



Executive functions in undergraduate students enrolled in a creativity course

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ABSTRACT

Frontal lobes maturation begins in childhood and continues into adolescence and early adulthood, it is related with increased abilities in abstract reasoning, attentional shifting, inhibition and processing speed but these abilities are not always consolidated in undergraduate students and would be advisable to include activities that promote their development during schooling. This paper presents an analysis of the changes observed in executive functions in a sample of 16 college students after having taken a class called Applied Creativity, in which divergent thinking is encouraged. The assessment was performed in a pretest-posttest design using Battery Performance of Executive Functions and Frontal lobes (BANFE). The results indicated significant differences in the functions of metamemory, figurative and abstract understanding, all of them related with the anterior prefrontal region.

Keywords:

Prefrontal lobe, abstraction, cognition, BANFE, memory

RESUMEN

La maduración de los lóbulos frontales inicia en la niñez, continua en la adolescencia y en la adultez temprana, su desarrollo está asociado al incremento en razonamiento abstracto, cambios atencionales, inhibición, y velocidad de respuesta, sin embargo estas habilidades no siempre se han consolidado en estudiantes universitarios y existen actividades que podrían fomentar su desarrollo. En este trabajo analizamos los cambios observados en funciones ejecutivas en 16 estudiantes después de cursar la materia Creatividad Aplicada, donde se promueve el pensamiento divergente. La evaluación se realizó utilizando un diseño pretest-posttest con la Batería Neuropsicológica de Funciones Ejecutivas y lóbulos frontales (BANFE). Los resultados mostraron diferencias significativas en las funciones de metamemoria, pensamiento abstracto y comprensión del sentido figurado, todas ellas relacionadas con la región prefrontal anterior.

Palabras clave

Lóbulo prefrontal, la abstracción, la cognición, BANFE, la memoria

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EXECUTIVE FUNCTIONS IN UNDERGRADUATE STUDENTS ENROLLED IN A CREATIVITY COURSE

Cognitive control, the ability to guide thought and action according with internal intentions, lies at the heart of highest mental faculties that make us human, such as planning, reasoning, problem solving and language (Miller y Cohen, 2001). In relation to these processes, it is often heard that college students do not study, create or innovate much enough (Salas, Morales, Arévalo and Assael, 2012). Consequently, some students take decisions after a very little reflexive period, and their processes of searching choices seem to be null, opposite to what was expected in a creative behavior (Loli-Pineda, 2014). A person is considered to be creative when he breaks up the convergent thinking rigidity, giving great advantage to skills such as flexibility, fluency, originality, problem identification and elaboration (Bono, 1990).

The teaching-learning process at college education needs of approaching the academic knowledge application to the society contextual needs, which are in a constant growth. To achieve this, it is necessary for universities to pay attention on the creative competence, so then they will be able to form people who can easily apply new ways of thinking so as to find and work out trouble at different situations and context. On another hand, Guilford (1977), defines the qualities and characteristics of creative personality: flexible, fluid, original, sensitive, with skills of elaboration, transformation, analysis and summarizing. Thinking about supplying a creative thinking from the educational side implies the creation of a folded structure of rich and deep symbols in meaning and scopes (Rendon, 2012).

The creative competence is reached throughout the formative process and it is evaluated on a daily basis in behavior and in ways of facing and solving trouble that stop development as well as throughout a brain performance evaluation (Ardila, Rosselli, Matute and Guajardo, 2005) specifically from a set of functions called executive. Although Executive Functions (EF) are the result of the interaction of several cortical and subcortical brain regions (Gazzaniga, Ivry and Mangun, 2002; Munakata, Casey y Diamond, 2004) the most studied brain region is the prefrontal cortex. This region has the most recent phylogenic and ontogenic development. It is given an important role in activities such as creativity, the complex activity execution, the development of formal operations of thinking, social behavior, decision making and ethical and moral judgment.

In a research with RMIf, the images of a group of musicians playing learnt-by-heart notes were compared to another group while improvising (Limb y Braun, 2008). The results showed changes in prefrontal activity during improvisation that were accompanied by widespread activation of neocortical sensorimotor areas, this volitive inhibitional control in spontaneous compositions could be associated to the deactivation of areas responsible for planning and behavior regulation.

Moreover, these EF, take part in control, regulation and efficient planning of human behavior, letting the participans to get successfully involved in independent, productive and self-useful behavior (Lezak, Howieson, and Loring, 2004; Ardila and Surloff, 2007) including the ability to leak information which interferes with the task, getting involved in certain types of behavior directed to a goal; anticipate consequences of one's own actions and the concept of mental flexibility (Denckla, 1996; Goldberg, 2001; Luria, 1980; Stuss y Benson, 1986).

For a better appreciation of its own, the frontal cortex has been divided into these three following regions:

- The orbitofrontal cortex (OBC). It is tightly related in such an important way with the limbic system and therefore its main function is the processing and regulation of affective states and behavior (Damasio, 1994). At the same time, it is involved with the environmental changes detection that may be risky or beneficial, which allows to perform judgments on the behavior and on decision making at certain or uncertain situations (Elliot, Dolan, y Frith, 2000).
- The prefrontal medial cortex (PFMC). It takes part into the inhibition processes, conflict detection and solution, as well as into regulation and attentional effort (Badgaiyan y Posner, 1997). Additionally, it participates in aggression and motivational states regulations (Fuster, 2002).



The dorsolateral prefrontal cortex (DLPFC) is related to planning, working memory, fluency, complex problem solving, mental flexibility, hypothesis generation, work strategies, serializing and sequencing. The dorsolateral prefrontal cortex polar portions have been related with metacognition, allowing behavior self-evaluation and its control (Maril, Simons, Mitchell, y Schwartz, 2003); as well as social cognition, self-consciousness and knowledge (Stuss y Levine, 2000). The functioning of this area in particular is so basic for the development of creative thinking. Regarding the working memory, i.e. the capability that allows keeping and manipulating information in the attention deposit during brief time periods, Drubach (2007) reports that disfunctioning (by injuries) also affects the capability to create.

Attached to this, Martindale (Rendón, 2012) compares the electrophysiological data of participants that show a high creativity with others that show a low one at the performance of the same task and among its results it can be highlighted that the process of diffuse attention is associated with the creative thinking in contrast with less creative people who set too much of their attention and therefore the performance on these tasks is diminished.

On the other hand, in image studies (Koechlin y Hyafil, 2007), the prefrontal anterior cortex (PFAC) has been associated with the functions of new behavioral routine learning and the using of alternative exploring options to discard those that seem to be irrelevant for decision making (Gläscher, Adolphs, Damasio, Bechara, Rudrauf, Calamia y Tranel 2012); with task resolution that involve episodic memory (Reynolds, McDermott, y Braver, 2006); and besides, significant activity in this cortical area has been found when individuals are asked to multitask being able to postpone the execution of one task to work on the other one resisting the distractions and being able to come back to the first task without disturbing its execution (Gilbert, Spengler, Simons, Steele, Frith y Burgess, 2006).

Consequently, the EF variables and creativity seem to supply valuable information on the advantages of generating or eliciting the creative competence at college educational level both to contribute to contextual and communitarian problem solution and to the resolution of the own life issues. Thus, this research, pretended to link precisely the variable of creativity formation throughout an enrolled course at college, with the evaluation of the EF, with the purpose of determining whether there would be any differences at the executive function profile before and after the application a program designed to increase the level of divergent thinking.

The objective was to test if a systemically designed course to the development of creative competence would increase the score gotten in EF tasks of the orbitofrontal area.

Method

This research project was non experimental and used a pretest-posttest design to determine if there would be statistically significant differences on the EF of the participants before and after taking the college subject called *applied creativity*, and as a second objective, gender differences were searched.

Participants

The sample was formed by 16 college students living in the south-central area of Mexico, enrolled at University (UPAEP), with an age range between 18 to 21 years old and with a middle high socio-economic status.

The selection of the sample was made by a simple probabilistic way with a draw of the whole number of enrolled students in the programs of the college subject called *Applied Creativity* during the 2013 spring term.

At first stage, all picked out students at the draw were asked to come and a total number of 40 were evaluated.

The participants signed a letter of informed consent and a personal data confidentiality agreement was given according to the regulations of the college ethics committee for the research conducting. For

the second evaluation, the 40 students were asked to come once again; however, just a party of 16 showed up for the evaluation.

Instrument. The Neuropsychological Battery of the Executive Functions and Frontal Lobes (BANFE) (Flores, Ostrosky and Lozano, 2008). It is structured starting from a test selection that were chosen and decided based on the autonomous-functional criterion (Table 1).

Table 1

Psychological functions evaluated with BANFE (from Flores, Ostrosky y Lozano, 2008)

METAFUNCTIONS Anterior Prefrontal Cortex (PFAC)	<ul style="list-style-type: none"> • Metamemory • Figurative sense comprehension • Abstract attitude
EXECUTIVE FUNCTIONS Dorsolateral Cortex (DLPFC)	<ul style="list-style-type: none"> • Verbal fluency • Productivity • Mental flexibility • Visuospatial planning • Sequential planning • Inverse sequencing • Codification control
WORK MEMORY Dorsolateral (DLPFC)	<ul style="list-style-type: none"> • Visual self-directed work memory • Verbal work memory - ordering • Visuo-spatial-sequential work memory
BASIC FUNCTIONS Orbitomedial (OBC y PFMC)	<ul style="list-style-type: none"> • Inhibitorial control • Rule following • Risk-benefit processing

The college subject called *Applied Creativity* is a course oriented to let them know the background and conceptual bases of creativity, its processes, media, products and implications on people as well as to show the different areas at which creativity is portrayed, all this by asking the students develop innovative proposals in their field disciplines where they can apply creativity concepts and techniques to significantly transform their environment and bring in original solutions to problems regarding their profession with respect and recognition to the existing diversity.

The electronic book which this course is based on is: “*Creatividad aplicada: competencias universitarias para profesionales del futuro*” whose link is: <http://www.elaleph.com/libro/Creatividad-Aplicada-Competencias-universitarias-para-profesionales-del-futuro-de-Adriana-Nachieli-Morales-Comp/660720/>

This course is divided into four modules whose most important topics are: creativity definition and the steps of the process of creating: incubation, illumination, elaborating and communication of results, cognitive functions according to Tony Buzan principles, types of thinking and forms of develop them, multiple intelligences theory and activities to improve them. This course has the objective of work a creative project out related to all these characteristics.

Results

The results obtained in the evaluation of the EF made after the four-month course *Applied Creativity* are described in detail below.

Students showed a qualitative increment at the scores gotten in the executive functions corresponding to the dorsolateral areas (DLPFC) and anterior prefrontal (PFAC) and a decrement at the task regarding the Orbital Medial Prefrontal Cortex area (OMPC).



Nevertheless, at applying the analysis with the *T Wilcoxon test* for related samples, it was just found significant difference ($p=0.002$, $gl=15$) at the general performance of tasks regarding the anterior prefrontal areal (PFAC) before and after having coursed the college subject *Applied Creativity* (Figure 1).

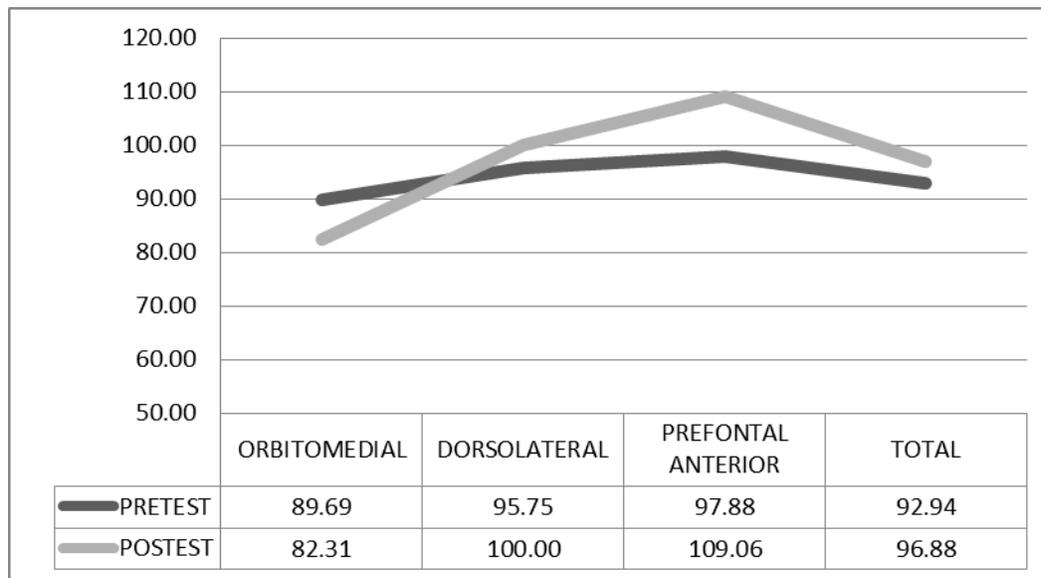


Figure 1. Pretest-Posttest comparison of the whole sample. Numbers indicate mean score obtained in each area tested

This difference highlights a general increment at the scores of students in activities regarding metamemory, figurative sense comprehension and abstract capability.

Moreover, in relation to the specific analysis of those scores (of the single tasks) with the Wilcoxon test, it was found that this difference was significant at the scores of the positive error ($p = 0.016$), i.e. in metamemory that is, the capability to make predictions based on the monitoring of their own performance. Thus, to the instruction of learning nine words, at which students are also asked to predict the number of those which they could evoke at each of the five trials; it is considered to be a positive error when the person predicts more than those which are really learnt. After the course, these predictions were more realistic.

Furthermore, the comparison of means between men and women was done and it was found that with a $sig.=0.043$, there is significant difference on the pretest, in the functions regarding the area of the OMPC, being observed that after having taken the course, this difference is faded.

The task analysis also underscores the fact that the processing and regulation of emotions and behavior likewise the capability to evaluate the cost-benefit analysis for OMPC were better for women before the course (mean= 97.44), decreasing after it (mean= 83.78).

Additionally, apart from this, in both men and women, tasks of trouble attention, inhibition, detection and solution as well as motivational stages PFAC got better scores right after the course (Figure 2). Although, according to the applied Chi-squared test, significant differences were not found between the pretest and the posttest divided by gender.

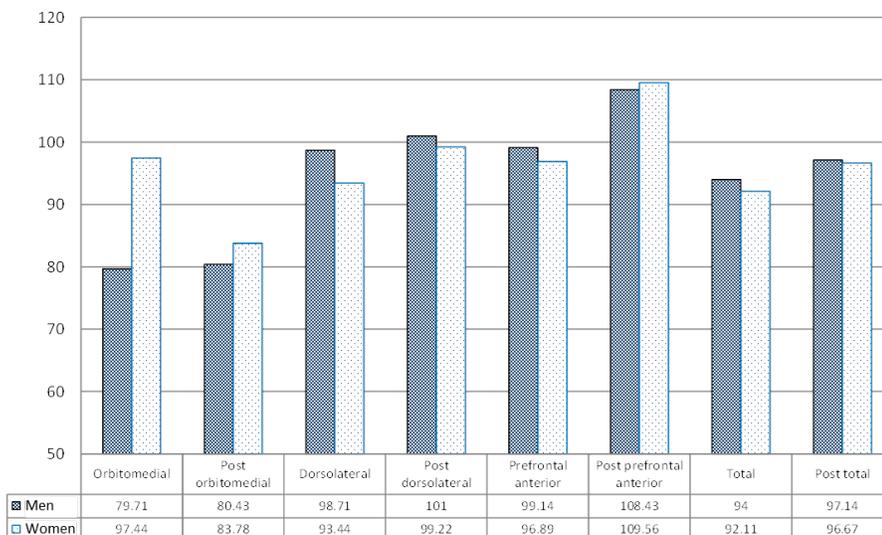


Figure 2. Pretest-Posttest comparison between men and women.

Discussion

According to the stated objective, in this research project, statistically significant changes were observed in some EF of students before and after having taken the college subject called *Applied Creativity*. Especially, an increment was observed on those abilities related to the anterior prefrontal area (PFAC) such as, the capability to develop a memory strategy (metacognitive control), additionally to make performance prediction judgments (metacognitive judgments) and adjustments between performance judgments and real performance (metacognitive monitoring); these processes also allow the comprehension of the figurative sense and a better abstract attitude (Lozano and Ostrosky, 2011).

The comprehension of the figurative sense is also an anterior prefrontal ability. This goes beyond the linguistic, semantic and syntactic comprehension, due to the fact that it requires active work to figure out a meaning that comes along with the verbal message (Luria, 1980; Nippold, Martin, and Erskine, 1998); this goes tightly linked with being able to interpret information so as to find out the sense or depth of words.

Changes observed could be associated to the activities done during the course, since it has as one of its goals to exercise the generic competence of autonomy, promotes that each and every student self-evaluates his own capabilities at goal reaching and set tasks letting them to be consistent of their own resources (De Prado, 1996) thus, this competence seems to be generating functional modifications on the PFAC.

Is important to mention that even when one of the objectives of the course was to endorse cognitive flexibility, those mechanisms didn't show any significant differences even when they were expected (Chavez-Eakle, Graff-Guerrero, García-Reyna, Vaugier and Cruz-Fuentes, 2007). However it is necessary to increase the sample and tasks to measure cognitive flexibility.

Additionally, divergent thinking, stressed out in the subject *Applied Creativity*, promoted a wider view on every subject or problem case set in class during the course letting them find facilitating edges of a global comprehension. This is how this way of thinking improved the figurative sense comprehension. Nevertheless, even statistically significant changes were not found at comparing scores, it is very likely that this improvement will be consolidated in the future as divergent thinking is cultivated.



Finally, the increment at abstract task scores may be the result of the course emphasis on the development of the creative process at its different stages where they existed with the integration tasks of multiple inferences (perceptual and semantic) to pick out the most appropriate global answers (based on characteristics in common) that replies back with the activation of the PFAC area that is associated with the abstract reasoning (Gilbert, Spengler, Simons, Steele, Frith and Burgess, 2006).

It is extremely important to consider the small size of the sample in this study and the circumstances at which work went on during the taking of this college subject called *Applied Creativity* because all students were under the pressure of participating in a contest. Nonetheless, the obtained results in this study are just a sample of the possibilities that this college subject has in order to help participants with the development of their executive functions.

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