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ORIGINAL

How can cognitive science contribute to sport? How can sport contribute to neuroscience?

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background In this mini-review we would like to focus on common points of neuroscience and sports science. We will shortly describe a few parts of this unity, namely: nerve conduction studies, cognitive profiles of sportsmen and an influence of physical training on cognitive functioning. We want to emphasize the importance of so far conducted research: on the one hand, its application in the methodology of sport training, and on the other hand, expanding the field of knowledge in neuroscience.

Material/Methods Analysis of articles in the EBSCO database using keywords: athletes, sportsmen, cognitive tests, physical training, elderly, psychological traits, cognitive profile.

Results Several methodological problems in examining cognitive functions and psychological traits of athletes has been indicated.

Conclusions Conclusions could be far-reaching; however, thanks to knowledge from sports science, scientists and clinicians have an opportunity to design a therapy for patients with mild cognitive impairments.

Key words cognitive profiles, athletes, sportsmen, psychological traits, ecological theory of perception

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INTRODUCTION

In this mini-review we would like to focus on common points of neuroscience and sports science. We will shortly describe a few parts of this unity, namely: nerve conduction studies (electromyography and electroencephalography), athletes' cognitive profiles and an influence of physical training on cognitive functioning. The effectiveness of nerve conduction studies as a tool in examining changes due to physical activity and distinguishing experts from non-experts in motor tasks will be considered. We want to emphasize the importance of so far conducted research: on the one hand, its application in methodology of sport training, and, on the other hand expanding the field of knowledge in neuroscience.

MATERIAL AND METHODS

Articles in the EBSCO database have been analyzed using keywords: athletes, sportsmen, cognitive tests, physical training, elderly, psychological traits, cognitive profile. The available literature was subjectively selected due to its usefulness in showing the influence of neuroscience on sport science and vice versa. Moreover, literature which reveals inconsistency in results was shown as well.

RESULTS

I HOW CAN SPORT CONTRIBUTE TO NEUROSCIENCE?

Nerve conduction studies

Electromyography

Resistance training causes muscular and neural adaptations [1, 2, 3, 4, 5]. The majority of researchers accepts that a delay before the onset of muscle hypertrophy occurs and that the neural factors are the causes of initial strength gain. Some researchers measure effects of training by means of electromyography (EMG). For example, Aagard et al. [6] claim that the evoked V-wave and H--reflex responses were observed to rise during the maximal muscle contraction after an intense heavy strength training, showing a notable increment in motor neurons output at the maximal voluntary contraction (MVC).

Type of sport, i.e. aerobic/endurance or resistance/anaerobic, is significant for EMG results. When examining in rest state, the soleus H-reflex amplitude was larger in aerobic athletes than in anaerobic athletes [7]. These results could be considered as a result of the athletes' variance in muscle fiber composition. Notably, other studies [8] reported that three weeks of strength or endurance training were presumably not enough to induce changes in muscle fibers composition. Surprisingly, the excitability in the H-reflex pathway increased, yet the V-wave amplitude remained the same in an endurance type training group. By contrast, a resistance training group noticed an enhancement in the V-wave amplitude, while little changes were observed in the H-reflex. Holterman et al. [9] noticed changes in the H-reflex amplitude in three initial weeks of strength training. The increase in efferent neurons output elicited by resistance training may comprise both supraspinal and spinal adaptation mechanism (enhanced central motor drive, raised motoneuron excitability, and decreased presynaptic inhibition) [6].

Electroencephalography

Electroencephalogram (EEG) is a useful tool in examining changes in the cortical activity due to training of the motor system. Numerous studies have examined differences in the onset time of the Movement Related Cortical Potential (MRCP) and its amplitude comparing experts and novice performers [10, 11, 12, 13]. One of the most important results is the fact that compared to non-experts, participants who are experts in particular motor patterns show a lower amplitude and a later onset of MRCP before performing a motor task which they have mastered.

Research from 2014 [14] examined a difference in MRCP between novices and experts in martial arts. One of the experiment protocols consisted of visual stimuli (five different pointed white arrows on a blackboard). Participants were asked to respond to the target arrow and not to respond when another arrow appeared. There were no statistically significant changes in motor response preparation revealed in electroencephalography, compared to the above mentioned studies which reported a more economical pattern of professionals' cortical activity. Worth noting is the nature of the paradigm used in the research [14], i.e. measuring responses to visual stimuli will be analyzed in a further part of this manuscript called Ecological approach to perception.

II WHAT CAN COGNITIVE SCIENCE BRING TO SPORT?

Mental profiles of athletes

Differences in psychological traits of sportsmen

Sports performance at top level requires adequate personality. A professional athlete has to keep cold blood during his or her performance in a tournament or a match. Therefore, researchers in the field of psychology assumed a hypothesis that athletes performing at an international level would possess qualities that facilitate success in such demanding tasks. However, research from 2010 [15] resulted in no significant differences between classes in taekwondo athletes in their psychological traits such as motivation, attention, emotional sensitivity, or positive attitude. Significant differences were found only between sexes in the 'trust' variable.

Obminski et al. [16] examined differences in personality traits and eye-hand coordination between less and more successful young male boxers. It was hypothesized that the examined variables would be a good predictor of success for participants at performances in the next two years. However, no statistically significant results were obtained [16].

Differences in athletes' cognitive profiles

Sports performance at top level, beside adequate personality, requires an adequate cognitive profile. To perform effectively in a dynamic environment, one has to own sharp mind which allows reacting quickly and adequately to changes, keep attention (on one or a few objects at the same time or in sequence, depending on the type of sport), perform quick motor responses, execute complex tasks under time pressure, to name only a few of athlete's mind capabilities. Not surprisingly, several studies focus on examining cognitive functions of professional athletes to test which of them are above the average.

Fontani et al. [17] examined 24 volleyball players, of whom 12 were classified as experts, and 18 karatekas, 9 classified as experts. The research protocol consisted of alert, go no-go, divided attention and working memory tests. For each tests, the reaction time (RT) and the number of mistakes were measured. Experienced karatekas performed better in rapid alert (204 vs 237 ms) but worse in split attention, and they made more errors overall. Younger volleyball players had better reaction time, although committed more errors in tests. The study has a few deficits: it comprised small groups, and differences in results within a group occurred.

Sánchez-López et al. [18] conducted research on 8 judo, 6 kung-fu and 6 taekwondo fighters, all of them classified as experienced. The research used the Test of Variables of Attention. Variability of RT, RT, failures and missed targets were noted. Results showed faster RT and less failures in kung-fu fighters. However, small groups were a deficit of this study.

Voss et al. [19] noted small groups deficits in research examining sportsmen's cognitive performance. As a reply, Voss et al. [19] conducted a quantitative meta-analysis of 20 studies. The sports types used in the analyzed research were classified as *static*, characterized by a slow tempo of performance (long running, swimming). Another category was *interceptive* sports, characterized by performance that is mainly based on coordination of the athlete's body, parts of the body or a held object and the environment. They found that athletes from the interceptive sport types and males showed the largest effects on cognitive measures. Athletes who practice *interceptive* sport types showed the greatest performance in cognitive tests measuring processing speed. Interestingly, Voss et al. [19] noted a lack of studies which used standard executive function tests. However, this meta-analysis revealed a few methodological problems. While examining professional athletes, a researcher is not able to resolve the nature vs nurture problem; namely, whether the examined athlete is naturally talented in faster processing speed, or whether this is an effect of physical training [19]? The problem will be described more widely in the last chapter of the manuscript. In the next chapter, the nature of examination cognitive functions will be considered.

Meta-analysis of Mann et al. [20] aimed to answer the question of differences in cognitive performance between novice and expert athletes. Results showed that experts' responses were faster than novices' in sports types defined as *interceptive*, *strategic* and *other*. Moreover, irrespective of the sport type, experts were better at response accuracy variable than novices.

Ecological theory of perception

Several studies has been conducted on examining athletes' cognitive performance [17, 18]. However, all of them were based on a protocol which included a computer screen or another kind of screen, and the participants' position during the examination was static, mostly while sitting. Standard paper and pencil neuropsychological tests were included in these tests as well. Another way to examine reaction of the vision system is to use a training protocol based on as fast as possible a reaction to lights which appear in the peripheral visual field [21]. However, Faubert et al. [22] estimate that sports training including responses to lights flashing in intervals could not be considered as a high-level visual processing task. In sports, especially in team sports, athletes perform in a rich and dynamic environment which require high-level visual processing skills. Using simple light technique to determine athletes' visual system capacity or to establish training protocol based on such lights system would be against the ecological approach to perception. James Gibson [23] described environment with its full complexity: medium, substances, surfaces, textures, illumination, obstacles, tools, objects, to name a few. Athletes execute their performance in an environment which consists of the above-mentioned and many others elements. Moreover, most of these elements are not static, but dynamic. Additionally, an athlete is constantly moving; as a consequence, he or she changes his or her perspective. Furthermore, according to Gibson [23] using screens in examining visual perception is inadequate because of differences between composition of the natural environment vs the screen. Accordingly, Faubert et al. [9] reported that performance of top-level athletes from different sports types in perceptual-cognitive training was dependent on their postures. Athletes examined in both a standing and a sitting protocol obtained different results.

One of interesting studies which used the ecological approach was made by Shim et al. [24]. Shim et al. [24] reported that the nature of the required responses in most of the studies on athletes (based on pushing a button, verbal reporting or writing) were different from responses during their sport performance for which they were trained. 13 skilled and 12 novice tennis players took part in 2 experiments [24] which were conducted in a typical environment of tennis performance, namely on a tennis court. In experiment 1, participants were asked to react as quickly as possible to the opponent's serve shown on a standard video or point-light display. Participants were holding racquets, their responses were recorded, apparatus attenuated visual and auditory cues. Experiment 2 consisted of two protocols, with only one main difference comparing to experiment 1, i.e. the source of ball serve which the participant had to respond to; in experiment 2 one protocol was based on cloaked ball machine serves, whole another one contained a live opponent. Methodology has been widely described elsewhere [24]. In the context of the present manuscript, the most important conclusion is based on the difference between results in experiment 1 and experiment 2. In experiment 2, the reaction times of 10 top level athletes were significantly better when they stood against a live opponent than a serving machine. These differences could be explained by better capacity of reading movement pattern cues developed by professional athletes [24].

After Johansson's research [25] which showed how well adapted our cognitive system is to the perception of human movement, another studies explored this topic [26, 27, 28]. A discovery of mirror neurons made this branch even more dynamic [29]. These results confirms a relationship between action and perception.

Influence of physical training on non-athletes

Numerous studies indicated an influence of physical activity on people without physical training background. It is well established that physical activity positively influences cognitive functioning of elderly people [30], with [31] and without known impairment [32]. Additionally, aerobic training increases the gray matter size in the hippocampus of elderly people [33]. Moreover, physical activity is a well-established tool to improve children's brain functioning and to change its structure [34, 35, 36].

DISCUSSION

Sport science and neuroscience have been in an extremely fruitful relationship. Electromyography as well as electroencephalography seems to be useful tools in examining effects of sport training; moreover, future studies are required to clarify all methodological uncertainty. Sport science has a lot to offer in terms of developing neuroscience. On the other hand, psychological examination of sportsmen's traits seems not to be the most adequate tool in predicting which athletes would be successful. However, examining cognitive profiles of sportsmen could bring several interesting conclusions.

Moreover, one of analyzed meta-analyses revealed the fact that expert athletes' responses were faster than novices' in sports types defined as interceptive, strategic and other. Moreover, irrespective of the sport type, experts were better at response accuracy variable than novices. Another meta-analysis stated that athletes from *interceptive* sport types and males showed the largest effects on cognitive measures. Athletes who perform *interceptive* sport types showed greatest performance in cognitive tests measuring the processing speed.

CONCLUSIONS

Noteworthy, athletes seem to perform best in tasks which are most similar to tasks which they are used to doing during their sports training and performance. Moreover, physical training seems to be the best established in scientific literature as a tool in a possible treatment of cognitively impaired elderly people.

Three main problems in examining cognitive functions of athletes have been indicated. First of all, the problem of nature vs nurture has occurred. Without longitudinal studies it is unknown if athletes of a particular kind of sport are naturally talented in some kind of cognitive functioning or if is this capability is due to training. Another issue is the nature of protocols used in examining perception and collecting responses. Athletes perform in an environment which is different from the laboratory environment based on sitting in front of the screen. Moreover, sport performance requires perception in a dynamic environment, where perception is coupled with action. Additionally, composition of responses in a laboratory examination is different from those which are required in the natural environment. The last considered issue is distinguishing between effects dependent on a specialist component of training and aerobic and strength training *per se*, which is an additional part of the training protocol in many types of sports.

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