SPORTS EXPERTISE: IS NATURE OR NURTURE TO BLAME? NO, IT'S THE BRAIN!

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ABSTRACT: For long, people have wondered about the reasons for the superior performance of elite athletes. As it seems, researchers have been divided between reasons that pertain to nature and those that pertain to nurture. More recently, more complex interactionist theories have come to light. These theories posit that both genes and environment contribute to the development of motor expertise in a non-linear way. It is possible that this discussion might never be resolved. Here, we propose that instead of concentrating on the reasons "why", we concentrate on the "how", i.e., brain function associated to motor expertise. There is much support for specific neural activation associated to expertise in sports. Here we discuss some of the main findings in this area and propose that by understanding the motor expert brain, we might optimize training and, ultimately, performance. Crucially, we suggest that neurofeedback techniques might constitute an important tool to achieve this.

KEYWORDS: Expertise in Sports, Expert Brain, Neurofeedback.

PERÍCIA NO DESPORTO: PARA ALÉM DO DEBATE ENTRE A GENÉTICA E O CONTEXTO… HÁ QUE OLHAR O CÉREBRO!

RESUMO: Desde sempre que as pessoas se têm questionado acerca das razões para o desempenho superior dos atletas de elite. Os investigadores têm estado divididos entre as razões relacionadas com a natureza ou com a "educação". Mais recentemente, teorias interacionistas mais complexas vieram à luz. Estas teorias postulam que tanto os genes como o ambiente contribuem para o desenvolvimento da perícia motora de uma forma não linear. É possível que esta discussão não possa ser resolvida. Aqui propomos que, em vez de nos concentrarmos nos "porquês", nos deveríamos concentrar no "como", ou seja, na especificidade da função cerebral associada à perícia motora. Existem muitas evidências que suportam uma ativação neural específica associada à perícia no desporto. Aqui, discutimos alguns dos principais resultados nesta área e propomos que através da compreensão do cérebro motor perito, poderemos otimizar o treino e, em última instância, o desempenho. Crucialmente, sugerimos que as técnicas de neurofeedback poderão constituir um importante instrumento para alcançar este objectivo.

PALAVRAS CHAVE: Perícia no Desporto, Cérebro Perito, Neurofeedback.

PERICIA EN EL DEPORTE: MAS ALLÁ QUE EL DEBATE NATURA-NURTURA… HAY QUE MIRAR EL CEREBRO!

RESUMEN: Desde siempre la gente ha preguntado por las razones del alto rendimiento de los atletas de élite. Según parece, los investigadores se han dividido entre los motivos que se refieren a la naturaleza y los que pertenecen a la "educación". Más recientemente, las teorías interaccionistas más complejas salieron a la luz. Estas teorías postulan que tanto los genes y el medio ambiente contribuyen al desarrollo de las habilidades motoras de una forma no lineal. Es posible que este conflicto pueda no ser resuelto. Aquí se propone que en lugar de centrarse en el "por qué" debemos centrarnos en el "cómo", es decir, la especificidad de la función del cerebro asociada con las habilidades motrices. Hay muchas evidencias para apoyar una activación neuronal específica asociada a la pericia en el deporte. Aquí, se discuten algunos de los principales resultados en este ámbito y se propone que, mediante la comprensión del cerebro motor experto, podríamos optimizar la formación y, en última instancia, el rendimiento. Fundamentalmente, se sugiere que las técnicas de neurofeedback podrían constituir una herramienta importante para lograr este objetivo.

PALABRAS CLAVE: Experiencia en el Deporte, Cerebro Experto, Neurofeedback.

Manuscrito recibido: 21/12/2015
Manuscrito aceptado: 12/06/2016

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Did you ever think about how the interest in studying exceptional abilities arose? No one can negate the human fascination for beautifully crafted motion or even harmonious sound arising from perfect motor coordination by elite athletes or by expert musicians? In reality, the interest in studying and understanding exceptional abilities and performance is not new. It derives mostly from the work of Charles Darwin in 1859 concerning biological determinism and species evolution that largely contributed to further works by some of the most prominent scientists of that time. One such scientist was Francis Galton who was the first to introduce what would be one of the main discussions in behavioral sciences — the nature-nurture debate (for review see Davids & Baker, 2007). The nature-nurture debate focuses on the relative contribution and influence that genetic and environmental constraints bear on human performance. Throughout history and driven by either biological or environmental determinism, this debate produced extreme positions and conclusions, usually favoring one side or the other when answering the question if exceptional individuals are born or made (see for example, Ericsson, 2007; Ericsson, Roring & Nadongopai, 2007; Howe, Davidson & Sloboda, 1998; Klissouras, Geladas & Koskolou, 2007). Indeed, recent ground-breaking work with twins has shown that expert performance is neither the result of nature's ruling, nor is it a consequence of nurture, but stems from genetic guided experience, i.e., an active model of experience, whereby the environment is selected and changed, partly due to each individuals' genetic bases (Plomin, Shakeshaft, McMillan, & Trzaskowski, 2014a). Such innovative findings suggest that there is a complex individualized mediation between genotype and phenotypic expression. In other words, genes mediate the search for environments that, themselves, might facilitate or inhibit the expression of genes. Indeed, Plomin, Shakeshaft, McMillan, and Trzaskowski (2014b) respond to Ericsson's environmentalist hypothesis by posing that expertise cannot be circumscribed to only a few very high performing individuals, limiting the possibility of studying the interplay between nature and nurture. Independently of the complex forces impacting the aforementioned feedforward model of expertise, the consequent phenotypic expression will ultimately impact brain function – as given, for example, by lower hemodynamic responses in the primary motor cortex associated to higher expertise in a coordination motor task (Carius, Andrä, Clauß, Ragert, Bunk, & Mehnert, 2016); by the coupling between action and perception leading to the fine tuning of motor resonance mechanisms associated to the activation of the Action Observation Network (AON) (Aglioti, Cesari, Romani, & Urgesi, 2008); or by higher brain plasticity associated to a higher expertise level (Debarnot, Sperduti, Di Rienzo, & Guillot, 2014). Genetics does play a role on the search for environments that might impact the expression of genetics but also, and as suggested by Debarnot et al. (2014), the main issue that extends from this, is that there should be differences in individual neural networks that might predispose individuals to practice a specific skill. Here we address this precise issue of the specificities of the expert brain.

Being an important component of daily human life, excellence in sports was targeted by these 'nature vs. nurture' conceptions. For a considerable amount of time, particularly between the 50s and 70s of the twentieth century, sport performance was viewed as a product of heritability. As a consequence of this, the concerns of sport scientists and sport programs were associated with the talent detection paradigm (Durand-Bush & Salmela, 2001). By definition, talent detection refers to the search of potential individuals who are not involved in any sport program (Williams & Reilly, 2000). On the basis of this perspective was the belief that there were innate attributes associated with excellence (Régnier, Salmela, & Russell, 1993) that served as predictors of future success (Howe et al., 1998). Talent detection in sports was particularly popular in East German and the Soviet Bloc countries and was influenced by these traditional training theories postulating that talent detection should be a fundamental stage of elite sport programs (Lidor, Côté, & Hackfort, 2009). Despite these ideas having suited the cultural, educational and political context of these countries and period (Lidor el al., 2009), efforts were focused mostly on unidimensional approaches favoring biological determinants (for review see Durand-Bush & Salmela, 2001). Significantly, time has shown us that these models of talent detection were ineffective and incapable of predicting adult sport performances. In this sense, the nature-nurture discussion concerning sports talent was revisited. The last decades of the twentieth century witnessed an important shift in the paradigm of talent detection (Durand-Bush & Salmela, 2001; Lidor, et al., 2009) and scientists progressively produced evidence that more than a genetic construct, talent and expertise result from a dynamic process of development and interaction between genetic and environmental constraints (Davids & Baker, 2007; Phillips, Davids, Renshaw, & Portus, 2010; Simonton, 1999). Such constraints might be training and psychosocial factors (Araújo, et al., 2010; Barreiros, Côté, & Fonseca, 2013; Côté & Vierimaa, 2014;) which are subtended by profound neural adaptations (e.g., Abreu, Macaluso, Azevedo, Cesari, Urgesi, & Aglioti, 2012; Abreu & Duarte, 2015; Aglioti et al., 2008; Draganski, et al., 2004; Nielsen & Cohen, 2008; Yarrow, Brown, & Krakauer, 2009).

It is precisely with this holistic and complex perspective in mind that we intend to explore the most recent advances concerning the neuropsychology of the expert athlete brain.

Performance in Sports and brain activity

It would be misleading to speak of talent and expertise and the development of performance in sports without considering the processes occurring in the brain (see for example, Machado et al., 2015; Zhao, Tranovich, DeAngelo, Kontos, & Wright, 2015). In this regard, one of the most studied topics has been the interaction between brain and cognition, perception, and action. In this sense, decision-making and the subtending brain functions have been amongst the most studied cognitive processes implicated in sports (Abreu, 2014; Abreu & Esteves, 2014). Indeed, there is much evidence concerning the superior capacity of expert athletes in comparison with less skilled ones. For example, experts are characterized by a higher use of the most important cues from the context in which they are competing. This is especially true when it comes to the biomechanical and postural cues extracted from the opponents' movements, associated to a more efficient recognition of patterns. Additionally, superior perceptive and visual skills allow experts to perform better in multiple anticipation and decision-making tasks as assessed by different techniques such as eye movement recording, film-based occlusion techniques or verbal reports (for a detailed review see Williams & Ward, 2007).

Recently, and in an attempt to explore the structural and physiological characteristics of expert and non-expert brains, researchers have focused on a different approach (Yarrow et al., 2009). For example, recognizing that intelligence and expertise may be related with superior neural efficiency, Grabner, Neubauer, and Stern (2006) studied the brain activity of chess players and concluded that not only is intelligence linked to a more efficient information processing system (especially the pre-frontal area), but domain-specific skills such as those related to chess, seem to lead to a higher activation of the parietal areas and a reduced activation of frontal areas of the brain which may be related with the specific development of chess skills through their intense and specific practice. A pertinent question imposes itself. Are these findings related to expertise in chess transferable to team sports? To answer this question we must consider that there is a motor to mental gradient of skill learning (Debarnot et al., 2014); different neural correlates subtend different types of expertise in decision making in sports (from motor to mental decision-making – see, for example, Abreu & Esteves, 2014); expertise is domain-specific but some domain general skills might be transferable (for a review see, for example, Abreu, 2014); expertise in one domain might modulate expertise in another due to shared resources (Fitzroy & Sanders, 2012); and acquisition of novel motor schemas might be anchored on previously acquired ones (Pereira, Abreu, & Castro-Caldas, 2013). Together, these considerations point to the fact that transferability of expertise is a complex matter, but selectively permeable between domains.

With the advent and development of new imaging techniques in Neuroscience, the study of the relationship between brain function and sports performance gained new ground and researchers have found important differences between athletes and non-athletes. For instance, skilled badminton athletes seem to have a different pattern of brain activity. When tested using Transcranial Magnetic Stimulation, it was found that the playing hand of experts presented higher amplitude of Motor evoked potentials (MEPs). These changes in excitability and reorganization of the corticomotor projection of the hand suggest that practice of skilled motor tasks can lead to functional plasticity (Pearce, Thickbroom, Byrnes, & Mastaglia, 2000). It is important to acknowledge that brain modulation is related with the specific context and tasks these athletes develop through time as shown by Fourkas, Bonavolontà, Avenanti, and Aglioti (2008). These authors investigated brain activity of tennis players during mental practice of a tennis forehand, table tennis forehand, and a golf drive. The athletes showed higher corticospinal facilitation only during motor imagery of tennis (but not of other sports) compared to novices. This suggests that context-driven experience specifically modulates sensorimotor body representations (for a detailed review see Yarrow et al., 2009). Later studies have supported this suggestion and given it further strength. Pereira et al. (2013), for example, found that athletes do not outperform non-athletes in motor memory consolidation tasks, but that they are more efficient in acquiring novel tasks, possibly because of an overlap between the required motor schemas and previously learned ones. Again, this implies a specificity of experience in modulating brain and behavior.

Recently, researchers have been able to investigate the athlete brain "in action", i.e., while performing motor tasks or anticipatory decision making associated to motor skills. Indeed, monitoring online brain function is now possible with technologies like functional Magnetic Resonance Imaging (fMRI). Some researchers found superior anticipation ability (i.e., faster and more accurate) in skilled athletes while monitoring the neural activation during the display of specific badminton images in an anticipation task. Furthermore, such skilled athletes showed higher activation of the fronto-parietal and temporal areas, specifically related to observation and anticipation (Wright, Bishop, Jackson, & Abernethy, 2010).

There has been a boom in the scientific literature concerning fMRI and many new insights concerning athlete decision-making and the brain have come to light. However, it is important to consider that despite this new interest, more studies are needed, namely those focusing on individual sports, as most focus on team sports. Indeed, it seems that the findings from studies focusing on individual or team sports - concerning anticipation in elite athletes – are quite different. For example, Abreu, Macaluso, Azevedo, Cesari, Urgesi, and Aglioti (2012) used fMRI to investigate the neural correlates of motor expertise in elite basketball players (i.e., team sport athletes) in an anticipation task. No differences were found between experts and novices in the activation of the fronto-parietal areas (part of the so-called mirror neuron network – a network of double duty neurons that activate both when one executes, observes or imagines an action). However, the authors found superior activation in the extrastriate body area during the prediction task, probably due to the expert reading of the observed motor action. Moreover, experts activated the bilateral inferior frontal gyrus and the right anterior insular cortex when producing errors suggesting a higher awareness of one's own errors. Finally, correct action prediction induced the activation of the posterior insular cortex in experts and the orbito-frontal activity in novices (higher-order decision making strategies). According to these authors, such activation pattern is associated to a superior body awareness that might allow experts to better recognize and interpret their own errors and become more accurate in their decision making processes.

Naturally, there are several limitations to these studies as the implications for sports training are seldom discussed. There is much need for applied research on this field. Some studies have attempted to systemize the theoretical data concerning the function and organization of expert neural networks in order to pinpoint the behavioral implications of the expert brain in action (see, for example, Abreu, 2014). From the drawn behavioral implications, we might tackle training programs, taking into account the potential and limitations of the expert brain. Although some have put forth suggestions concerning specific applications to enhance motor learning (Kleynen et al., 2015), these suggestions were collected from experts on motor expertise and not on data obtained from motor experts *per se*.

Although research in sports expertise still needs further investment, there is no doubt that along with objective performance differences (e.g., technical and tactical) athletes with different levels of skill (i.e. expert vs. amateur vs. novices) also show important differences in brain function. Indeed, the specification of the neural markers of expert anticipation is still open to debate and some suggest that there is more to action anticipation than the sensorimotor regions implicated in the observation of action, i.e., the so-called Action Observation Network (AON) (Kilner, 2011) as was later reiterated by Abreu et al. (2012). Certainly, the issue of what makes us motor experts, be it practice or genetic pool, will continue to interest researchers. However, no matter whom you investigate, when highly tuned anticipation and decision making is necessary, be it in individual or team sports, it seems that there is a specific brain modulation. This should hold the attention of coaches and athletes in order to better suit their training programs. If we are able to better understand the expert brain in sports, we can adapt training programs in order to optimize expert brain function. It is with this idea in mind that we will focus, in the next section, on some recent contributions of neuropsychology in sports training and the development of peak sport performance.

Sport training, peak performance and the role of neuropsychology

The development of talent and expertise has long been based on the optimization of sport performance, centered on long-term and systematic preparation at different training levels (i.e., tactical, technical, physical and psychological). In this regard, research in sport psychology has had an important role in the advancement of knowledge concerning the different factors that might contribute to the development of expertise. Namely, sports psychologists have concentrated in studying real-life context in applied settings with teams, coaches and athletes, as well as researching in laboratory settings. For instance, it is already well reported in the scientific literature (see Hardy, Jones, & Gould, 1996) how important the development of psychological training programs are in elite sports (e.g., goal setting, emotional control, attentional control). However, with the advancement of technology, other techniques, such as neuropsychological ones, have gained more importance and recognition. Underlying the use of these new techniques is the idea that physiological changes are also accompanied by psychological or mental changes, since there is a complete interdependence between body and mind (Bar-Eli, 2002). A classic example of this is the relationship between stress, anxiety and physiological parameters such as sweating, increased heart rate and breathing frequency. In this sense, the athlete's performance will be better the more the athlete is able to adapt to the specific tasks and context of their sport through practice and training, but also a constant adjustment between their physiological state and their mental and emotional condition.

With this neurophysiological perspective in mind, researchers and coaches begun to explore mechanisms that would enable them to manipulate these neurophysiological variables and optimize performance. Among these mechanisms, biofeedback has been one of the most used in sports. Biofeedback can be defined as a procedure in which online information - concerning the psychophysiological processes that are taking place - is given to the participant. This information is usually not known (autonomous mechanisms). Disclosing this information allows the participant to realize the activity of his/her bodily functions, thus affording the necessary information for a heightened voluntarily control (Jodra, 2002). This feedback is usually given by an electronic mechanism that may take various forms and functions. Indeed, there are several types of biofeedback to evaluate various physiological parameters such as muscular tension (electromyography, EMG), the peripheral temperature and electrodermal activity of the skin (e.g., skin conductance sensor), brain activity (electroencephalography, EEG; functional Magnetic Resonance Imaging, fMRI), heart rate (heart-rate monitors), amongst others (Blumenstein, 2002). The use of biofeedback independently or in combination with other mental training techniques has been implemented in the training programs of several sports (e.g., golf, shooting, gymnastics, swimming, athletics, handball, and judo) and has been widely described in the literature. For example, monitoring heart rate, brain activity and respiration through biofeedback has been particularly effective in target sports (e.g., archery and golf), while the evaluation of electrodermal and muscle activity may be important in sports such as gymnastics where concentration is key (for a detailed review see Blumenstein, 2002).

One of the main criticisms or disadvantages pointed to biofeedback has been the use of many "electronic paraphernalia" that favor a laboratorial and less adequate assessment of the specific context in which sport performance occurs (Bar-Eli, 2002). However, technological developments have enabled us to overcome some of these barriers even in techniques that involve some apparatus such as EEG biofeedback, which in recent years has been widely used in the field (Park, Fairweather, & Donaldson, 2015; Thompson, Stefert, Ros, Leach, & Gruzelier, 2008). Indeed, this biofeedback, also known as neurofeedback, involves monitoring the brain activity, for instance, by placing electrodes across the scalp (i.e., frontal, occipital, parietal and temporal areas) to record electrical activity of the brain. The spectral content of these neural oscillations can be associated to certain behaviors. fMRI, whilst a favored technique for neurofeedbak does not offer the possibility of context-embedded investigation like EEG, but can also be used with the purpose of training participants to voluntary control functionally distinct brain areas leading to functionally specific behavioral effects (e.g., Scharnowski et al., 2015). The advantages of using neurofeedback pertain to the possibility of teaching athletes to voluntarily change their neuronal activity by increasing their recognition of their own neuropsychological states desired to optimize their sport performance (Park et al., 2015, Thompson et al., 2008). We can find support for this in a recent study showing that just a few neurofeedback sessions can significantly change the activation of the areas implicated in processing confidence in sports performance (prefrontal cortical areas) in an Olympic athlete (Graczyk et al., 2014). Another application of neurofeedback might pertain to the described effectiveness of motor imagery in motor performance. Neurofeedback imaging techniques have been used to guide the activation of neural areas (such as the primary motor cortex) during motor imagery, leading to a stronger correspondence between motor imagery training and actual motor activation (Blefari, Sulzer, Hepp-Reymond, Kollias, & Gassert, 2015).

Unlike other costly techniques that are difficult to operate outside the laboratory and of which we still know little about its side effects, neurofeedback is an entirely harmless technique, relatively inexpensive and fully portable these days, especially suitable for sports like golf. Nevertheless, and despite the significant advances made, some authors stress the need for more research to continuously support the validity of this methodology (Park et al., 2015).

CONCLUSION

As more complex interactionist perspectives take over (Davids & Baker, 2007), it no longer makes sense to talk about nature vs. nurture in sports performance. However, independently of the training environments, interacting genetic constraints and duration and efficacy of training, one invariable finding has been that the expert brain in sports shares a series of functional markers that allow for efficient decision-making, emotional balance and a focus on performance. We are now witnessing a change in paradigm. From a research framework that focused on the "why" (genes or practice) we have now gained new insights on the "how". It is time to abandon extreme positions concerning the reasons for attaining expert performance and truly invest on how expert performance is operationalized in terms of brain function. A true understanding of the expert sports brain will surely allow for an improvement of the training programs, contextual settings and emotional tuning. The only thing we cannot change so far is the genetic pool. So when we watch the amazingly crafted gestures of a ballerina, instead of wondering where she came from or how she trained, we should wonder about the synapses that fire away in the brain. The brain is to blame.

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