

**PLASTIC AND FUNCTIONAL EFFECTS OF EXERCISING ON THE BRAIN:  
ORIGINAL WAYS TO ENHANCE COGNITION THROUGH SPORTS  
PRACTICE**

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**Abstract**

Recently, numerous studies have demonstrated the significant effect of exercising on human cognition and brain's plasticity, in children as well as adults. While providing the latest development and findings in a fast-growing area, this paper offers several original ideas on how the relevant research in connected fields such as cognitive sciences, neuropsychology and neuroanatomy can be applied to sports practice, in order to optimize its cognitive outcomes. The authors provide the reader with practical situations in a sport context, easy to apply in any kind of environment, and targeting cognitive functioning. Overall, it shows how sport can constitute a viable alternative to more traditional computerized tasks when it comes to enhancing general cognitive abilities at all ages.

**Key words:** neuroplasticity, cognition, exercising, sport, enhancement

**Introduction**

Our modern society puts increasing demands on cognitive functioning, from children to the elderly, which have led to different research fields dedicated to general cognition enhancement. These last few years, an abundant number of studies have paved the way to a relatively new current, underlining the specific role of exercising toward enhancing cognition. After briefly reviewing relevant research on the benefits of physical activity and sports to cognitive functioning, we will present and discuss in this paper the implications of this line of research for individuals practicing sports, through creative applied situations.

**Health benefits from physical activity**

Health benefits from exercising have been illustrated by a vast body of literature. Physically active people tend to display higher levels of physical fitness than non-active individuals. Research has shown that practicing a physical activity on a regular basis has consequences on body weight (Annesi, 2010), reduces significantly fat body mass and cardiovascular disease risks (Dunn et al., 1997; Geus, Van Hoof, Aerts, & Meeusen, 2008), lowers unhealthy cholesterol, and decreases anxiety and depression occurrences (Brill, Kohl, & Blair, 1992; Rees & Sabia, 2010), to cite just a few (see for a review Penedo & Dahn, 2005; and O'Dougherty, Arikawa, Kaufman, Kurzer, & Schmitz, 2009, for a study targeting women).

This wide impact of exercising has become more and more prevalent in people's mind, facilitated by the emergence of rather unhealthy and sedentary habits in our modern societies. From that particular assessment, awareness of the findings linking exercise to a decrease in many risk factors led many government-funded institutions to preach for more active lifestyles and recommend physical activity programs in schools and communities.

However, general health benefits are not the only one affected by exercise. Studies have found that cognition can also be greatly altered by exercise, and our understanding of the underlying reasons grows with the publication of new experimental work.

## Physical activity and cognition enhancement

Findings showing a relationship between physical activity and cognition have been partly explained physiologically, emphasizing the stressing role of physical activity on the brain, which in turn responds through adaptation and neural growth (neurogenesis) in order to better cope with upcoming challenges (Mattson, 2004). Animal studies have also shown that exercising has a wide impact on the brain, facilitating the creation of new synapses (Lou, Liu, Chang, & Chen, 2008) and the formation of new blood vessels (angiogenesis), as well as increasing neurotransmitters concentrations (Mora, Segovia, & del Arco, 2007) and overall brain volume (Colcombe et al., 2006). Thereby, it has become legitimate to wonder whether physical activity could help maintain or even develop cognitive functions.

Furthermore, recent work has shown that regular physical activity benefits cognition in various ways (Etnier, 2008; McMorris, Tomporowski, & Audiffren, 2009; Spirduso, Poon, & Chodzko-Zajko, 2008). A positive impact has been reported on a variety of mental conditions, ranging from Attention Deficit Hyperactive Disorder (ADHD) (Azrin, Vinas, & Ehle, 2007; Harvey et al., 2009), and schizophrenia (Crone, Tyson, & Holley, 2010; Pajonk et al., 2010), to autism (Lang et al., 2010; Vernazza-Martin et al., 2005), dementia (Heyn, Abreu, & Ottenbacher, 2004; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001), cognitive decline (Bruehl-Jungerman, 2005; Lewis, 2004; Fabre et al., 1999; Kramer et al., 2001) and Alzheimer's disease (Radak et al., 2010), among others.

Studies also pointed out a relationship between exercising and learning (Vayman, 2004) or memory (Hillman, 2008; Stroth et al., 2010), exercising and fluid intelligence (Singh-Manoux, Hillsdon, Brunner, & Marmot, 2005), or between physical activity and executive functioning (Kubesch et al., 2009; see Colcombe & Kramer, 2003; and Hall et al., 2001, for reviews). Executive functioning is currently seen as a multi-component process, involving tasks such as planning, scheduling, or inhibiting actions; it emphasizes on working memory and it is possibly linked to intelligence processes (Miyake et al., 2000). Performance on cognitive tasks that do not involve executive functioning, on the other hand, was not enhanced by physical activity (Kramer, Hahn, & Gopher, 1999).

Research has also underlined a significant relationship between cognitive functioning and physical activity in children. Perceptual skills, intelligence quotient (I.Q.), achievement level, verbal tests, mathematical tests, developmental level, academic readiness, and executive control seem related to physical activity in children (Sibley & Etnier, 2003; Buck, Hillman, & Castelli, 2008; Davis & Lambourne, 2009). Thus, within the field of academics, there is evidence for correlation between physical activity and students' academic achievement. Students with better grades constantly show greater physical fitness performance (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001; Castelli, Hillman, Buck, & Erwin, 2007). However, these studies did not infer on the direction of that relation, that is, whether or not physical activity is one of the causes of academic success. Regardless of that particular matter, physical activity seems to induce better cognitive readiness in subsequent tasks, which underlines its specific value in children daily routine (Ratey & Hagerman, 2008).

## Sports, cognitive functioning and strategic choices

Most of the work reported above emphasized on regular aerobic physical activity. Sports practice, however, often involves more than just aerobic training. Besides the physiological component, many sports engage in various cognitive tasks, ranging from basic to extremely complex, that are not required when running on a treadmill. What impact does practicing sports have on cognition?

Recent work (Moreau, Clerc, Mansy-Dannay, & Guerrien, 2010) pointed out that spatial abilities, such as mental rotation, are positively affected by an intense sport practice. This was found in a cross-sectional study comparing performance on various tasks between elite and novice athletes, as well as between athletes and students. Not only did elites perform better on sport-specific cognitive tasks, as expected, but they also performed better than

novices on general tasks, such as mental rotation tests. This is in line with current research assessing motor processes involved in mental rotation, in cross-sectional and longitudinal experimental designs, supplemented by neuroscientific data (Jansen, Wiedenbauer, & Hahn, 2010; Amorim, Isableu, & Jarraya, 2006; Ozel, Larue, & Molarino, 2004; MacIntyre, Moran, & Jennings, 2002; Voyer, Nolan, & Voyer, 2000; Lord & Garrison, 1998). Besides, mental rotation tests have shown to be reliable predictors of academic success and professional achievement (Halpern & Collaer, 2005). What relevant information does it provide? In fact, this means that general cognitive abilities can be trained through sports practice, if adequately intense, as they could be trained through mechanical reasoning or videogaming, for example (Halpern & Collaer, 2005). Because these abilities will be of great use in people's academic and professional lives, developing them seems quite crucial.

However, these particular findings do not necessarily apply to any type of sports. In fact, the sample considered in the previously detailed study (Moreau et al., 2010) was gathered from different combat sports, which all have in common important body rotations in three-dimensional space. Features of the sports themselves probably led to specific changes in cognitive abilities. However, significant differences can also be found when assessing cognitive functioning in athletes practicing different kind of sports, such as team sports for example. Voss and colleagues reported higher performance for expert athletes in tasks measuring processing speed and attention (Voss, Kramer, Basak, Prakash, & Roberts, 2010). In their study, athletes practicing interceptive sports showed the greatest scores. These sport-specific results underline the fact that it might be quite difficult to link sport in general to detailed cognitive abilities, but rather that each type of sport has a different impact toward particular cognitive abilities.

Another important factor to consider when assessing cognitive functioning in sports is the strategic variable. Recent work on spatial ability has underlined the fact that elite athletes do not perform better on mental rotation tasks on the sole basis of better cognitive abilities per se, but also because they tend to choose the optimal strategy to the particular problem encountered, hence selecting the most suitable course of actions for each particular item presented (Moreau et al., 2010). Thus, elite athletes use flexibility between potential strategies (one of the components of executive functioning), whereas novices tend to stick to stereotyped procedures, less demanding on cognitive resources.

### **How to enhance cognitive functioning through sports practice**

What can be inferred from research in sport and cognitive sciences? How can these findings be relevant to individuals practicing sports? It seems legitimate to wonder what one could do in order to improve one's cognitive abilities. Enhancing cognition is a lucrative market that has seen new openings in the last few years, mostly involving computerized training. The question of whether sport practice can be a healthy, inexpensive and convenient alternative to enhance cognition is worth exploring, in order to precise the standards that should be met to obtain the best results. Are there any rules of thumb that can be applied to increase the benefits of practice? New trends from experimental work lead to identify several helpful key-points that can be addressed in order to improve human cognition through sports practice.

#### *Elite level practice*

Elite sports practice represents a constant challenge for the brain, because athletes are confronted to other individuals that have developed high skills and abilities as well. In their case, everyday training involves higher cognition processes (Moreau et al., 2010), not because of automated actions, but in the selection of the best course of actions depending on how well they read the environment. Thus, brain-imaging studies have shown that the complexity of elites motor coordination induces plasticity in cerebral areas such as the motor

cortex (Tyč, Boyadjian, & Devanne, 2005), the cerebellum (Park et al., 2009), or the hippocampus (Wei & Luo, 2009).

### *Diversity*

Elite competition is not always a possible or desirable choice. However, there are many other ways to develop the brain through exercising. Research in neuroplasticity suggests that diversity is decisive to develop new brain area and increase neural growth. This can be achieved through practicing diverse sports, in different categories (team sports and combat sports, for example). A wide range of perceptive modalities will ensure the exhaustive development of a vast panel of abilities and skills. Diversity can also be reached by seeking modified or new motor coordination and patterns. This means that a goalkeeper could sometimes play on the field, for example, or that a tennis player who usually favors a baseline game might want to come to the net more often. New coordination will take place, leading to plastic neural changes if maintained overtime.

Moreover, diversity between sessions will help maintain attractiveness to sports practice (Alpert, 2010), hence promoting further individual involvement. This is rather central, because long-term commitment is one of the major key to any successful training program.

### *Challenge*

Routine is the enemy of the plastic brain. To avoid it, the use of challenging situations can be beneficial. In sport, this can mean setting new goals, in training or competition, to encourage further improvements. This can be achieved through direct confrontations or by comparing performances (essentially for sports in which performance can be measured objectively). Also, pairing with other players or athletes can help establishing a positive rivalry that will encourage further objectives and challenges, potentially higher than those initially planned.

Challenge can also arise by adding difficulties in the session. This could come from suppressing one particular perception modality (e.g.: blindfolding to suppress visual information) in order to emphasize on sensory information that are not usually central to individual motor responses.

### *Novelty*

New situations tend to stimulate specific parts of the brain, such as the prefrontal cortex, because of the explicit learning processes involved. In fact, novelty calls for attention resources, which in turn help engaging other executive processes, such as decision-making, for instance. This facilitates one's reflection about one's own practice, raising new aspects that were not necessarily conscious before.

To that particular purpose, coaching can represent a unique and interesting way to access a deeper understanding of one's own practice. Indeed, verbalizing and teaching skills to others do not engage the same cognitive processes than when executing an action, thus implying transfer of motor knowledge to higher cognitive structures.

### *Willingness*

Studies show that neural plasticity induced from exercising is more significant and long-lasting when it is self-motivated rather than forced by external factors (Farmer et al., 2004). Thus, the motivational variable is essential to successful training programs targeting neural development. In other words, athletes have to be willing to get involved in their practice to maximize subsequent cognitive enhancement. Besides, intrinsic motivation will help engage in long-term training programs which are needed to build long-lasting improvements.

### Aerobic work

Original findings come from studies involving aerobic exercising (Colcombe et al., 2006; van Praag, Kempermann, & Gage, 1999). This variable should not be discarded if the objective is to enhance cognition and brain function. The most suitable combination would be to include an aerobic factor to the previously detailed key-points. In fact, most sports already incorporate aerobic work, which tends to simplify greatly any potential dilemmas. Furthermore, a better overall physical condition will allow people to become more involved in their respective sport, thus leading them to favour additional beneficial factors for cognition enhancement.

### Conclusion

The idea that brain plasticity continues throughout adult life gives an opportunity for everyone to work on developing new skills and abilities, at all ages. Sport can be a convenient way to achieve that particular purpose, not to forget that it induces other changes on different components (e.g. general health). With the latest research in mind and a little imagination on how to apply it in our environments, great improvements can be made, possibly as beneficial as those obtained through specific computerized tasks.

Further research is needed to precise which particular sport can be beneficial to a specific cognitive ability. In fact, gathering existing data can only give a general idea of the type of sport that favours a specific type of cognitive processes, and more work need to be done in order to build a more exhaustive bidirectional model stating relationships between particular sports and the development of specific cognitive abilities or skills.

Furthermore, it would also be interesting to quantify the amount of practice necessary to obtain significant results. Indeed, studies have emphasized on different type of practices, in schools, clubs or elite institutions, without clearly defining the quantity of work required and the time spend practicing to show significant improvements. Are cognitive improvements following a linear path along this of sports practice, or are there any plateau effects? Assessing precisely these variables could allow people at any age to sustain or enhance their cognitive abilities through a specific practice of adequate sports.

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