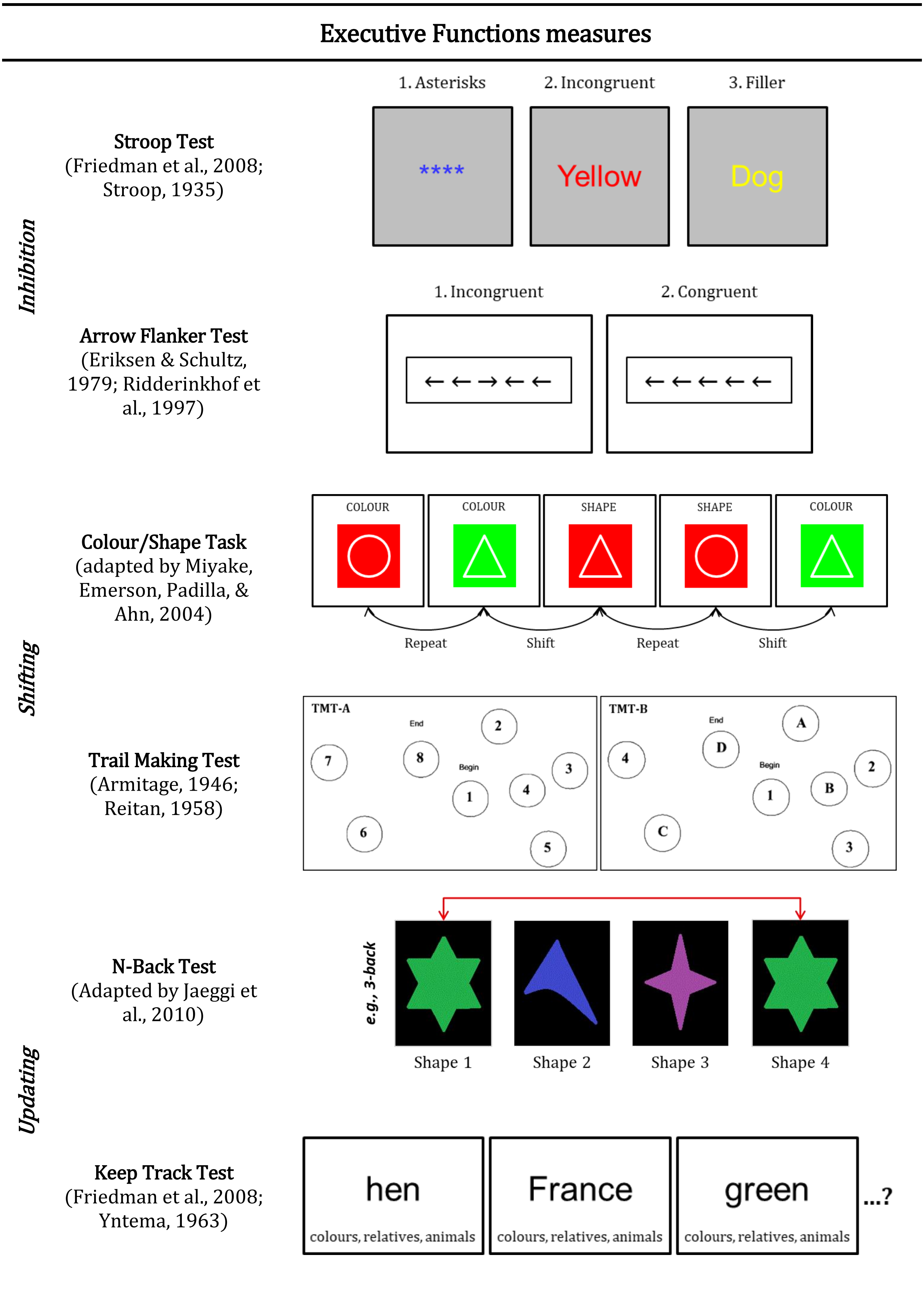
Figural Intersection Test
(Pascual-Leone & Baillargeon, 1994)



Direction Following Task
(Cunning, 2003; Pascual-Leone & Johnson, 2005)

e.g., "Place a big white square on a small yellow space"




Executive Functions measures
Inhibition
Stroop Test
(Friedman et al., 2008; Stroop, 1935)
1. Asterisks
2. Incongruent
3. Filler
****
Yellow
Dog
Arrow Flanker Test
(Eriksen & Schultz, 1979; Ridderinkhof et al., 1997)
1. Incongruent
2. Congruent
Shifting
Colour/Shape Task
(adapted by Miyake, Emerson, Padilla, & Ahn, 2004)
COLOUR
COLOUR
SHAPE
SHAPE
COLOUR
Repeat
Shift
Repeat
Shift
Trail Making Test
(Armitage, 1946; Reitan, 1958)
TMT-A
TMT-B
End
Begin
Updating
N-Back Test
(Adapted by Jaeggi et al., 2010)
e.g., 3-back
Shape 1
Shape 2
Shape 3
Shape 4
Keep Track Test
(Friedman et al., 2008; Yntema, 1963)
hen
France
green
colours, relatives, animals
colours, relatives, animals
colours, relatives, animals
...?

Test of Attentional and Interpersonal Style (TAIS)

Test di Stile Attentivo e Interpersonale

0 = Mai; 1 = Raramente; 2 = Qualche volta; 3 = Spesso; 4 = Sempre

Per favore, cerchia il numero che ti descrive maggiormente.

1. Sono brava nell'analizzare rapidamente situazioni complesse, come per esempio lo svilupparsi di una partita di calcio o distinguere, tra 4-5 bambini, quale abbia iniziato una lite.	0	1	2	3	4
2. Mi risulta facile associare tra loro idee appartenenti a diversi campi.	0	1	2	3	4
3. Nei giochi, commetto degli errori perché mi concentro su un giocatore e mi dimentico degli altri.	0	1	2	3	4
4. Mi riesce facile impedire ai miei pensieri di interferire con ciò che sto ascoltando o guardando.	0	1	2	3	4
5. In una stanza piena di bambini o su un campo di gioco, mi rendo conto di ciò che ognuno sta facendo.	0	1	2	3	4
6. Ho talmente tante cose in testa, che mi confondo e divento smemorato.	0	1	2	3	4
7. Mi confondo quando cerco di seguire attentamente attività complesse dove accadono molte cose contemporaneamente, come una partita di calcio o un circo.	0	1	2	3	4
8. Trovo difficoltà a sgombrare la mente da un pensiero o un'idea.	0	1	2	3	4
9. Quando la gente mi parla, mi rendo conto di essere distratta dai miei pensieri e dalle mie idee.	0	1	2	3	4
10. Mi riesce facile evitare che ciò che ascolto e vedo interferisca con i miei pensieri.	0	1	2	3	4
11. Mi bastano poche informazioni per elaborare un gran numero di idee.	0	1	2	3	4
12. Quando la gente mi parla, mi rendo conto di essere distratta da ciò che sento e dalle cose che mi circondano.	0	1	2	3	4

"Circumplex" Questionnaire

Nome: ______________________

Cognome: ______________________

Data: ______________________

Di seguito leggerai alcuni aggettivi che descrivono emozioni. Pensa a come ti senti, GENERALMENTE, prima di una gara o una partita e indica quanto ciascuna delle emozioni seguenti rispecchi il tuo vissuto, cerchiando un numero da uno a sette, dove:

1 = mai; 2 = quasi mai; 3 = raramente; 4 = qualche volta;
5 = spesso; 6 = molto spesso; 7 = sempre

Ricorda di rispondere con la massima sincerità, poiché non ci sono risposte corrette o errate.

Stressata	1	2	3	4	5	6	7
Rilassata	1	2	3	4	5	6	7
Scoraggiata	1	2	3	4	5	6	7
Felice	1	2	3	4	5	6	7
Tesa	1	2	3	4	5	6	7
Stanca	1	2	3	4	5	6	7
Eccitata	1	2	3	4	5	6	7
Calma	1	2	3	4	5	6	7
Stimolata	1	2	3	4	5	6	7
Depressa	1	2	3	4	5	6	7
Arrabbiata	1	2	3	4	5	6	7
Serena	1	2	3	4	5	6	7

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How do we learn to "kill" in volleyball?: The role of working memory capacity and expertise in volleyball motor learning

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ABSTRACT

This study examines young volleyball players' learning of increasingly complex attack gestures. The main purpose of the study was to examine the predictive role of a cognitive variable, working memory capacity (or "M capacity"), in the acquisition and development of motor skills in a structured sport. Pascual-Leone's theory of constructive operators (TCO) was used as a framework; it defines working memory capacity as the maximum number of schemes that can be simultaneously activated by attentional resources. The role of expertise in motor learning was also considered. The expertise of each athlete was assessed in terms of years of practice and number of training sessions per week. The participants were 120 volleyball players, aged between 6 and 26 years, who performed both working memory tests and practical tests of volleyball involving the execution of the "third touch" by means of technical gestures of varying difficulty. We proposed a task analysis of these different gestures framed within the TCO. The results pointed to a very clear dissociation. On the one hand, M capacity was the best predictor of correct motor performance, and a specific capacity threshold was found for learning each attack gesture. On the other hand, experience was the key for the precision of the athletic gestures. This evidence could underline the existence of two different cognitive mechanisms in motor learning. The first one,

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relying on attentional resources, is required to learn a gesture. The second one, based on repeated experience, leads to its automatization.

Introduction

It is, by now, well established that sport and cognitive activity are highly interconnected: Diamond (2000) underlined the link between cognitive and motor development because when the first is affected (e.g., due to a neurodegenerative disorder), the second is also affected. Ellemberg and St-Louis-Deschênes (2010) compared the effect on cognitive performance of 30 min of aerobic exercise with the same time spent watching television, finding that even a single session of aerobic exercise is able to produce a significant, although not permanent, improvement in cognitive performance. Similar results were reported by Pesce, Crova, Cereatti, Casella, and Bellucci (2009) and by Davranche, Hall, and McMorris (2009). These and many other studies point to a strong connection between sport and cognitive development, but they study how physical activity affects our cognitive processes, whereas the influence in the opposite direction is still under-researched. Among the studies that examined this relation, those based on Baddeley and Hitch's (1974; see also Baddeley, 2000) model of working memory were mainly interested in identifying a specific subsystem for movement configuration (separate from the visuospatial sketchpad) by using a dual task paradigm (Quinn & Ralston, 1986; Smyth, Pearson, & Pendleton, 1988; Smyth & Pendleton, 1989); however, these first studies used very simple motor tasks and made no hypothesis on the relation between working memory and motor learning. More recently, Seidler, Bo, and Anguera (2012) showed that individual differences in spatial working memory are predictive of the rate of motor learning in both explicit and implicit sequence learning.

From a different perspective, thinking about working memory as a domain-general measure, reflecting an individual's ability to control attention, Engle (2002) suggested that working memory can be important during challenging activities in contexts that are "rich in distractors" such as sports. Behmer and Fournier (2014) suggested that neural efficiency during a new motor task is influenced by individual differences in working memory capacity, or "M capacity," assessed with the operation span. Pertaining to focusing attention and avoiding distraction, Furley and Memmert (2012) observed that basketball players with higher working memory are better at decision making, inhibiting irrelevant auditory information, and adapting their tactical decisions in a task involving videos of complex game situations.

All of these studies suggest that working memory plays an important role in facilitating motor learning and improving tactical decision making. In this study, we examined how children's and adolescents' ability in a structured sport, volleyball, is affected by working memory.

However, it is also clear that expertise—that is, the experience and amount of time that an athlete has spent practicing his or her sport—is involved in the cognitive processes related to sport ability. The role of expertise and automatization has long been recognized in cognitive development (Chi, 1978; Chi, Glaser, & Rees, 1982) and in particular seems to be very important in motor learning. In fact, whereas at the beginning performing a motor task still requires attentional resources, with practice it becomes more and more automated. A classical distinction in physical education and sport science was offered by Fitts (1964; see also Fitts & Posner, 1967), who proposed three phases of motor learning: the cognitive, associative, and autonomous stages. The first phase is characterized by a considerable cognitive load because movements are mainly controlled for in a conscious manner and learners need to use attentional resources in order to perform the correct sequence of movements: in this phase, movements are usually slow and hesitant. The associative phase begins once the athlete has acquired the basic movement pattern and is characterized by more fluent movement adjustments. Because certain motor patterns tend to co-occur, it becomes less effortful to perform them together;

they become associated. Finally, after extensive practice, the performer achieves the autonomous phase, characterized by fluent and apparently effortless motion. At this point, the athletic gesture is performed automatically and movement execution requires little or no attention; the athlete has reached expertise in that gesture, and embodied procedural knowledge prevails over declarative knowledge. Evidence supporting this stage process has been found by Eversheim and Bock (2001), who investigated the changes of resource demand during the tracking of a visual target under reversed visual feedback, and by MacMahon and Masters (2002), who tested the effects of introducing a random letter generation task (which places a high load on working memory) on explicit learning of a golf putt. As a result, the distracting task had disrupted the increment of declarative knowledge on how to perform the gesture.

In this study, we investigated the respective roles of working memory capacity and expertise in learning the motor skills required to perform an attack (i.e., the so-called "third touch," the one with which a player pushes the ball into the opponent's court) in volleyball. Focusing on a specific class of athletic gesture (attack) is a methodological choice to satisfy the need of a sufficiently objective measure of individual ability in well-controlled tasks. Attack in volleyball can be performed with gestures of different complexity, which young athletes get to master following their hierarchy of difficulty; to test motor learning, we designed a specific set of attack tasks of increasing complexity. We expected that the developmental growth of working memory capacity enables the young athletes to coordinate an increasingly large number of units of information to perform more and more difficult athletic gestures. We also expected that expertise has an effect both on the automatization of certain movements, which reduces the load they place on working memory, and on the smoothness of the athletic gesture.

Most current theories of working memory posit a central role of attentional resources in determining the capacity and functioning of working memory; for example, Cowan (1995) proposed that working memory is based on representations activated from long-term memory, with a capacity-limited focus of attention; theories of working memory involving a limited "executive attention" were also proposed by Kane and Engle (2002, 2003) and by Barrouillet and Camos (2007). The theory of constructive operators (TCO; Pascual-Leone, 1987; Pascual-Leone & Goodman, 1979) is consistent with this attention-based view of working memory and, in addition, provides a precise developmental model of capacity growth. Furthermore, the TCO assumes "schemes" as the units of cognition, which seems to be particularly suitable for sport abilities because they involve different types of information (e.g., procedural and declarative; visual, motor, and conceptual), and the definition of schemes can apply to all of them. Therefore, we use the TCO as the framework for this study.

The TCO includes two levels of constructs: schemes and general-purpose operators. Schemes, which can be described as organized sets of reactions to types of situations, are the units of analysis of cognitive processes, whereas general-purpose operators are resources of the mind without a specific content. They increase or decrease the activation of schemes and enable the formation of new ones. The outcome of a cognitive process depends on which schemes are activated and how those operators influence their activation. One of the operators postulated in the theory is an attentional resource called the M (mental energy) operator, which increments the activation of those schemes that are relevant to a task but not automatically activated. The capacity of this attentional resource is expressed as the maximum number of schemes that it can activate at the same time. Pascual-Leone (1987) suggested a possible neuropsychological base for this mechanism in the prefrontal lobes that would use the resources of the reticular system in order to activate schemes localized in different cortical areas; evidence supporting this view was provided by Arsalidou, Pascual-Leone, Johnson, Morris, and Taylor (2013). According to the TCO, M capacity develops during childhood and adolescence; at 5 or 6 years of age, a child can typically coordinate two schemes, and this number increases by 1 unit every second year until about 15 years. At that point, the individual is able to coordinate, on average, up to seven schemes.

Pascual-Leone's TCO has been supported in diverse developmental domains including, first of all, perceptual–attentional tasks such as the Compound Stimuli Visual Information task and the Figural Intersection Test (e.g., Pascual-Leone, 1970; Pascual-Leone & Johnson, 2011) and also in conditions of dual-task performance (Foley & Berch, 1997) and in relation to cognitive styles (Globerson, 1983). It has also been extensively supported in reasoning tasks such as combinatorial reasoning (Scardamalia, 1977), the "horizontality of water level" problem (e.g., Morra, 2008), problem solving in the domain of chemistry (e.g., Niaz, 1988), and arithmetical problem solving (Agostino, Johnson, & Pascual-Leone, 2010). It has been also studied in the domain of language, in particular metaphor comprehension (Johnson & Pascual-Leone, 1989), semantic and syntactic language competence (Im-Bolter, Johnson, & Pascual-Leone, 2006), vocabulary learning (Morra & Camba, 2009), writing argumentative and narrative texts (Balioussis, Johnson, & Pascual-Leone, 2012), and in the domain of children's drawing (e.g., Panesi & Morra, 2016). Furthermore, the TCO was the framework for studies of moral reasoning (Stewart & Pascual-Leone, 1992), understanding of emotions in the presence of misleading or conflicting information (Morra, Parrella, & Camba, 2011), and theory of mind during adolescence (Im-Bolter, Agostino, & Owens-Jaffray, 2016; see also Morra, Gobbo, Marini, & Sheese, 2008, for a more extensive discussion of the TCO).

Although Pascual-Leone's theory was successfully tested in several diverse domains, only rarely was motor learning studied in this framework; however, completing motor gestures also can overload M capacity. A recent study showed that M capacity is involved in the development of an early motor skill such as scribbling (Morra & Panesi, 2017). The most important experiments on motor skills, designed within the framework of the TCO, were carried out by Todor (1975, 1977, 1979; see also Pascual-Leone, 1987). In Todor's Rho Task, participants were asked to perform as quickly as possible a simple action made of two basic movements: one circular and one linear. M capacity was predictive of developmental improvements in the strategies by which the participants accomplished the task. Although the Rho Task is the only motor one for which an explicit TCO model was proposed and tested, it involves a very simple movement, hardly comparable to the complexity of real-life motor tasks.

Corbett and Pulos (1999) carried out a study on motor learning in an ecological situation with the TCO as theoretical framework. It was a longitudinal study of kindergartners' gross motor abilities such as hopping, skipping, and rope jumping. Their purpose was to analyze the relationship among gross motor development, cognitive development, and attentional skills, and they found that the ability that correlated most with M capacity was the rope jump. Indeed, to jump over the rope, children must attend to several schemes at one time to coordinate arm and leg movements. They also found correlations between cognitive measures (Piagetian tasks) and gross motor abilities; these correlations, however, were drastically reduced when controlling for attentional capacity, suggesting a causal role of attentional capacity in both cognitive and motor tasks.

These results indicate a strong relation between attentional capacity and motor skills acquisition that led us to undertake preliminary observational research (Bisagno & Morra, 2013) with a small group of young volleyball players. Our observations suggested that these young athletes seemed to be able to integrate a number of motor schemes that increased with age, improving technically in terms of mastery of the athletic gesture. In other words, a cognitive limit, such as the need to coordinate a number of schemes exceeding the individual's capacity, turned—for young volleyball players—into a limitation for more refined skill learning, if not compensated by automatization of well-accomplished gestures.

These findings suggest that M capacity represents a predictor for refined and complex motor learning. One of the main purposes of our study was to apply a general theory of cognitive development to motor learning using a precise developmental model in order to test our hypotheses in quantitative terms. In particular, we investigated whether M capacity is a prerequisite of learning specific technical gestures and how expertise is involved in this process. More specifically, the aims of this study were as follows:

– Testing the hypothesis that M capacity represents a predictor of motor learning in the specific task of attack in volleyball; that is, a higher M capacity allows young athletes to succeed in more complex attack tasks.
– Verifying the role of expertise in motor learning by testing whether the automatization of certain gestures allows experts to perform better than average in complex tasks in terms of both correct execution and precision. In other words, our hypothesis was that more experienced athletes can both accomplish more complex attack tasks and do so by performing a cleaner and more effective gesture.

To verify these two hypotheses, we collected data from a sample with a broad age range, which brought about large variability of both M capacity and volleyball expertise.

To design attack tasks of increasing difficulty, which place an increasingly high demand on M capacity, we resorted to a task analysis. For this reason, a third objective can be added to the previous two objectives: evaluating the goodness of our task-analytic model.

Method

Participants

This study involved 120 young volleyball players (105 female and 15 male), from five different clubs; the reasons why the sample is not balanced by gender are the preponderance of female rather than male volleyball teams in Southern Piedmont, Italy, where the data collection took place, and the greater availability of female volleyball players to participate. To avoid possible biases caused by the small size of the male subsample and its unequal distribution within the various age groups, we report in detail the analyses carried out only on the female subsample. In addition, we report very briefly the analyses carried out on the full sample. Participants were divided into six age groups of $n = 20$ each. The age groups were as follows:

- 6–8 years: mean age = 7 years 8 months, *SD* = 10 months (16 girls and 4 boys);
- 9 and 10 years: mean age = 10 years 0 months, *SD* = 6 months (15 girls and 5 boys);
- 11 and 12 years: mean age = 12 years 0 months, *SD* = 7 months (20 girls and 0 boys);
- 13 and 14 years: mean age = 13 years 7 months, *SD* = 5 months (20 girls and 0 boys);
- 15–17 years: mean age = 16 years 4 months, *SD* = 11 months (19 girls and 1 boy); and
- A group of adults, "expert" athletes with at least 10 years of volleyball experience: mean age = 22 years 2 months, *SD* = 2 years 6 months (15 women and 5 men).

Materials and procedure

For this study, we collected two major types of data: measures of the participants' motor skills and of their M capacity. In addition, we considered the players' years of volleyball experience and their number of training sessions per week during the current year as measures of expertise.

M capacity measures

The M capacity of each participant was measured in an individual session of about 80 min duration. Three tests were administered to each athlete in order to average performance in different domains as a control for test impurity. Two of these tests involve visual–spatial materials, namely the Mr. Cucumber test (Case, 1985) and the Figural Intersection Test (FIT; Pascual-Leone & Baillargeon, 1994; Pascual-Leone & Ijaz, 1989), whereas the Direction Following Task (DFT; Pascual-Leone & Johnson, 2005, 2011) uses verbal materials. The DFT and FIT have been validated with both adults and children also in Italy (Morra, 1994; Morra, Camba, Calvini, & Bracco, 2013), whereas the Mr. Cucumber test has been validated only with children (Case, 1985, 1995; Morra, 1994); for this reason, it was used in this research conditionally to some preliminary analysis. The tests were administered in the following order.

Mr. Cucumber test. In this test (Case, 1985), the child is shown the figure of a character, Mr. Cucumber, on whose body parts there are some colored stickers. The number of colored stickers to remember increases from level to level from 1 to 8. There are three items on each level. On levels from 1 to 5 the stimulus is presented for 5 s, and on the following levels it is presented for as many seconds as the number of stickers. The participant's assignment is to observe the position of those stickers and then, pointing on a Mr. Cucumber without any sticker on him, to indicate where they were placed. A level is considered passed if the participant succeeds in at least two of three items. The final score is represented by the highest consecutive passed level plus .33 for each correct item beyond that level.

Figural intersection test. The Figural Intersection Test (FIT; Pascual-Leone & Baillargeon, 1994) consists of a booklet in which geometric shapes are represented; for each item, on the right side of the sheet the shapes are scattered, and on the left side of the sheet instead the same shapes (possibly rotated or changed in size) overlap and form a configuration. The participant is required to identify in the configuration on the left side the intersection of the forms that are shown on the right side; some items also have one irrelevant extra shape in the left configuration that should be ignored by the participant. The number of shapes on the left side, in each item, represents the number of cognitive units that the participant needs to integrate, that is, the item's complexity. There are eight levels ranging from 2 to 9 shapes; there are 36 items in all that are not presented in order of complexity but rather in a pseudorandom order. An item is considered correct if the participant marks only the intersection of the relevant forms. A level is considered failed if the person commits two or more errors. The final score is given by the last consecutive level where the participant has achieved this criterion plus 1 for each level eventually passed beyond that. The 6- to 8-year-old subsample was administered a shorter version of the FIT from which the 10 most difficult items (belonging to levels 7–9) had been excluded.

Direction following task. In the Direction Following Task (DFT; Pascual-Leone & Johnson, 2005, 2011), the participant must follow oral instructions of different complexity (in which the cognitive load varies systematically). The materials consist of 20 plastic forms varying in shape, size, and color and a closable board, on which there are 10 square spaces of different size and color; the participant must place the forms on specified spaces, following the experimenter's directions, and each item is scored as passed or failed. Spaces can be described with one or two words (the color and/or the size), and a shape can be described with a combination of one to three features (e.g., a circle, a small circle, or a small green circle). The information load is varied by manipulating the number of objects (one or two), spaces, and features specified in an instruction, so that a particular amount of M capacity is assumed to be required to pass the items of a given type. There are five items for each of nine instruction types. Because the Italian grammar is different from the original English language of the test, Morra et al. (2013) presented scoring rules adapted for the Italian translation of the test, which were also used in this research.

Volleyball tasks

To evaluate the athlete's motor learning, six attack tasks of increasing difficulty were designed; the first of these tasks was used only with the 6- to 8-year-olds as a control task, which we expected to be performed successfully even by the youngest age group, and the subsequent ones were performed in order of difficulty by all participants until they failed. In each task, the player was required to perform a specified action in order to score a line attack (a toss that is parallel to the court's sideline) in Area 1. The player was also required, if he or she was able, to score a direct hit inside a hula-hoop ring, located in that area. Specifically, the target was 4 m away from the net—1 m beyond the "attack line"—for children up to 10 years and 7 m away from the net for athletes 11 years and older. The six tasks were as follows:

1. *Basic (control) task:* This task involves just throwing the ball with two hands toward the hula-hoop target placed at a distance of 4 m with no hedges between it and the participant. This task was performed only by participants in the 6- to 8-year-old group as a control task for comparison with the following one; as expected, all children easily succeeded in this task. Therefore, it was not taken into account in the data analyses.
2. *Tossing the ball over the net:* This task is exactly the same as the previous one, but the participant needed to roll over the net. In this task and all of the following tasks, the target distance was diversified for younger and older participants, as explained above.
3. *Set with feet on the ground:* The ball was thrown, by a partner or the coach, to the player, who needed to push it with a setting, without approach, toward the area of the field indicated by the hula hoop.
4. *Set attack with approach:* This task is the same as the previous one but was preceded by a run-up.
5. *Spike with a run-up:* This task is the same as the previous one but with a spike instead of a set.

6. *Spike against the block:* This task is exactly the same as the previous one but with the presence of an opponent who jumps with raised arms, performing a block.

The trials, all video-recorded, were performed during the regular hours of training (after about 20 min of warm-up and some basic exercises with the ball at the discretion of the coaches). For each task, each participant performed five items; a task was considered passed with a minimum of three of five correct executions. In case of two or fewer correct executions, the test was discontinued to the next level without the athlete passing the task. Performance on each task was scored in two ways:

(a) *correct execution* of the gestures: the number of items on which the athlete performed the required action without committing a foul and the ball reached the target area of the field; and
(b) *precision:* the number of correct executions in which the participant also scored a hit in the hula-hoop ring.

Task analysis

To identify the tasks' difficulty according to the TCO and, in particular, to quantify the demands they place on M capacity, we performed a task analysis indicating which schemes need to be activated with the attentional resources of the M operator. This task-analytic model is hypothetical; we postulated which schemes are involved in each task based both on the first author's experience as a volleyball coach with young athletes and on some observations gathered during our previous study (Bisagno & Morra, 2013) with a small sample of young volleyball players. For example, in that study we had a 6-year-old to toss the ball over the net and observed that he alternated between two types of error; either he pushed too low when he sent the ball to the right direction or, when he was able to overcome the net, he aimed too far and/or to the wrong place. This suggests a difficulty, for this child, in taking into account all of the information involved in the task. It also suggests that direction, distance, and vertical push are involved in this task as three distinct schemes because different errors occur when one or another of them is missing. In general, in task analysis, any common error can be regarded as a "pointer" to a required scheme.

In general, we assumed that if a certain task requires, for example, activation of four schemes by the M operator, an individual with a lower M capacity will not be able to accomplish it or will perform it in an incorrect manner—unless some of those schemes are automatized enough not to require "mental energy."

According to our task analysis:

- Basic task (throwing the ball to the target with no hedges) = M demand of 2 units, corresponding to the schemes target distance and target direction on the horizontal plane, which are two distinct pieces of information, both of which are necessary to throw the ball to the right place.
- Tossing the ball over the net = M demand of 3 units, corresponding to the previous two schemes plus a third one, the vertical push, which is necessary to overcome the net.
- Set with feet on the ground = M demand of 4 units. Assuming that—with sufficient experience—the distance and the vertical push are combined and chunked into a single representation, the schemes necessary to succeed in this task should be direction on the horizontal plane, overcoming the net, body and hands positioning (to properly embrace the ball without committing a foul), and clearance timing, which involves coordinating one's movements with the ball's parable in order to push it at the right moment.
- Set attack with run-up = M demand of 5 units: direction on the horizontal plane, overcoming the net, monitoring the airborne phase of the ball (which is necessary to choose the time for jumping), run-up control" (i.e., the sequence of steps and takeoff considered as a single scheme because the neatness of this movement should already have been well practiced and automated without the ball), and attack timing (in harmony with the ball's downward trajectory). The hand positioning for set as a technical gesture should already be fully acquired at this point, and, therefore, is considered automatized enough not to demand attentional resources from the individual.

- Spike with run-up = M demand of 6 units: direction on the horizontal plane, throwing depth, monitoring of the airborne phase of the ball, run-up control, attack timing (in this case the need to hit the ball just above the net tape), and (control of the) closing movement of the wrist, which is needed to confer to the ball the spike's characteristic downward trajectory.
- Spike against the block = M demand of 7 units. It seems plausible to assume that the presence of the block performed by one opponent, in the final task, adds an extra load of 1 unit of information to represent the obstacle that must be avoided.

As explained above, this task-analytic model is hypothetical, and checking its accuracy through the results was one of the goals of this study.

Results

Predictors and dependent variables

The following variables were considered as predictors:

- M capacity, defined as the average of the scores in the three tests: the Mr. Cucumber test, the Figural Intersections Test, and the Direction Following Task; and
- Two measures of experience, namely the number of years playing volleyball and the current number of training sessions per week.

Four dependent variables are considered in the following analyses; two of them are related to correct execution of volleyball trials, and the other two are related to the precision of the athletic gestures, that is, to the perfect hits into the hula-hoop ring. In particular, we calculated the following:

(a) Total number of correct executions, which is given by the sum of all the items properly accomplished by an athlete in all task levels except the basic task. The maximum possible score was 25 (5 items in each of the five tasks).
(b) Volleyball level, defined as the highest task at which the participant performed correctly on at least three trials (maximum possible score = 6).
(c) Total precision, which simply consists of the number of perfect hits into the hula-hoop ring at all task levels except the basic task (maximum possible score = 25).
(d) Corrected precision, defined as the mean of the regression residuals, across all task levels performed by the athlete, of the number of perfect hits on the number of correct trials. Because the athletes who succeeded in a higher number of tasks would have had more chances to score hits into the hula-hoop ring, this variable was constructed as a measure of motor precision that controls for simple correct execution.

Preliminary analyses

It was verified that all tests used to assess M capacity were correlated among them; actually, all of the tests showed a highly significant correlation with one another ($p < .001$; see Table 1) even partialing out the effect of age; these results are consistent with the literature (e.g., Pascual-Leone & Johnson, 2011).

The two measures of experience (number of years playing volleyball and current number of training sessions per week) instead were only weakly correlated ($r = .18$, $p = .08$) when controlling for age.

Because the scores in the M capacity tests are meant to measure the number of schemes that the participant is able to integrate, it is also important to check that their means and age trends do not diverge excessively from one another. To assess the impact of age on the three test scores, we ran a multivariate analysis of variance (MANOVA) with three dependent variables (FIT, Mr. Cucumber, and DFT) in which age group was the between-participants factor. The age group factor was significant, with Pillai's trace = .756, corresponding to $F(15, 297) = 6.67$, $p < .001$. This effect was also highly

Table 1
Descriptive statistics and correlations between all variables.

	Mean	*SD*	DFT	CUC	FIT	Volleyball years	Training sessions per week	Correct executions (trials)	Volleyball level	Total precision	Corrected precision
DFT	5.19	1.71		.374***	.503***	.020	.154	.411***	.375***	−.005	−.095
CUC	5.59	1.66	.609***		.528***	.199	.128	.539***	.468***	.077	−.027
FIT	5.71	2.04	.688***	.697***		.113	.172	.522***	.443***	.061	−.050
Volleyball years	5.32	4.19	.558***	.605***	.569***		.175	.223*	.117	.335**	.293**
Training sessions per week	2.58	0.72	.385***	.358***	.388***	.465***		.323**	.306**	.120	.032
Correct trials	14.52	4.79	.679***	.735***	.724***	.727***	.523***		.899***	.173	−.055
Volleyball level	3.03	1.04	.643***	.686***	.670***	.650***	.505***	.948***		.083	−.098
Total precision	1.56	2.35	.206*	.260**	.246*	.445***	.250	.359***	.289**		.943***
Corrected precision	0.00	0.53	−.027	.023	.004	.203*	.061	.019	−.019	.911***	

Note. Correlations with age partialed out are above the diagonal, whereas Pearson correlations are below it. DFT, Direction Following Task; CUC, Mr. Cucumber test; FIT, Figural Intersection Test.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

significant for each particular test, $F(5, 99) = 26.57$, $p < .001$, $\eta^2 = .573$ for the DFT, $F(5, 99) = 15.27$, $p < .001$, $\eta^2 = .435$ for the Mr. Cucumber test, and $F(5, 99) = 17.89$, $p < .001$, $\eta^2 = .475$ for the FIT.

To obtain a more detailed decomposition of the effects of age and test, and to assess whether there were any differences between the test scores, we also ran a mixed-design analysis of variance (ANOVA) in which age group was the between-participants factor, whereas the within-participant factor was the test (with three levels: FIT, Mr. Cucumber, and DFT). This analysis yielded significant effects of age group, $F(5, 99) = 31.30$, $p < .001$, $\eta^2 = .613$, the test, $F(2, 198) = 7.87$, $p < .001$, $\eta^2 = .074$, and a nonsignificant interaction, $F(10, 198) = 1.85$. A polynomial decomposition of the age group effect revealed a strong linear component ($p < .001$), a minor quadratic component ($p < .01$) due to reduced growth after 13 years of age, and nonsignificant higher-order components. Paired *t* tests with Bonferroni correction revealed that the DFT mean score (5.19) was somewhat lower than the means of both the Mr. Cucumber test (5.59) and the FIT (5.70), $t(104) = 2.79$, $p < .02$ and $t(104) = 3.52$, $p < .01$, respectively; the means of the Mr. Cucumber test and the FIT did not differ from each other, $t(104) = 78$.

It is unclear why the DFT had a lower mean than the other two tests; previous research with both children and adults yielded similar means with directions in both English (Pascual-Leone & Johnson, 2005, 2011) and Italian (Morra et al., 2013). Perhaps the particular population of volleyball players is particularly apt at encoding visuospatial materials; this point may call for further research. Nevertheless, the mean score of each test in each age group, shown in Table 2, was very close to the theoretical expectation except for slightly higher than expected means of the Mr. Cucumber test in the two youngest age groups and the FIT in the 13- and 14-year-old group. As a conclusion of these preliminary analyses, we decided to define the measure of M capacity as the average of all three tests because although the difference among tests was significant, the effect size was not large, the Test × Age Group interaction was nonsignificant, and there was a strong linear increase with age, with nearly all mean scores (Table 2) in agreement with the literature. In particular, the Mr. Cucumber test also proved to be adequate for the older age groups.

As a preliminary analysis to verify the role of M capacity and experience as predictors of volleyball performance, we examined correlations when controlling for age. Partial correlations only retain individual differences, statistically eliminating the age-related variance, thereby ensuring that a correlation between a volleyball measure and a predictor is not an artifact due to variance shared with other age-related variables. As can be seen in Table 1, even when controlling for age, the correlations between each of the M capacity tests and the measures of volleyball correct execution remained very high, whereas the "precision" measures were not related to M capacity. Considering the average of M capacity tests, its partial correlation with volleyball level was $r = .53$, $p < .001$, and with correct executions it was $r = .61$, $p < .001$. Among the measures of experience, trainings per week correlated with both measures of execution, whereas years of volleyball positively correlated with both measures of precision and, to a lesser extent, with the number of correct trials.

Table 2
Means and standard deviations of the M capacity tests by age group.

	DFT		FIT		CUC	
	Mean	SD	Mean	SD	Mean	SD
6- to 8-year-olds	3.16	0.75	3.38	0.81	3.68	1.00
9- and 10-year-olds	3.73	0.98	4.40	1.30	4.84	1.34
11- and 12-year-olds	5.03	1.27	5.15	1.93	5.13	1.57
13- and 14-year-olds	5.70	1.30	6.80	1.50	6.17	1.40
15- to 17-year-olds	6.95	1.31	7.10	1.52	6.54	1.15
Adults	6.10	1.02	7.00	1.65	7.02	0.95

Note. DFT, Direction Following Task; FIT, Figural Intersection Test; CUC, Mr. Cucumber test.

Regression analyses

Regression analyses were performed for each of the four dependent variables: total number of correct executions, volleyball level, total number of perfect hits, and corrected precision, including M capacity and experience measures as predictors. We used a stepwise method with $p < .05$ as the inclusion criterion.

For the total number of correct executions, as one can see in Table 3, the predictors accounted for a large portion of variance, and the main predictor was M capacity ($ß = .55$), followed by years of volleyball ($ß = .30$) and training sessions per week ($ß = .15$). This result is consistent with our hypothesis that an adequate M capacity is required to coordinate all relevant motor, perceptual, and cognitive schemes. Similar results were found analyzing volleyball level; also in this case, M capacity was the first predictor ($ß = .54$), followed by years of practice ($ß = .22$) and trainings per week ($ß = .17$). We also calculated the unique variance accounted for by each predictor and the portion of variance shared by more than one predictor. M capacity by itself shows an R^2 value of .17, meaning that it explains 17% of the variance—much more than the other predictors. Moreover, a large amount of variance was shared among all three predictors ($R^2 = .23$) and between M capacity and years of volleyball ($R^2 = .25$). This is explained by the fact that M capacity, years of volleyball, and number of training sessions per week all increase with the age of the participant, so it is not surprising that they share a large portion of explained variance. A similar pattern was found for volleyball level. The prominent role of M capacity as a predictor of acquisition of volleyball skills is the main finding in this study.

Whereas the results for correct performance clearly pointed to a major role of M capacity in learning the actions involved in the attack, very different results emerged for precision (see Table 3). The variance accounted for in these analyses was much less than that for the correct performance variables. In both cases, years of volleyball experience was the only significant predictor ($ß = .45$ for total precision and $ß = .25$ for corrected precision). The partial correlations for the other predictors at the point when the stepwise procedure stopped indicate clearly that the excluded variables did not contribute to precision scores. From these results, it seems that expertise is essential not only for the ability to perform more complex tasks or to integrate a higher number of schemes but also for the nicety of the gesture. Hence, it is conceivable that—through years of practice—the described technical gestures become smoother and acquire a more fine-grained motor coordination, thereby facilitating the more experienced athletes in hitting a small target such as the hula hoop.

Cross-classification prediction analyses

Having verified the prediction that M capacity is involved in the correct execution of the various technical gestures, we tried to infer whether there is a minimum (threshold) prerequisite M capacity for accomplishing each given technical gesture. To do so, we classified participants according to their

Table 3
Regression analyses for each dependent variable.

Predictor	Correct executions ($R^2 = .74$)			Volleyball level ($R^2 = .64$)			Total precision ($R^2 = .20$)			Corrected precision ($R^2 = .06$)		
	β	p	Unique R^2	β	p	Unique R^2	β	p	Partial correlation	β	p	Partial correlation
M capacity	.55	<.001	.17	.54	<.001	.16	–	n.s.	−.03	–	n.s.	−.18
Years of volleyball	.30	<.001	.05	.22	.009	.03	.45	<.001	–	.25	.010	–
Training sessions per week	.15	.012	.02	.17	.014	.02	–	n.s.	.05	–	n.s.	−.02

Note. The unique R^2 of each predictor is reported for correct executions and volleyball level. The total R^2 is much larger than the sum of unique variances because a large amount of variance was shared by two or more predictors (see text). Reporting unique R^2 is not necessary for total precision and corrected precision because only one predictor was found to be significant. For these two latter analyses, we indicate the partial correlation of each variable at the point when the stepwise procedure stopped.

M capacity, approximated to the nearest integer (3–8), and the volleyball level they reached. The contingency table (Table 4) shows the observed frequency of participants with a certain M capacity who passed each level. A prediction analysis of cross-classification (Hildebrand, Laing, & Rosenthal, 1977) was performed on these data; our theoretical prediction stated that all frequencies should be zero for the volleyball levels that (according to our task analysis presented above) require a larger M capacity than the participant has. This test compares the observed frequencies in the critical cells (i.e., in the cells for which a frequency of 0 is predicted) with those expected by chance (expected frequencies reported in parentheses in Table 4 only for the critical cells). Hildebrand et al.'s (1977) index *Del* expresses the degree to which the prediction that a certain set of cells has null frequency explains the difference between observed and expected frequencies in the critical cells. A positive value of *Del* indicates that the observed frequencies in the critical cells are lower than those expected by chance; its maximum value is 1 (when all of the critical cells are empty). A z value and a confidence interval can be calculated for *Del*. If the confidence interval includes only positive values, then the prediction is better than chance; if the interval, besides being positive, also includes $Del = 1$, then one can accept the hypothesis that the frequencies in the predicted cells are not different from zero.

The predictions based on the originally hypothesized task analysis were not confirmed, $Del = .406$ ($SE = .119$), $z = 3.41$, $p < .001$, 99% confidence interval (CI) [.098, .714]; although the positive value of *Del* was highly significant and the whole confidence interval lied in the positive range, it did not include the value of 1. Actually, two cells predicted to be empty instead had a high frequency; that is, a sizable number of participants with an M capacity of 3 were able to perform the set with feet on the ground, and some participants with an M capacity of 4 were able to perform the set with a run-up. This suggests that our original task analysis (the one presented in a previous section) overestimated by 1 unit the M capacity required for the set with feet on the ground and for the set with run-up.

Consequently, we revised the initial model. We did not alter the general prediction of an M capacity threshold for each task, with increasing thresholds for more complex tasks and the specific assumptions that these thresholds would be 6 units for the spike and 7 units for the spike against the block. However, now we assumed thresholds of 3 units (instead of 4) for the set with feet on the ground, and 4 units (instead of 5) for the set with run-up. This "revised prediction" entails that only the cells highlighted in Table 4 should be empty. As one can see in the table, the total of observed frequencies in the

Table 4
Contingency table between volleyball level and M capacity.

M capacity	3	4	5	6	7	8
Spike against the Block	0 (0.86)	0 (0.52)	1 (1.14)	0 (1.00)	3	1
Spike	0 (5.31)	0 (3.25)	2 (7.09)	11	9	9
Set with Run-up	1 (7.20)	5 (4.40)	17	10	8	1
Set (feet on the ground)	11 (2.91)	4	2	0	0	0
Toss	5	2	2	0	0	0
Basic Task	1	0	0	0	0	0

Note. The numbers in parentheses indicate the frequencies expected by chance in the cells that, according to the predictions derived from our original task analysis, should be empty. The cells with gray shading are those predicted to be empty according to our revised task analysis (see text).

critical cells was 4 compared with a total of expected frequencies in the critical cells = 26.37; *Del* = .848 (*SE* = .074), $z = 11.40$, $p < .001$, 99% CI [.656, 1.040]. Because the confidence interval is entirely positive and includes *Del* = 1, this revised prediction can be considered accurate. Of course, revising a quantitative prediction also implies revising the task analysis on which the original prediction was based. In the final Discussion, we explain in more detail which aspects of the task analysis need to be modified according to the revised prediction and which behavioral observations suggest that it is justified to do so.

Analyses on the full sample

We also performed all of the analyses reported above on the entire sample ($N = 120$) and found results substantially similar to those for the female subsample; although the values of correlations or other statistics changed by 1 or 2 hundredths, the pattern of significant results remained the same. In particular, also in the entire sample M capacity turned out to be the crucial predictor for the proper execution of the attack in volleyball, whereas regarding precision the only significant β was obtained for years of volleyball.

Discussion

The aims of our study were (a) testing the hypothesis that M capacity represents an important predictor of motor learning in the specific task of attack in volleyball, (b) verifying the role of expertise as a predictor of both correct execution and precision, and (c) evaluating the adequacy of our task-analytic model.

We found that the results supported the first two hypotheses of this research. M capacity proved to be a highly predictive variable for correctly performing the attack in volleyball; conversely, expertise seems to represent the crucial predictor of the technical gesture polish.

This clear dissociation between the measures of correct execution and those of precision seems to indicate the existence of different learning processes serving different purposes. This seems consistent with Fitts's (1964; see also Fitts & Posner, 1967) theory, namely that when an athlete learns a new motor gesture, he or she goes through three stages—cognitive, associative, and autonomous—which differ from one another in both the degree of mastery with which the gesture is accomplished and its demand of attentional resources. So, in the cognitive phase, when a gesture is learned in the first place, one needs to rely on M capacity, exploiting attentional resources, whereas in the associative stage, motor sequences are easier to accomplish because their succession has been repeated many times. Pascual-Leone (1976a, 1976b; see also Pascual-Leone & Goodman, 1979) made a similar distinction by positing two different types of learning that lead to the formation of a superordinate scheme from the coordination of two (or more) schemes activated simultaneously. He described two L (for structural learning) operators labeled LC and LM. The first one involves a gradual learning process based on the repeated coactivation of two or more schemes; LM learning, on the other hand, is rapid and produced by the use of the M capacity. Based on these theories, we can suggest that the cognitive phase involves the LM operator, whereas in a subsequent associative phase the LC operator is summoned, which coordinates different schemes because of their repeated coactivation, that is, experience. In other words, to correctly perform a motor task, the fundamental requirement is the ability to integrate all motor schemes involved; once the "basic" movement has been acquired, repeating it again and again allows the athlete to automatize it and increase its precision in order to reach a nearly perfectly polished gesture.

It is reasonable to think that M capacity and expertise jointly influence performance; for example, experience can lead to automatization or chunking of certain motor schemes, thereby lightening the M demand for a given motor task. On the other hand, well-developed M capacity can assist the athlete in quickly learning the technical gestures, allowing faster improvement.

Our main result of a prominent role of M capacity in motor performance seems consistent with findings of other studies (Behmer & Fournier, 2014; Furley & Memmert, 2012; Seidler et al., 2012), which showed how individual differences in working memory are related to motor sequence learning and decision making in complex situations. This study also confirms Corbett and Pulos's (1999) idea that the motor abilities that correlate most with M capacity are the most complex ones, which require one to attend to several schemes at one time; this not only is true for very young children but also can be seen as a developmental pattern.

Finally, our third hypothesis (Bisagno & Morra, 2013) that M capacity sets a limit in performing certain gestures was supported by the prediction analyses of cross-classification; the more specific task analysis predictions were confirmed only in part, but the results themselves offered indications on how to improve the model. In particular, it was possible to observe how the set from standstill, which—according to our task analysis—should have requested an M capacity of at least 4 units, was actually performed by athletes with an M capacity of 3 units. In the same way, the set with run-up seems to require fewer attentional resources than predicted (4 instead of 5 schemes); we can use this information to correct our task analysis.

The schemes that we assumed to be necessary for the execution of the set from standstill were direction on the horizontal plane, passing over the net, body and hands positioning, and clearance timing. Those for the set with run-up were direction on the horizontal plane, passing over the net, monitoring the airborne phase of the ball, run-up control, and attack timing. To discover where the flaw in our model was, we returned to the video-recordings and noted that, in the set with feet on the ground, errors due to wrong positioning of body and hands were practically nonexistent. It is quite possible that the body and hands positioning, in the set gesture, is so extensively trained that it does not represent a load for M capacity. Regarding the set with run-up, it seems possible that the direction on the horizontal plane and passing over the net schemes at this point are actually chunked into a single representation; this possibility was suggested to us by the rarity of observation of balls thrown against the net in the video-recordings of sets with run-up. Our task analysis of the spike instead seems to already be accurate. The six hypothesized schemes were direction on the horizontal plane, throwing depth, monitoring the airborne phase of the ball, run-up control, attack timing, and closing movement of the wrist. Further observation of the recordings of the athletes engaged in the task, and of their most common errors, confirmed in particular that monitoring the airborne phase of the ball and attack timing are actually different schemes. The errors related to this skill, in fact, seemed to be mainly of two types; some athletes started the run-up in the wrong moment, and others delayed the "stroke" with their arm too much.

The possibility of testing a precise task analysis model is one of the advantages of the TCO; indeed, this framework affords a quantification of individual participants' M capacity and a quantitative evaluation of the capacity demand of each task, and it offers a developmental model of capacity growth. Studying the role of working memory in this perspective allowed us not only to find a global relation with motor learning but also to formulate specific quantitative hypotheses; this is not possible in all approaches. For example, we can make a comparison with another recent study by Buszard et al. (2017), who found differences in basketball shooting learning between children (aged 8–10 years) of higher and lower working memory capacity. However, the framework they used did not allow them to formulate precise assumptions on the cognitive demand of learning from the instructions provided to the participants, or on the size of the working memory capacity of the participants, derived from the working memory tasks they used. Consequently, in Buszard and colleagues' study, only an interesting but global relation between working memory capacity and motor performance could be detected. Thus, an advantage of the TCO framework is enabling more fine-grained predictions on performance as well as putting them in relation with a more general cognitive-developmental model.

Identifying in the TCO a good framework for the theoretical modeling of motor learning processes can be useful not only for research purposes but also for practical applications. In fact, knowing the M demand of each technical gesture would allow us to improve training curricula for young athletes and, through a separate automatization of some schemes involved in movements, could facilitate faster learning of complex tasks. Besides the creation of customized curricula, the task analysis of movements could assist in training those "late" athletes who start playing sports after 10 years of age and, therefore, must quickly learn complex athletic gestures. Also on the practical side, the benefits that coaching could gain from this line of study are, therefore, many and worthy of being explored.

A limitation of our research is the low number of male participants in the sample and their uneven distribution among the age groups; for this reason, our findings are generalizable only to female volleyball athletes. However, we have no reason to think that male athletes rely on different cognitive processes when they are learning a new motor gesture. To verify this, it would be interesting to repeat this study with both a male sample and a female sample.

Another possible development could be studying the role of M capacity and expertise in other sports with different characteristics; indeed, a classical categorization of sports distinguishes them according to the prevailing type of movement: Poulton (1957) defined as "open-skills sports" those occurring in contexts with a high number of uncontrollable variables such as volleyball, all other team sports, and disciplines involving a direct opponent (e.g., fencing, combat sports, tennis). In these sports, the gesture cannot be completely programmed in advance, so the load placed on M capacity seems to be quite high. By contrast, "closed-skills sports" are characterized by an environment with a low number of uncontrollable variables because every single gesture is highly automatized. This happens in disciplines such as gymnastics, dance, shooting, and bowling. It would be interesting to test the hypothesis that in open-skills sports, where specific techniques are learned and then adapted to the contingent game situation, M capacity is very predictive of high performance because athletes have a higher amount of information to "handle," whereas in closed-skills sports, where automatization reduces the load placed on working memory, expertise should be more predictive of good performance. (See also Furley, Schweizer, & Bertrams, 2015 on the distinction between automatic and WM-demanding processes in sport performance.)

Finally, it would be interesting to expand this study by including a greater number of predictors of sports performance such as executive functions, attentional style, and emotion regulation. Research on the role of executive functions in sports performance is rather limited and very recent; most studies find a significant role of executive function in predicting a good performance, mainly in team sports (Chang et al., 2013; Nakamoto & Mori, 2008; Verburgh, Shreder, Van Lange, & Oosterlaan, 2014; Wang et al., 2013), so it seems legitimate to hypothesize that open-skills sports, where a fast reaction to the unexpected is needed, involve executive mechanisms more strongly than closed-skills sports. Moreover, it would be interesting to investigate the relation between executive functioning—inhibitory mechanisms in particular—and working memory in predicting sport performance; indeed, this relation is already attested in other domains such as academic performance and problem solving (Rosen & Engle, 1998; Zook, Davalos, DeLosh, & Davis, 2004). In addition Pascual-Leone (1983; see also Howard, Johnson, & Pascual-Leone, 2014) hypothesized a role of inhibition in synergy with the M operator. However, this relation is still under-researched in the motor performance field even though some studies (e.g., Furley & Memmert, 2012) found a relation between working memory and inhibitory control, which could suggest a moderation effect. Regarding attentional style, Nideffer (1976) suggested that different kinds of sport could benefit from different regulation of both focus and direction of the attention; for example, athletes of open-skills sports could benefit from a more widespread and external focus of attention in order to monitor the environment, whereas athletes practicing closed-skills sports would find a narrow and internal focus of attention more effective in order to correctly practice their routines. Finally, emotion regulation could play a moderating role in the relation between M capacity and performance. In this respect, some studies highlight how negative emotions (i.e., competitive anxiety) can subtract cognitive resources from the athlete, thereby worsening his or her performance (Baumeister, 1984; Beilock, 2007; Hill, Hanton, Matthews, & Fleming, 2010; Klein & Boals, 2001); on the other hand, Talarico, Berntsen, and Rubin (2009) suggested that positive emotions could "enhance" various memory systems. Another interesting hypothesis to test is whether there is a moderation effect of the negative and/or hedonic tone experienced by athletes before the competition on the relation between M capacity and sports performance.

In conclusion, we think that this study shows that it is rewarding to formulate detailed and developmental models in order to examine the role of working memory and cognitive processes and to derive testable hypotheses on the acquisition of abilities, also in the field of sports.

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