ALPHA ABSOLUTE POWER

Motor learning of practical pistol shooting

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Abstract – The present study aimed at investigating changes in behavior (shooting precision) and electrophysiological variables (absolute alpha power) during the motor learning of practical pistol shooting. The sample was composed of 23 healthy subjects, right-handed, male, between 18 and 20 years of age. The task consisted of four learning blocks. A *One-way ANOVA* with repeated measures and a *post hoc* analysis were employed to observe modifications on behavioral and electrophysiological measures ($p<0.05$). The results showed significative differences between blocks according to motor learning, and a significant improvement in shooting's accuracy from both blocks. It was observed a decrease in alpha power in all electrodes examined during task execution when compared with baseline and learning control blocks. The findings suggest that alpha power decreases as the function of the motor learning task when subjects are engaged in the motor execution.

KEY WORDS: qEEG, pistol shooting, motor learning.

Potência absoluta de alfa: aprendizagem motora do tiro prático de pistola

Resumo – O presente estudo teve por objetivo investigar alterações nas variáveis comportamentais (precisão do tiro) e eletrofisiológicas (potência absoluta de alfa) durante o aprendizado motor do tiro prático de pistola. A amostra constituiu-se de 20 sujeitos saudáveis, destros, sexo masculino, faixa etária entre 18 e 20 anos. A tarefa consistiu de quatro blocos de aprendizagem. A análise estatística das variáveis comportamentais e eletrofisiológicas foram realizadas por meio de uma *ANOVA* one-way e uma análise *post hoc* ($p<0,05$). Os resultados demonstraram diferenças significativas entre os blocos em função do aprendizado motor, bem como uma sensível melhora na precisão do tiro de ambos os blocos. Foi observada uma diminuição na potência de alfa em todos os eletrodos analisados durante a execução da tarefa, quando comparados aos blocos de linha de base e controle da aprendizagem. Os achados sugerem que a potência em alfa diminui devido o aprendizado motor quando sujeitos estão engajados na execução de uma tarefa motora complexa.

PALAVRAS-CHAVE: EEGq, tiro de pistola, aprendizagem motora.

The knowledge of motor learning effects on the cortex has become a challenge in neuroscience due the process of brain plasticity. The acquisition of new procedural knowledges supposedly is related to change in motor behavior (i.e., learning), while retention of these knowledges is associated with memory aspects[1]. Learning and memory are strongly related, once both processes share a similar neural mechanism. Both are also involved with attention´s control, sensory integration and perception[2]. Learning gradually produces a reduction in error embedded in the task, increase coordination, agility and speed in movement execution[3]. Learning processes produces an internal representation which is seen through an increment in synaptic efficacy ("strength") of neuron populations in cortical and subcortical structures[4]. The execution and consolidation of motor act would lead to a new neural circuit organization, due the interaction of processes responsible for short (i.e., sensory), working and long-term memory[3,5]. The adjustment of this novel network would produce a reference´s system, which is influenced by experience[6].

It is known that the motor skills' learning is not dissociated from higher processes, such as: attention, memo-

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Received 4 October 2007, received in final form 3 March 2008. Accepted 25 March 2008.

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ry, strategy and goal oriented. The incorporation of motor gesture produces neuronal changes that can be detected with quantitative eletroencephalography (qEEG)[7]. Several studies have linked changes in cortical maps according to the practice of closed skills, such as: shooting[8-12], bowing and arrowing[13,14] and golfing[15]. In this manner, tasks as target shooting provide an original opportunity to study the processes of skill acquisition on the neural level. The shoot represent a complex motor-perception task which require a high level of procedural instructions, focal attention on aim apparatus, fine motor control in trigger activating, and postural stability[9-11]. These demands include temporo-spatial integration of visual, vestibular and propioceptive information[16-19]. The essential behavioral measures to assess learning and performance, such as precision, values and impact dispersion, can be obtained and quantified, which facilitate the assessment between processing and cortical performance[10,11,19]. The alpha power has been inversely correlated neural activation[20,21]. Moreover, recent findings have reinforced the hypothesis of inverse relationship between the alpha power and attention effort, planning and motor responses execution regarding the target shooting[7-9,12].

Thus, the present study aimed at investigating changes in neural patterns in alpha band in frontal areas related to cognitive aspects during motor learning of practical pistol shooting.

METHOD

Sample

The sample was composed for 20 healthy individuals of both sexes with ages varying between 18 and 20 years, right handed as Edinburgh inventory[22] and with director right eye, absence of mental and physical illness (previous anamnesis). The subjects didn´t make use of any psychoactive or psychotropic substance at the time of the study. Moreover, they have not a sleep period less than 6 to 8 hours at night before the experiment, and do not have previous experience in target shooting. All subjects signed a consent form and were aware of all experimental protocol. The experiment was approved by the Ethics Committee of Federal University of Rio de Janeiro.

Experimental procedures

The task was performed in a sound-attenuated room on *indoor* shoot *Stand,* adapted for practical pistol shooting, built inside Psychiatry Institute of Federal University of Rio de Janeiro. All subjects seated comfortably in a chair to reduce the artifacts muscle, and a shoot table was used to support the hands and the gun. Each subject was separately assessed in 3 moments: Base Line (BL_1), Motor Learning (ML) and Learning Control (LC). In first moment (BL_1) the subject was sitting comfortably in a chair, putted immediatly behind shoot line, with the hands over the lap. Besides, a qEEG was performed for 12 minutes (6 with close and open eyes). In second moment (ML) the subject was sitting with open eyes, holding a pistol (Taurus PT-380) and performing the complete task. The experiment consisted of 4 shoot blocks (B_1, B_2, B_3 and B_4) with 10 trials each, divided into 2 parts of 5 shoots with an interval of 2 minutes between them. The intervals favored the recovery of the active limb, avoiding muscular fatigue, and allowing any possible instruction. During the shoot execution, the participants should fire on the target mantaining the pistol aim apparatus, and the target center aligned. The qEEG was continually recording over the shoot blocks. During the task the lights were attenuated, the Shooting's room was isolated, thus, the subject does not suffered the interference of other visual stimuli than the perception of visual stimulus (weapon and target). The subjects utilized special glasses for shooting to minimise the double vision during the aim, which allowed the two eyes open during the shooting, preventing the facial fatigue in order to prevent artifacts. The third moment was performed 2 minutes after the last learning block, in same conditions as $BL_{1,}$ trying to verify significant differences between electrophysiological variables in relation to BL_1 and ML.

Data acquisition

All data related to shoots were recording by *Sam Trainer system* (Knestel Elektronik, Germany), which consiste of an electronic device to register the data, based on an infrared signal interface emited for an optic device, adapted below the pistol's frame and reflected for 4 infrared sensors arranged symmetrically on a target located 5 meters in front of shooter. This system provides the impacts' value, horizontal and vertical deviation prior the shooting (i.e., 6 seconds). Based on the report, it was possible to determine the shoot precision and the impacts dispersion, allowing the mensuring of subjects' performances. The results obtained between 0,1 and 10, correspondents to electronic target area (10 cm in diameter) were selected, in order that this measure correspond to the center of the classic target on the practical pistol shooting. Impacts value equal or lower 6 were considered to low precision, between 6,1 and 9 moderated and above 9,1 very good. At the shooting moment, an eletronic sensor adapted to weapon emited an eletric pulse that marks in real-time the note channels of *Braintech* 3000 (Emsa – Medical Instruments, Brazil). In this manner, it was possible to control the EEGq recording during the 3 seconds prior to shoot and to delimitate the interests' epochs. The International 10/20 System for electrodes[23] was used with the 20-channel EEG system Braintech-3000 (EMSA-Medical Instruments, Brazil). The 20 electrodes were arranged in a nylon cap (ElectroCap Inc., Fairfax, VA, USA) yielding monopolar derivations referred to linked earlobes. In addition, two 9-mm diameter electrodes were attached above and on the external corner of the right eye, in a bipolar electrode montage, for eye-movement (EOG) artifacts monitoring. Impedance of EEG and EOG electrodes was kept between 5-10 KΩ. Visual inspection and independent component analysis (ICA) were applied to remove possible sources of artifacts produced by the task. The data acquired had total amplitude of less than 100 µV. The EEG signal was amplified with a gain of 22,000, analogically filtered between 0.01 Hz (high-pass) and 35 Hz (low-pass), and sampled at 240 Hz. The software Data Acquisition (Delphi 5.0), developed at the Brain Mapping and Sensory Motor Integration Lab, was employed with the following digital filters: notch (60 Hz), high-pass of 0.3 Hz and low-pass of 25 Hz.

Data analysis and dependent measures

During the experiment, the behavior and electrophysiological variables were analysed. The behavior variables were obtained on the subjects' performance in practical pistol shooting (i.e., shooting precision and impacts dispersion). The electrophysiological variables were recording from qEEG. The computation's variable was performed after the recording and archiving of the qEEG data. The electroencephalographic signals were analyzed by MATLAB 5.3 (Matworks, Ltd., USA), which performed the Fourier Transform (FT). In this manner, based in EEG free epochs (i.e., no artifacts), a threshold given by mean added up three standard deviation was established, and epochs with total power higher than this threshold were not integrate the analysis.

Statistical analysis

An *ANOVA one way* with repeated measures was used to verify the main effect for learning blocks (B1, B2, B3 e B4) on the dependent measure (performance in practical pistol shooting), followed by a Scheffé test (p<0.05). Another four *ANOVA one way* with repeated measures were performed to verify the main effect for blocks (six blocks - BL1, B1, B2, B3, B4, e LC) on the alpha power varibility in frontal cortex, followed by a Scheffé test (p<0.05). The EEG absolute power values were log-transformed by *SPSS* software (version 15.0) to approximate a normal distribution.

RESULTS

The first analysis showed a significant difference between the subjects performance over the learning blocks ($F_{(3,400)}$=4.214; *p*=0.006). The Scheffé test demonstrated differences between B4 and B1 (*p*=0.034) and B4 and B2 (*p*=0.035) (Fig 1). In second analysis, it was verified a significant difference in alpha absolute power variability in F3 during the blocks ($F_{(5.600)}$=9.741; *p*=0.000). Post hoc analysis stablished a significant decreasing over the motor learning blocks (B1, B2, B3 and B4), when compared with control blocks (BL_1 and LC), however, B4 was not significantly different in relation to BL_1 (*p*=0.374) and LC (*p*=0.599) (Fig 2). The third analysis revealed that the alpha absolute power variability in F4 could be expliained by blocks effect ($F_{(5.600)=}$19.544; *p*=0.000). The Scheffé test demonstrated a significant decreasing over the blocks (B1, B2, B3, and B4), when compared with control blocks (BL_1 and LC) (*p*=0.025) (Fig 3). The fourth analysis indicated main effect for blocks ($F_{(5.600)=}$6.531; *p*=0.000) in alpha absolute power for F7. Post hoc analysis revealed a significant decreasing during the blocks (B1, B2, B3 and B4), when compared with control blocks (BL_1) (Fig 4). The fifthly and last analysis demonstrat-

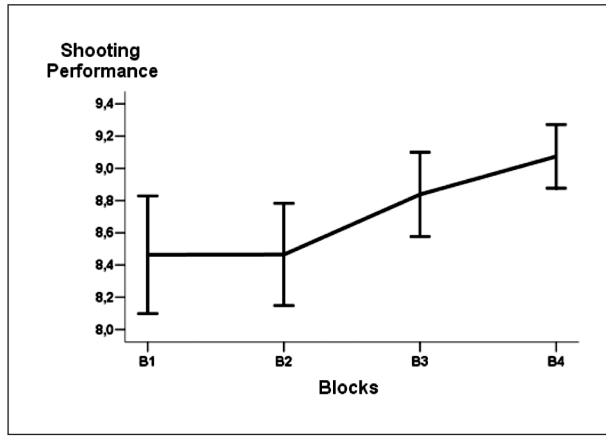

Fig 1. Subjects' performance during motor learning blocks (shooting blocks): impacts precision and dispersion.

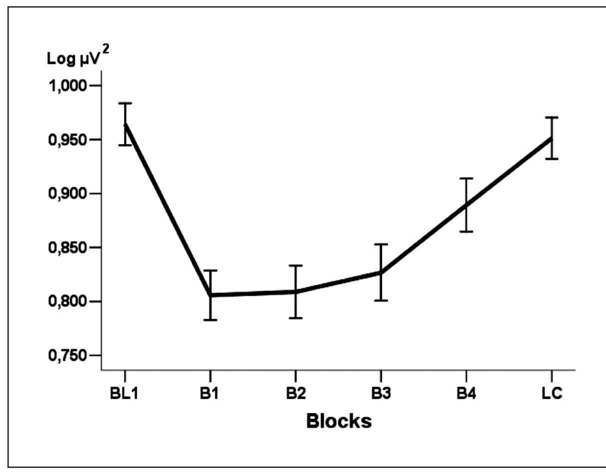

Fig 2. Variability in F3 alpha power during the blocks.

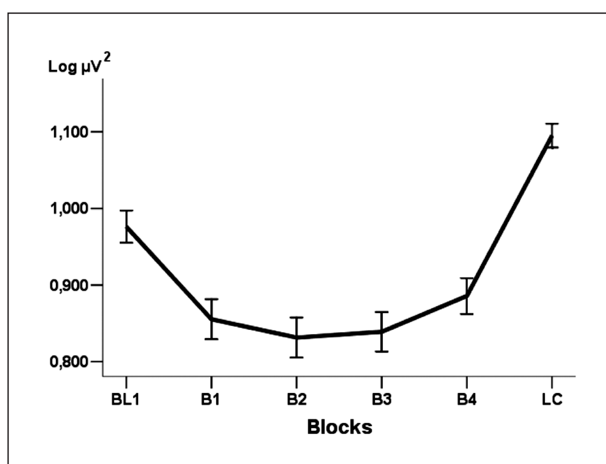

Fig 3. Variability in F4 alpha power during the blocks. The increasing in alpha power in LC when compared with BL_1 (p=0.025) suggest the possibility of a learning consolidation.

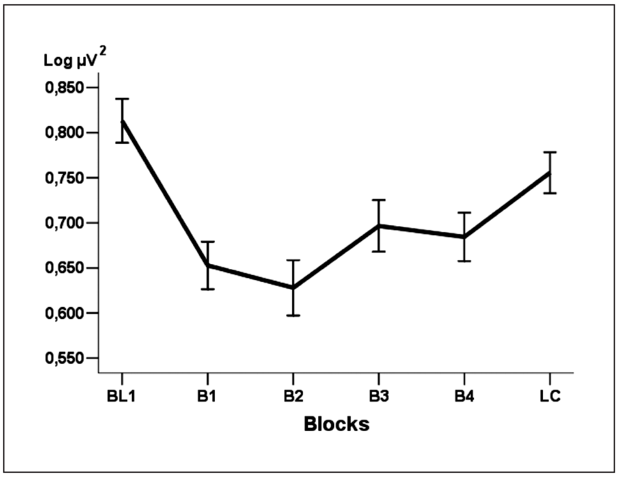

Fig 4. Variability in F7 alpha power during the blocks.

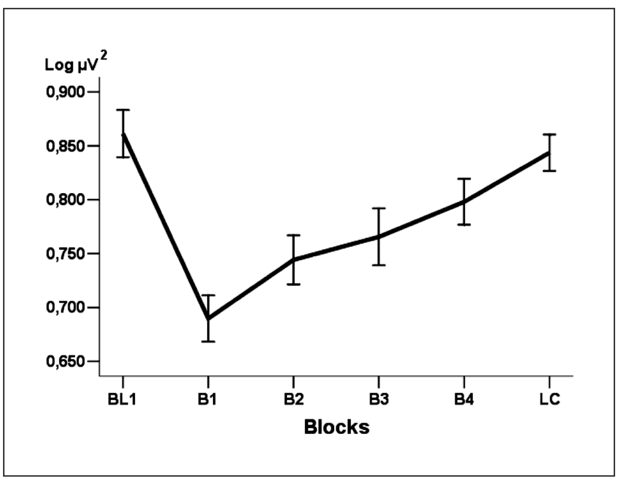

Fig 5. Variability in F8 alpha power during the blocks.

ed a main effect for blocks ($F_{(5.600)}$=8.540; *p*=0.000) in alpha absolute power in F8. The results (Scheffé test) demonstrated a significant decreasing during the blocks (B1, B2, B3 and B4), when compared with control blocks (BL_1) (Fig 5).

DISCUSSION

Our results will be discussed according to blocks main effect in relation to behavior (i.e., precision and shoot dispersion) and electrophysiological (alpha power in F3, F4, F7 and F8 electrodes) measures.

Behavior measures – The results demonstrated an improvement in sujects performance over motor learning blocks, more evidently between B4 and B1, and between B4 and B2. In early phase of learning the sensorial stimulus dependence is essential for task execution[4,5]. The subjects were involved in basic skills coordination of task, such as, shoot position, weapon holding and breath. Probably, it occurred a decreasing in attention processes related to main habilities, in other words, in target and trigger activating. It would explain the high variability in shooting precision and an increasing in the lower precision shoots in early blocks (B1 and B2). In contrast, in the final blocks (B3 and B4), it was demonstrated an increasing of basic skills' domain and attention. In advanced stages of learning, the subjects better understanding the rules and the strategies of the task, and they can execute more automaticaly the fundamental habilities and reducing task complexity[24]. Consequently, the shooter can maintain attention specifically in main shoot requirements, such as, integrate the better moment for trigger activation with the continue flow of visual and propioceptive feedback during the aim, even though minimizing intentionally the regulation of each component of the process separataly[8,13,15]. The final result was refined of a motor-perception process, which leads to quality of movement improvement[25-29].

Electrophysiological measures – The alpha band (8-12 Hz) was used to evaluate cognitive changes produced by sensory-motor task (practical pistol shooting)[20,21,30]. Specifically, it was used absolute power measures to observe possible cortical changes. Absolute power is defined as total energy intensity of an electrode on a certain region at different frequency bands[15,17,28]. There were seen significant differences between the interest blocks (BL_1, B1, B2, B3, B4 and LC), which are related to variability in alpha power with the cognitive processes during learning task. First, it was verified a significant decreasing in all electrods (F3, F4, F7 and F8), when compared the control blocks (BL_1) and learning blocks (B1, B2, B3 and B4). Historically, alpha power was inversely correlated to population of pyramidal neurons involved in perceptive, cognitive or motor tasks[8,9,11,12]. The evidences suggest that the increasing of alpha power plays a significant and adaptive role in the organization of visuo-spatial and motor processes during the target shooting. This gradual increase in alpha power can be considered an indication of learning, as it is linked to attention focused in the development of strategies and cognitive visuo-motoras[11,12]. The alpha band is associated with an increased neural synchrony and short effort, therefore, it is coupled with the best motor performance[27]. In this sense, the lower alpha absolute power over the motor learning blocks in relation to BL_1 and LC would explained by total inexperience on the task, fact which required beginners a high mental effort to integrate relevant stimulus of the task to produce a motor outcome according to experimental procedures. Second, the movement is learned into segments, and the learning results in automation of these segments, more and more complexes. The prefrontal cortex is responsible to select the segments, requesting one just after other[8,9,12,21]. Moreover, cognitive demand is inversely related to the use of segment structures (e.g., arm and hand)[28]. Therefore, our results demonstrated an increasing in alpha absolute power over the learning blocks, which suggests a decreasing of the cognitive demands during the task, suggesting an indicative of motor learning[7,9,29]. Third, the motor learning produces changes in cortical activation, in other words, along the practice occurred an increasing in alpha power (slow and rhythmic) in premotor areas. Our hypothesis is that during planning to action occurr a comparison between elements pre stored, (i.e., implicit memory) and new parameters of the upcoming motor action, leading to a major acuracy and less cognitive effort[29]. The difference of processing between relevant and irrelevant tasks is probably facilitated by accumulation and storage of information in long-term memory[30], already the automation resulting of a decreasing in relationship between stimulus and answers and a reduction in information demand provides from the memory[10,12]. An increase in alpha absolute power after motor learning can be interpreted as a reduction of neuron activity in specified regions, indicating a neural specialization. In this sense, our results suggest that the increasing in alpha power on the learning control block in F4 electrode when compared with others demonstrate a learning consolidation, as observed in Figure 3. In this manner, the experimental model used showed an effective motor learning. Therefore, new investigations should replicate these findings maybe using new paradigms investigating other bands, as beta and theta due yours relationship respectively to motor and attention processes.

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