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Arguments for a unified psycho-neuro-motor approach in Human Performance training
Argumente pentru o abordare unitară, psiho-neuro-motorie, în antrenarea Performanţei Umane

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Abstract

Background. The purpose of this paper is to demonstrate the psycho-neuro-motor approach in order to understand, develop, and especially to strengthen the Human Performance (Human Performance – HUP – a concept developed in a holistic vision by Hillerin, Văleanu & Dop in 2003).

Objectives. The research was initiated with the aim of introducing a psychological component in neuro-motor training to analyze and identify changes in human behavior under different conditions (environments or in response to stimuli) and to recover/improve human performance.

Methods. We used a specific training methodology and technology on human subjects, namely: Computer Assisted Information Orthotics (CASINOR), which basically consists of placing the subject in a feedback loop with an information device that offers him real-time visual feedback on the executed movements (Văleanu 2003), a neuromuscular control device and a helmet that acquires EEG signals which are processed (using specific software) to obtain an indicative brain mapping.

Results. By comparing the study's results under various neuromuscular testing conditions (with or without visual feedback and mental training), using brain mapping technology, major differences of the electrical impulses propagation in certain directions of the cortex, depending on the protocol chosen by the methodologist were observed.

Conclusions. From these results, the interdependence of the three components (psycho-neuro-motor) was demonstrated, as well as the importance of their unified approach for assessment, improvement and recovery, in other words human performance training with applications in elderly or disabled assistance, sports performance, training for demanding activities (firefighters, military personnel) and preparing the human crew for prolonged space flight.

Keywords: psycho-neuro-motor, training, Human Performance.

Rezumat

Premize. Scopul acestei lucrari este de a demonstra necesitatea abordării psiho-neuro-motrice pentru întelegerea, dezvoltarea şi mai ales pentru consolidarea Performanţei Umane (conceptul Human Performance -HUP- elaborat într-o viziune holistă de către Hillerin, Văleanu şi Dop în 2003).

Obiective. Cercetarea a fost iniţiată cu scopul introducerii componentei psihologice în antrenamentul neuro-motor, de a analiza şi identifica modificările comportamentului uman în diferite condiţii (medii sau ca răspuns la stimuli), în vederea recuperării/îmbunătăţirii performanţei umane.

Metode. S-a folosit metodologia şi tehnologia de antrenament specific, cu subiect uman, şi anume: ortezarea informaţională asistată de calculator (CASINOR - Computer ASsisted INformational ORthotics), ce are ca principiu introducerea subiectului într-o buclă de reacţie informaţională cu un dispozitiv ce îi oferă acestuia un feedback vizual asupra mişcărilor executate în timp real, un dispozitiv de control neuromuscular şi o cască ce achiziţionează semnale EEG care, cu ajutorul unui soft specific, sunt procesate în vederea obţinerii unui mapping cerebral orientativ.

Rezultate. Prin compararea rezultatelor studiilor efectuate în diferite condiţii ale antrenamentului neuro-muscular (cu feedback vizual, făra feedback şi antrenament mental), s-au constatat cu ajutorul mapping-ului cerebral, diferenţe majore de propagare a impulsurilor electrice pe anumite direcţii ale cortexului în funcţie de protocolul ales de metodolog.

Concluzii. În urma acestor rezultate, s-a demonstrat interdependenţa celor trei componente: psiho-neuro-motric, dar şi importanţa abordării unitare a acestora pentru evaluarea, perfecţionarea şi recuperarea, cu alte cuvinte, antrenarea performanţei umane cu aplicaţii pentru asistarea şi recuperarea persoanelor în vârstă sau cu dizabilităţi, performanţă sportivă, antrenarea pentru activităţi solicitante (pompieri, personal militar) şi în pregătirea echipajului uman în vederea zborului spaţial prelungit.

Cuvinte cheie: psiho-neuro-motric, antrenament, performanţă umană.

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Introduction

The interest in the human performance concept, as defined by Hillerin, Văleanu and Dop in 2003 (Hillerin, 2003), of the group of authors, involving institutions with common research objectives, led to an exploratory experimental approach regarding the connections between cortical excitation and movement, which can be evidenced by EEG and brain mapping.

The advantage of this approach is dictated by the fact that in terms of human performance required for long-term space flights (no gravity, isolation, stress) and also in sports (effort at the limit of tolerance, coordination, time restrictions) or motor recovery programs (readjustment difficulties and mobility restrictions), conditioning the dynamics of results depends on the contribution of several factors, among which, in our opinion, motor, psychological and neural components play a decisive role. In developing human performance, an important role is played by the dynamic balance between stress and recovery in cycles of adaptation (Loehr, 2012) in all areas where stress and recovery are present as the basis for adjustments to keep the human being within acceptable health limits.

Hypothesis

The starting hypothesis states that both the quantity and quality of the information available to a subject, when achieving a certain movement, significantly and mutually affect both cortical activity functioning and the quality of mechanical results of the required exercise.

Methods and technologies

We mention that the research protocol was approved by the management board of the STARWALKER Competence Center, Space Applications for Safety and Health Laboratory at the Institute of Space Sciences, being consistent with legal provisions on the protection of individuals, and technological and ethical standards comply with the requirements of the European Union.

The research protocol:

a) *Time and place of the research*

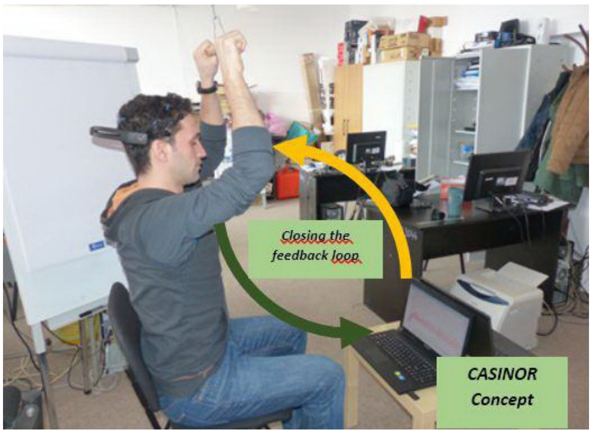
The study was conducted between December 2014 - March 2015, at the Institute of Space Science, Space Applications for Health and Safety Laboratory, Măgurele, Ilfov.

b) *Subjects*

Considering the fact that this was an exploratory approach, tests were performed on two volunteer subjects from the laboratory personnel, who knew and agreed on the experimental protocol and dissemination of results.

c) *Applied tests*

For the studies, we used the CASINOR concept methodology - Figure 1 (Computer ASsisted INformational ORthotics, computer-aided orthotics information), which is basically introducing the subject in an information feedback loop with a device (computer) that offers him real-time visual feedback of the mechanical results of the performed movements.



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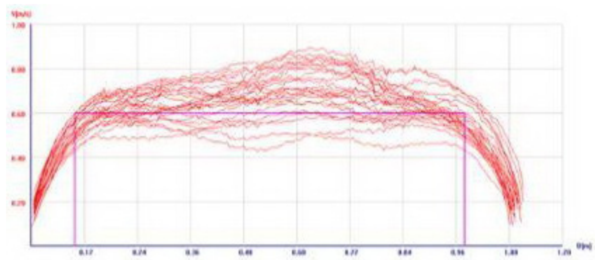


b.

Fig. 1 a,b – Computer assisted informational orthotics – CASINOR®.

The device used in the experiments was the in-house designed Move1Du type which uses know-how and technological solutions that fall within the CASINOR® concept (1), ”principles to achieve motion simulators” (Hillerin, 1983) and ”use of computer-assisted instrumentation to drive motor and volitional capacities” (Văleanu, 2003). The device is designed to perform neuromuscular control exercises for the upper limbs, for the training of the overall capacity of psycho-neuro-muscular control, neuro-motor recovery and/or enhancement of the subject’s mental control. The methodological principle consists of movements carried out by the subject under low resistance movement conditions, of inertia-gravity type (weight), with speed control load so that the subject has to maintain a value close to a predefined constant, displayed on the computer.

In parallel, we used an Emotiv wireless EEG headset (14 channels + 2 reference channels), which provides an optimal spatial positioning, of sufficient resolution for the current state of our experimental studies (2). This equipment, along with the Emotiv 3D Brain Map Premium software (3), acquires EEG signals and provides a real-time electrical activity intensity map of the cortex in four significant frequency bands of brain waves (delta, theta, alpha and beta).

The experiment was divided in three stages:

1. In the first stage, the subject performed neuromuscular control exercises with eyes closed. A reference was given, namely that he had to overcome a resistance (gravity and inertial mass) of about 2 kg and that movement had to be carried out at a constant speed throughout its amplitude: V (velocity) = 0.4 m/s, in 25 repetitions. We will further refer to this type of exercise as „without visual feedback.”

2. In the second stage, the subject was able to verify the accuracy of the performed movements against the model, by viewing the graphic image of the speed-position relations in the phase space, in real time. The movement was the same as described above, and the model parameters were: V (velocity) = 0.4 m/s in D (position) = 1.2 m, in 50 repetitions. Such exercises will be referred as „with visual feedback".

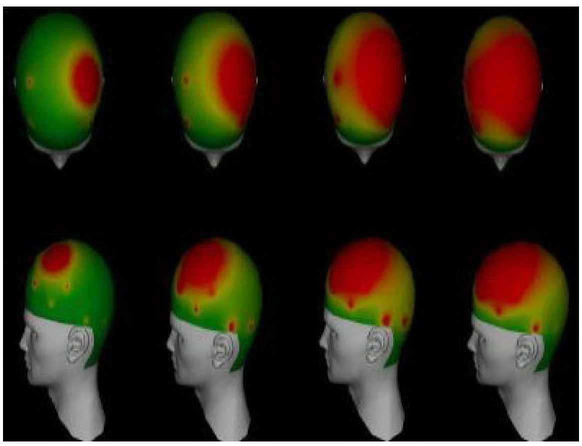
3. In the third stage, the subject performed the exercise only mentally, with sound and visual isolation. The subject was asked to imagine the movement, such as that of the previous exercise, for a total of 20 repetitions.

Results

The central nervous system is generally seen as being organized in three hierarchical levels (Scott 2004), namely: cortex, brainstem and spinal cord. The first level is the spinal cord including motor neurons (the final pathway for conducting voluntary motor impulses) and interneurons (which integrate/provide feedback sensations in muscles, joints and skin). On the second level (intermediate level), there is the brainstem with a role in homeostasis, in conducting, selecting and increasing electrical impulses from the spinal cord, as well as in opposite direction, from higher nerve centers. Associating the intermediate level with some areas of the cortex (Rodier 2002) improves both postural and fine control, and may vary depending on the speed and quality of locomotion patterns. The last level is the cerebral cortex, involved in cognitive, perceptual and executive processes, connecting them through a variety of circuits or entry, exit and re-entry loops of collected and processed information (4). This includes in terms of motor behavior the planning and execution of motion, depending on requirements/conditions.

Discussion

Stage 1. The acquisition data obtained and processed for the visualization of brain mapping (Figure 2) while performing neuromuscular control exercises with the eyes closed, using the Epoc EEG headset together with the 3D Brain Map Premium software, suggest a pronounced involvement of the left hemisphere, which is responsible, in VELCOPAL's opinion, for: logic/reasoning (Vengopal, 2012), control of the right side of the body, mathematical calculations, analytical thinking, grammar/vocabulary, reading, writing, understanding language, science, sequential thinking, objectivity and other functions.



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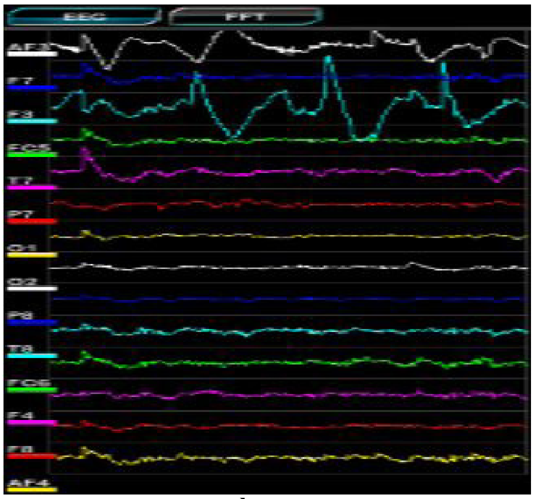

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Fig. 2 a,b – Brain mapping and EEG signal recording during neuromuscular control exercises without visual feedback.

Brain areas activated during exercises:

- The prefrontal cortex (association area: voluntary motion planning).
- Premotor cortex involved in the preparation/planning, coordination and execution of movement.
- The sensory parietal area is the area of integration of peripheral sensory information, in our case it receives signals from cutaneous and kinesthetic analyzers (5).
- The motor cortex is where movement is initiated.
- Basal ganglia have functions such as: motion control, development of motor skills, learning or acquisition of habits.
- The cerebellum is responsible for the coordination of voluntary movements, motion learning, balance, postural reflex learning, sequential learning.
- The brainstem has the role of conducting, selecting and increasing the impulses sent to the spinal cord (motor neurons => muscle).

The indicative route of electrical impulses in the cortex during the execution of neuromuscular control movements without visual feedback can be seen in Figure 3.

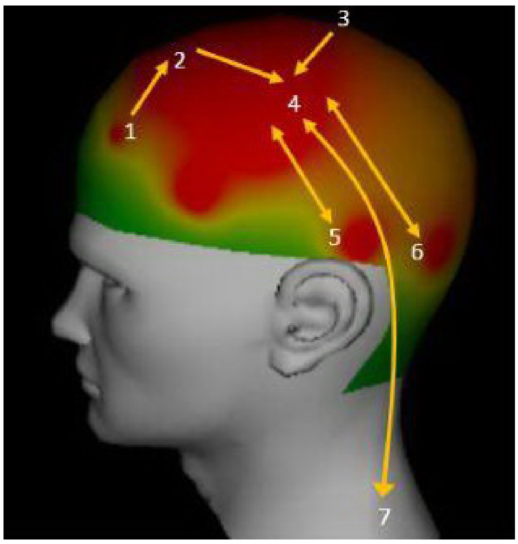


Fig. 3 – 1. Prefrontal cortex, 2. Premotor cortex, 3. Parietal cortex, 4. Motor cortex, 5. Basal ganglia, 6. Cerebellum, 7. Descending pathway – motor cortex - brainstem - spinal cord.

On the Move1Du/Motrix application, there is a mismatch between the requested task (to perform a movement at a constant speed) and the execution of movements by the subject in the given conditions – Figure 4.

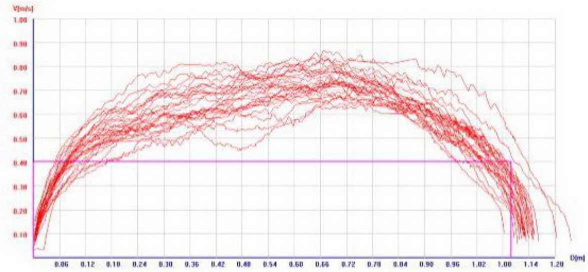
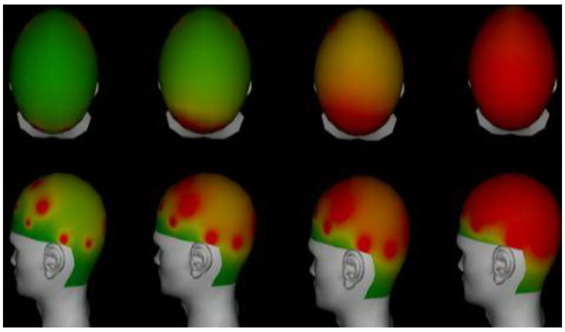


Fig. 4 – Graphical representation of acquisitions during neuromuscular control exercises without visual feedback.

Stage 2. Neuromuscular control exercises were performed with visual feedback as previously described.

The brain mapping recorded (Figure 5) in this stage indicated an approximately equal dispersion of electrical impulses on the surface of both hemispheres, with considerable dynamic changes in the electrical impulse directions (different from the previous stage).



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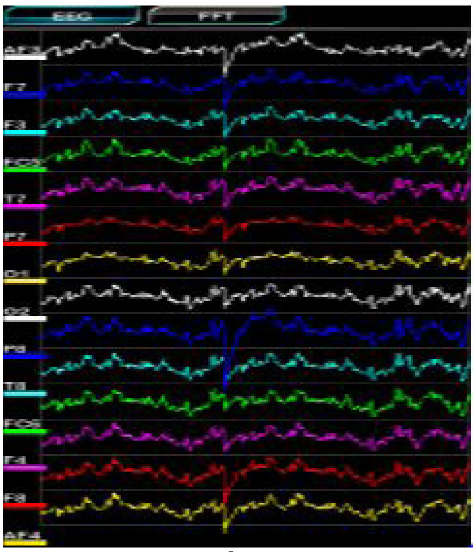


b.

Fig. 5 a, b – The brain mapping and EEG signal recording during neuromuscular control exercises with visual feedback.

Brain areas activated during exercises (Figure 6):

- The primary visual cortex that receives and processes impulses through the optic nerve.

- Impulses are then directed to the parietal somatosensory association area that receives information from the three sensory systems: visual, auditory, somatosensory (receiving sensations from muscle and skin). This area plays an important role in building the image of the body and its segments, the environmental image (Trimble 2007), while having the function to plan/adjust the movement depending on environmental conditions in which it takes place, according to the applied methodology.

- Next is the activation of the premotor cortex area (involved in preparation/planning and execution of movement, imitation, learning), which simultaneously receives impulses from the prefrontal area (involved in planning, reasoning and judgment). The impulses are then directed to the primary motor cortex which has the role to coordinate and initiate movement for each body segment, represented on its surface.

- A concomitant exchange of information occurs between the motor cortex and basal ganglia.

- In the descending pathway, an exchange of information occurs between the motor cortex and the cerebellum (Scott 2004), followed by transmission of impulses through the brainstem to the spinal cord and effectors (motor neurons-> muscle).

The indicative route of electrical impulses in the cortex during the execution of neuromuscular control movements with visual feedback can be observed in Figure 6.

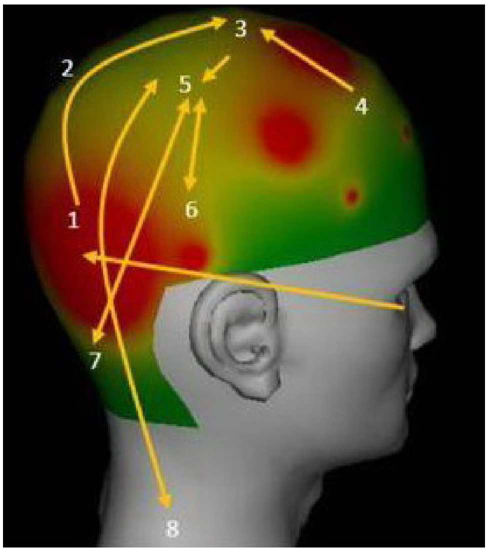


Fig. 6 – 1. Visual cortex, 2. Associative parietal-premotor circuit, 3. Premotor cortex. 4. Prefrontal cortex, 5. Motor cortex, 6. Basal ganglia, 7. Cerebellum, 8. Motor cortex - brainstem - spinal cord circuit.

Neuro-motor behavior considerably improved (Figure 7) as a result of using visual feedback. Integrating the whole somatosensory association system, the subjects managed to come closer to the graphical model.

The grades assigned to subjects during executions (Figure 8) in stages 1 and 2, from the point of view of movement precision, indicate the effectiveness of neuromuscular control exercises with visual feedback and its impact on the development of motor skills.

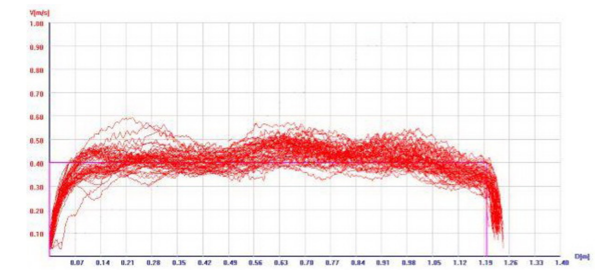


Fig. 7 – Graphical representation of acquisitions during neuromuscular control exercises with visual feedback.

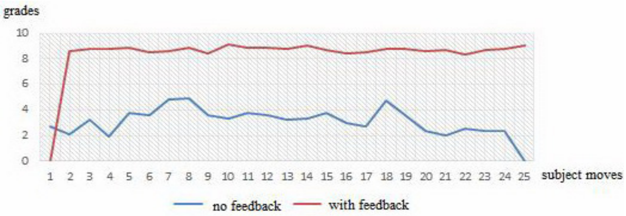
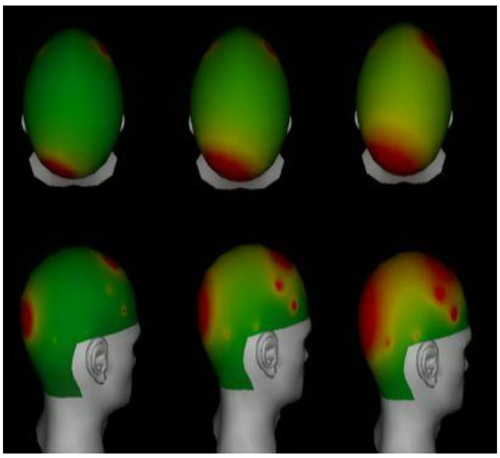


Fig. 8 – The graphs of grades resulting from the evaluation of movements corresponding to the type of exercise (with feedback/ without feedback).

Stage 3. In this stage, the subject was requested only to imagine, with no sound or visual feedback, the movements related to the neuromuscular control exercises executed in the previous stages.

Brain mapping (Figure 9) in the case of mentally simulated exercises showed a different distribution of electrical impulses and increased activity of the right hemisphere. Thus, circuits are formed which link the prefrontal cortex (representing the creation of new behavioral patterns) with the parietal-temporal-occipital association cortex, which has an important role in certain aspects of visual memory (Axmacher, 2008), mental mathematics, three-dimensional awareness of the body, construction of the mental image of the proposed exercise. According to Buckner (2008), the imagination network is involved in building dynamic mental simulation based on past personal experiences, by remembering previous movements (with visual feedback), realizing based on thought, on imagination, the prospect of a movement/ execution (in our case, during mental exercises).



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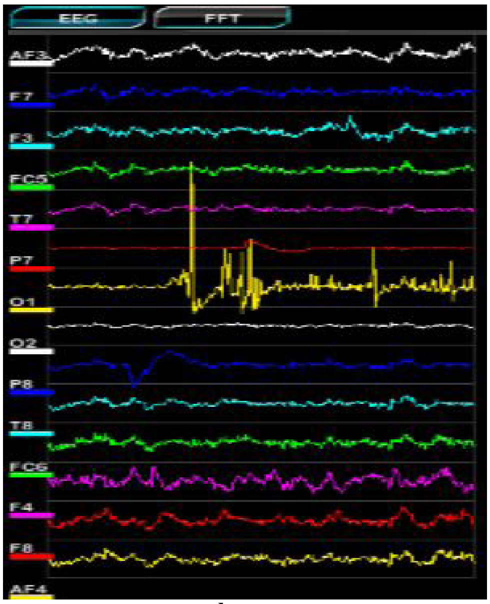

b.

Fig. 9 a, b – Brain mapping and EEG signal recording in mental neuromuscular exercise simulation.

Conclusions

1. The behaviors observed in the subject performing the exercises are due to neuromuscular and mental-volitional control mechanisms.

2. Based on these results, the interdependence of the three components (psycho-neuro-motor) was demonstrated, as well as the importance of their unitary approach for evaluation, improvement and recovery, in other words, human performance training, with applications in the assistance and recovery of elderly or disabled people, in sports performance, in training for demanding activities (firefighters, military personnel) and in preparing the human crew for prolonged space flight. The results open the perspective of using brain mapping for the real-time monitoring of training to achieve human performance aspects specifically targeted on the training objectives.

Conflicts of interest

In this experimental article, there are no conflicts of interest.

Acknowledgements

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