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RELACIÓN ENTRE LAS FUNCIONES EJECUTIVAS Y EL RENDIMIENTO ACADÉMICO EN ESTUDIANTES DE PSICOLOGÍA

Relationship between executive functions and academic performance in psychology students

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KEYWORDS

Executive functions
Inhibitory control
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Academic performance

ABSTRACT

Executive Functions (EF) (Working Memory, Inhibitory Control, and Cognitive Flexibility) have been associated with Academic Performance (AP). A non-experimental, correlational study was conducted to analyze the predictive relationship between EF and AP in 185 psychology students, selected through a non-probabilistic sampling. The following evaluation applications were utilized: Continuous Attention Test, Visuospatial memory test, Wisconsin Card Sorting Test Variant, Stroop Effect - Colors Game. The results showed a direct positive effect of working memory and inhibitory control and a negative effect of cognitive flexibility on AP. It might be concluded that EF have a low level of prediction on AP.

PALABRAS CLAVE

Funciones ejecutivas
Control inhibitorio
Memoria de trabajo
Flexibilidad cognitiva
Rendimiento académico

RESUMEN

Funciones Ejecutivas (FE) (Memoria de Trabajo, Control Inhibitorio y Flexibilidad Cognitiva) están asociadas con el Rendimiento Académico (RA). Constituye un estudio no experimental, correlacional que relaciona la FE y RA en 185 estudiantes de psicología, seleccionados muestreo no probabilístico. Se aplicaron las pruebas de atención continua, memoria visuoespacial, variante del test de clasificación de tarjetas de Wisconsin, Juego de colores- efecto Stroop. Los resultados mostraron un efecto positivo entre memoria de trabajo y control inhibitorio y negativo de la flexibilidad cognitiva sobre el RA. Se puede concluir que la FE tiene un bajo nivel de predicción sobre el RA.

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1. Introduction

Executive Functions (EFs) consist of a constellation of higher-order cognitive functions related to the planning of goal-oriented behavior. Muriel Lezak (2004) defines them as "the mental capacities needed to formulate goals, plan how to achieve them, and carry out that plan effectively." The latter includes a series of cognitive processes such as working memory, planning capacity, inhibition, and cognitive flexibility.

According to Miyake's theoretical model (Miyake et al., 2000) based on structural equations, three factors integrate the unity and diversity of EFs ("updating," "inhibition," "shifting"). The first factor is known as working memory (WM) and consists of a temporary storage system that allows the control, maintenance, and updating of information (Baddeley & Hitch, 1974). Inhibitory Control (IC) allows the suppression of previously activated cognitive content and the resistance to the interference of stimuli that capture attention (Bjorklund & Harnishfeger, 1995). The third component, called Cognitive Flexibility (CF), refers to regulating attention and the course of action according to environmental demands (Lezak 2005; Stuss & Alexander, 2007). Specifically, it has been found that WM requires the activation of the dorsolateral prefrontal cortex (Sherwood et al., 2016), the IC, the pre-supplemental motor area and the inferior frontal gyrus (Simmonds et al., 2008), the CF of medial prefrontal and lateral areas, as well as the lower operculum (Taylor et al., 2007), which are processes and structures that do not finish reaching their full maturation until adulthood.

People who present an Academic Performance (AP) below the desired level have implications at personal, social, family, and educational areas (Strauss et al., 1982). Other factors that have been decisively related to AP have been age, socioeconomic status, and daily study hours (Ali et al., 2013). Some variables that seem to modulate the previously obtained results appear to be EFs; since it is associated with the degree of attainment of goals in the educational area and is related to professional success (Schmidt, 2017).

It is necessary to investigate the relationship between EF and AP since from the educational systems and professionals it is required to know elements that allow intervention, both, in activities that promote the optimal development of EF and in the event of academic difficulties to reduce poor academic performance as well as future economic and social implications (Amador & Krieger, 2013; Sánchez & García, 2014).

Previous studies have shown the relationship between EFs and learning difficulties in reading, and writing (Graham, 1997; Mclean & Hitch, 2001; Mirmehdi et al., 2009). St. Clair-Thompson and Gathercole (2006) consider that WM, IC, and CF are directly related to AP in subjects such as English. Other research aimed at improving students' EFs by training in tasks that demand the WM and IC of the response has shown that they can be helpful to elements for improving AP (Mokhtar & Aghababaei, 2013). According to Castillo-Parra et al., (2009), EFs allow students to be differentiated ac-cording to their AP level, and WM can be used to identify those with a higher level.

At the university level, it has been shown that learners studying psychology and presented with problems in executive functioning had lower AP and perception of more serious difficulty in handling the problems of their daily lives (Petersen et al., 2006). In addition, a decrease in variables such as attention and problem solving has been directly linked to lower AP (May et al., 2015).

For their part, Prosen and Vitulic, in 2014, after using the instrument Executive Skills Questionnaire for Students, found that the EFs of planning, attention, and CF are essential skills for achieving an excellent academic goal. In a systematic review, studies showed that the main EFs involved in the AP of university students is WM and, to a lesser extent, planning skills, IC, and CF (Besserra-Lagos et al., 2018). In another investigation based on an adult non-university sample (age range 18-25 years old) after applying the Stroop test and the digit test in direct and inverse order of the Wechsler scale, AP was strongly linked to WM a lesser extent to IC (Casas-Ortiz, 2013). Similarly, Van der Ven et al., (2012) confirm that AP is related to WM, but not to IC and CF, which are contradictory to those found by Espy et al., (2004) who states that AP has a stronger association with IC to WM and CF.

To determine which EFs are predictors of AP, Gutiérrez-Ruiz et al., (2020) by means of a correlational analysis study, applied the Wisconsin classification cards test, the Stroop test, the direct and inverse order digit test of the Wechsler evaluation battery and demonstrated that WM and CF are predictors of general AP. On the other hand, Dubuc et al., (2020) questioned the role of WM and IC since they

represent a limited predictive capacity for AP. Even research studies indicate that the AP of university students is not directly related to the EFs (Barceló et al., 2006; Pérez, 2019), which highlights the need to increase the number of studies that indicate the specific relationships between both constructs (Stelzer & Cervigni). Based on these data, the interest in analyzing the executive factors related to AP is supported, since determining the possible existing relationship can influence the improvement of reinforcement and early intervention programs to identify and strengthen cognitive capacities (Gardner, 2009).

For this reason, this study aims to analyze the predictive relationship between EFs and AP in psychology students.

2. Materials and Methods

2.1. Participants

A non-experimental, correlational, cross-sectional study was carried out. The re-search complied with the ethical code for research with human beings of the Helsinki Declaration. The population consisted of 417 students enrolled in Clinical Psychology at the National University of Chimborazo (Riobamba, Ecuador). A non-probabilistic convenience sampling was used for the sample selection since the participants had access to the institution. Two hundred and forty-seven participants completed a questionnaire to assess the EFs and AP. The inclusion criteria to participate in the study were to be enrolled in the Clinical Psychology course in the academic period May-September 2020 and sign the informed consent. All participants were confined during the academic semester and participated in the virtual teaching and learning process due to the Covid-19 pandemic. Participants were excluded if they had a chronic neurological condition, had suffered from a neurological pathology in the last three months, or had clinically relevant residual psychopathological disorders that could influence the current results and if they were taking medications that could affect cognitive performance. In addition, 62 participants were excluded because of missing data.

After applying the criteria above and filtering the data, a final sample of 185 participants was obtained, 45.32% of whom were students from the province of Chimborazo (Ecuador), predominantly right-handed, with a mean age of 20.66 years, minimum of 18, and a maximum of 28. There was a higher proportion of cases belonging to the female gender (74.61%), presumably because they tend to choose to study psychology to a greater extent and 58.27% of the students were part of the first, second, ninth semesters, so there is a lack of representation in the other semesters.

2.2. Procedure

The research project was approved by the Institute of Science, Innovation, Technology and Knowledge (ICITS) of the National University of Chimborazo. First, the Clinical Psychology program secretary was asked for the e-mail addresses of currently enrolled students. To get access to this information, authorization was obtained from the dean of the Faculty of Health Sciences. Next, a questionnaire was designed on the Microsoft Forms platform, as the entire university community uses it. It was designed by a researcher and supervised and corrected by the project director. The questionnaire consisted of different questions (open-ended, Likert-type, etc.) whose purpose was to record sociodemographic information, the scores obtained in the EFs tests, and the AP. Once the feasibility and operability of the questionnaire were guaranteed, one of the researchers recorded a video in which the objective of the research was briefly explained, and instructions were given on how to carry out the different tests. All the students gave their informed consent by completing and uploading their digital signatures to the questionnaire on the Microsoft Forms platform.

Due to the impact of the Covid-19 pandemic, the neuropsychological assessment process was carried out using a cell phone and downloading a series of applications as an indispensable element for obtaining data. It was indicated that only the data obtained during the first application of each test were valid.

The evaluation was carried out contingently to complete the previous exam period in a time interval between June and July 2020 and was performed in a self-administered way.

The assessment procedure was as follows: first, students downloaded the Stroop Effect - Colors Game, followed by the Visuospatial memory test using mobile application, Tower of Hanoi, then the Wisconsin Card Sorting Test (WCST) Variant: Cards, and finally, the continuous attention test. All participants uploaded to the Microsoft Forms questionnaire; the evidence of the results was obtained using a screenshot. Subsequently, the students recorded their AP, AP level, and the perception of the influence of COVID-19 on AP. Several e-mails were sent on different occasions to remind those students who had not completed the tasks.

2.3. Tools

The mobile Apps were selected based on the adequate reliability and internal con-sistency of the instruments they use.

Continuous Attention Test

It is an application developed by the Neurorehabilitation and Brain Research Group (2019) and based on the "continuous performance test" software that allows the evaluation of attention based on a series of measures such as IC, impulsivity, vigilance, inattention, sustained attention (Conners, 2004). The task requires the participant to press the space key whenever the letter "X" does not appear. It lasts approximately 5 to 10 minutes and can be helpful for the diagnosis of attention problems, such as in patients with attention deficit and hyper-activity disorder. The variables used for its coding were the following: omissions, com-missions, standard error, variability, perseverations, reaction time along with the stimulus blocks, change in reaction time produced by inter-stimulus blocks, and standard error in the change produced during the inter-stimulus reaction time.

Visuospatial memory test

It is an application developed by the Neurorehabilitation and Brain Research Group (2019). based by the Wechsler Memory Scale (Wechsler, 2004) and the Corsi Block-Tapping Test (Corsi, 1972). It consists of users repeating sequences of blocks in the same order as they appear on the screen (direct order condition) or, on the contrary, playing them backward (reverse order condition). It is a test that assesses visuospatial WM (Wechsler, 2004). Participants were asked to per-form the test by choosing the "full" option and placing their device under a horizontal orientation. The variables coded for both conditions were as follows: correct sequence, wrong sequence, omissions, reaction time, perseverations, and percentile score.

Wisconsin Card Sorting Test (WCST) Variant: Cards

Mobile application developed by Metatrans Apps (2020), based on the original design by Grant and Berg (Grant & Berg, 1948). It is a test that consists of presenting a series of cards (60), which the subject must match according to a series of cards presented as a model. These can be associated according to the color, number, and shape of the elements. It is considered a test that assesses CF, reasoning, and problem-solving processes, being sensitive to frontal lobe damage (Lezak, 2004). The following variables were considered for its recording: number of correct and incorrect responses and reaction time.

Stroop Effect – Colors Game

Application designed by Sánchez (2020) to assess IC, resistance to interference. The test consists of naming the print color of the color names, ignoring the verbal content when the verbal content is never congruent with the print color, which is called the Stroop effect (Stroop, 1935). In the test, it was established by default that the exposure time of each stimulus would be one second, and the game mode

is by time. The test was divided into two subtests according to the level of difficulty (easy and intermediate).

In the first condition, the subject must determine whether the word is written in the same color as the color in which it is painted, and in the second condition, the subject must point out only the color of the word. The variables selected were the number of correct answers, number of incorrect answers, and total score in both conditions.

The tests used to measure EFs in university students include variables related to the ability to process visuospatial information, which is considered as the ability to perform automatic tasks (Ball et al., 2004).

Academic performance

The AP was evaluated by obtaining the academic average of all the subjects taken be-fore the assessment process, and its values were on a scale of 1 to 10. The level of AP [(0-5.9=sufficient; 6-7.9=acceptable; 8-8.9=Notable; 9-10=excellent)] and the perception of the influence of Covid-19 on AP were recorded as additional variables on a measurement scale of 1 to 10, in which the higher the score, the greater the degree of influence of this situation on AP.

2.4. Statistics Analysis

Initially, a sample of 247 data was obtained corresponding to the number of students who had recorded their scores on the questionnaire. The data matrix was refined to detect possible errors in the data entry process. Missing data were reviewed, and all cases with incomplete data were analyzed and eliminated as this is a statistical exclusion criterion for structural equation analysis. After applying data imputation methods, a base with a higher level of purification was obtained, consisting of 185 participants. Descriptive statistics for each variable observed in the model and multivariate normality tests were per-formed to evaluate the underlying statistical assumptions of the SEM estimation methods.

Subsequently, AMOS, an extension of SPSS, version 25, was used to applicate the structural equation model (SEM) based on a series of endogenous (AP), latent (different EFs such as WM, IC, and CF), and observable (variables inherent to each mobile application) variables, with their respective measurement errors. A series of inferential estimations were run. The indexes were modified in the properties of the analysis. Subsequently, an analysis of the covariance between the errors attributed to some of the variables was performed.

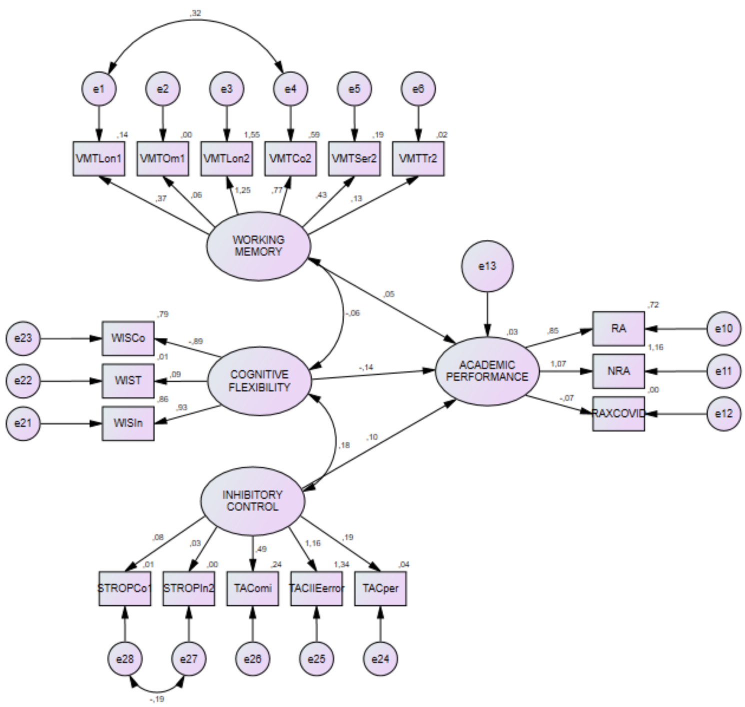
3. Results

To analyze the type of causal relationships between the variables, a SEM was applied, as shown in Figure 1. The statistical procedure includes 39 variables, of which 17 were observed, 22 unobserved, 21 exogenous, and 18 endogenous. An endogenous latent variable (AP) defined by a series of direct indicators and three latent variables (WM, CF, and IC) based on different observable variables are presented. The error terms associated with the endogenous variables represent the prediction error. The purpose was to deter-mine the magnitude of the direct and indirect effects of EFs on AP, based on a series of variables. The method used for parameter estimation was a Maximum Likelihood since it provides consistent estimates, low bias and allows estimation of the variables in the absence of normality (Rial et al., 2006).

The modification indexes provided by the program have suggested incorporating into the model the covariance relationships between the items "number of correct responses in the first condition" and "number of incorrect responses in the second condition" of the Stroop Effect - Colors Game since in the first condition automatic processes are required. In contrast, there is greater involvement of the interference phenomenon in the second condition, where previously learned responses must be inhibited so that both aspects are related. This analysis was also carried out for the items "error commissions" and "length of the number of items" of the Visuospatial memory test. This association is logical from a conceptual point of view since the more significant the length of items in a learning and memory task, the greater the error commissions.

As it can be seen, the EFs variables have a direct positive effect on AP (IC and WM), compared to EFs, although it is the one with the most significant weight in the explanation of AP. The multiple correlation analysis indicates that IC can forecast the 10% (R2= 0.10) of the variance of AP, while CF predicts the -14% (R2= - 0.14) of the negative variance of AP. In the case of bidirectional influences between CF and IC, a positive regression coefficient was found (β= .18), and a negative coefficient between CF and WM (β= -.06), which shows that the more alteration there is in one latent variable, the more difficult it is to obtain a positive result in the other. Bidirectional relationships between WM and IC have been omitted.

Figure 1. Estimated parameters of the EFs and AP according to SEM**.**



Fuente: Manuel Cañas Lucendo, 2022

Concerning WM, it is observed that the items that contribute most to the configuration of WM are length (VMTLong2), the number of right sequences (VMTCo2), and the number of wrong sequences (VMTSer2), number of reaction time (VMTTr2) under the re-verse order condition of the Visuospatial memory test, with factor loadings of 1.25 (0.77 0.43 and 0.13 respectively). The relationships between variables are shown in Table 1.

In the case of the EFs, the observable variable with the highest factorial weight (.93) is the number of incorrect responses (WISIn). In contrast, the number of correct responses has a negative regression coefficient (β= -.89), both belonging to the Wisconsin Card Sorting Test (WCST) Variant: Cards.

Concerning IC, it is observed that the variables of change in inter-stimulus reaction time (TACIIEerror) produce the highest factor loadings (1.16), together with the number of omissions (TAComi) of the continuous attention test, (.49) in comparison with the number of incorrect responses of condition 2 of the Stroop Effect - Color Game (.03).

With respect to AP, the observable variables with the highest level of factorial contribution have been the AP level (NRA) and the average AP score (1.07 and .85), compared to the item assessing a possible influence of the Covid-19 situation (RAXCOVID) on AP which shows a negative regression coefficient of low level of intensity (β= -.07).

Table 1. Relation among variables.

Correlated variables	Regresion Values	Standardized regression values		
	Estimation	**EE**	**CR**	**Estimation**
APL – AP	1.03*	.17	6.05	1.07
WM - AP	.038*	.021	1.81	.47
IC - AP	.07*	.05	1.42	.96
CF - AP	-.15*	.09	-1.74	-.137
VMTLon2 – WM	3.28*	.53	6.16	1.25
VMTCo2 – WM	3.11*	.42	7.40	.77
VMTSer2 – WM	.60*	.11	5.38	.43
VMTTr2 – WM	116.75*	32.00	3.64	.13
WISCo – CF	-.68*	.10	-6.70	-.89
TAComi - IC	1.49*	,51	2,91	,49
TACIIEerror -IC	.02*	.01	1.83	1.16

Abbreviations: AP, Academic Performance; APL, Academic Performance Level; CF, Cognitive Flexibility; CR, Critical Ratio; EE, Estimation error; IC, Inhibitory control; TAComi, number of omissions of the continuous attention test; TACIIEerror, change in inter-stimulus reaction time of the continuous attention test; VMTLon2, Visuospatial Memory Test Length 2 (reverse order version); VMTCo2, Visuospatial Memory Test Correct Sequences 2 (reverse order version); VMTSer2, Visuospatial Memory Test Error Sequences 2 (reverse order version); VMTTr2, Visuospatial Memory Test Reaction Time 2 (reverse order version); WISCo, number of correct responses of the Wisconsin Card Sorting Test (WCST) Variant: Cards; WM, Working Memory; *, significant value of statistical probability (p<.05).
Fuente: Manuel Cañas Lucendo, 2022

It should be noted that all the estimated parameters are significant, and the fit of the structural equation to the empirical data is acceptable, as revealed by the fit indices com-pared to the expected indices, as shown in Table 2.

Table 2. SEM fit indexes and expected indexes.

Indexes	χ^2	**NFI**	**CFI**	**TLI**	**RMSEA**
Expected	>.05*	.9-1	.9-1	.9-1	.05-.08
Obtained	175.2*	.889	.956	.947	.055

Abbreviations: CFI, comparative fit index; TLI, non-standardized fit index; NFI, normalized fit index; P, statistical probability; RMSEA, Root mean square error of approximation; χ^2, Chi-square statistic; *, significant value of statistical probability (p<.05).
Fuente: Manuel Cañas Lucendo, 2022

4. Discussion and Conclusions

The detection of characteristics predictive of AP has been a topic of interest for decades. In recent years, EFs has emerged as a reliable predictor of AP (St. Clair-Thompson & Gathercole, 2006). The test of EFs have limited validity and reliability as measures of WM, CF and IC have limited influence on students' AP, any study findings should be made with caution. Multiple regression analysis has shown that variables measuring WM are less associated with AP than IC and CF. In the same direction, Dubuc, et al., (2020) reported a weak association between WM, IC, and AP, and therefore have limited predictive capacity. Although variables such as element length, the number of correct and incorrect sequences contribute decisively to WM, this concept has shown minimal significant prediction with AP, is about what is expected as short-term visual recall is not expected to have much influence on university student' assignment or essay writing.

However, previous studies affirm that WM is strongly related to the learning process and, therefore, AP in childhood, adolescence, and university stage (Besserra-Lagos et al., 2008; Ramos et al., 2018; Simone et at., 2018). It is assumed that the ability to update information in WM continuously is associated with the academic performance of university students (Wiest et al., 2020). The discrepancy in the results obtained might be because many research studies have used self-report measures, and no studies use mobile application to measure EFs. Since other studies have demonstrated the relationship between the WM and high levels of AP (Castillo-Parra et al., 2009), implementation of neurocognitive training exercises to enhance verbal and visuospatial aspects of WM is considered useful. The inclusion of this type of active methodologies could increase students' level of intelligence (Mokhtar & Aghababaei, 2013).

Other variables such as "omissions" and "change of reaction time at different inter-stimulus interval standard error" of the continuous attention test have contributed to IC, which has been a factor directly related to AP. Nevertheless, our results agree with the authors who consider that IC has little explanatory power for AP (Casas-Ortiz, 2013). Our findings are related to those obtained by Espy et al., (2004) who state that AP is more strongly associated with IC than WM and CF. This research work contributes to the study of this association in the Ecuadorian university population.

Currently, students face a multitude of existing stimuli from different interactive de-vices, so it is a crucial aspect to maintain control of selective and sustained attention, ignore possible distractors and minimize interferences which are aspects related to the IC. In this sense, low levels of HF in childhood and adolescence could be associated with a lower level of AP in adulthood (Besserra-Lagos et al., 2018). For this reason, it is important to carry out neuropsychological evaluations at different evolutionary moments of the teaching and learning process to determine the degree of achievement of the IC and its possible impact on the AP.

The SEM has also shown that variables such as the number of correct and incorrect answers of the Wisconsin Card Sorting Test (WCST), despite contributing to the CF factor, have a very weak and negative association with the AP so that a decrease in CF is associated with better scores in the AP. This would imply that switching between mental sets would not be a very useful strategy to generate adaptive responses and facilitate problem-solving in the educational setting. The hypothesis that CF is not predictive of AP has already been confirmed by other authors (Barceló et al., 2006).

The SEM results indicate bidirectional relationships between WM and CF of a negative nature and positive relationships between IC and CF; WM facilitates attentional processes such as IC and is associated with CF through new solutions to problems, situations inherent during the teaching and learning process (Prosen & Vitulić, 2014). Information processing speed is a subcomponent of cognitive functioning (Edwards et al., 2009; Kail & Salthouse, 1994). Ríos, et al., (2004) mention that executive control requires high-level processes such as IC, WM, and CF; in addition to others of low level such as the information processing speed.

On the other hand, Pineda, et al., (2000) established a factorial structure in a population of university students, reporting an explanatory variance of the construct in which CF represented 26.6%, CI 15.1% and processing speed 19.7%. Thus, these are considered interrelated components of EFs.

Obtaining data about the university students' FE will allow us to make a diagnosis of those who present difficulties in WM, IC, and CF processes, etc., to design intervention programs to consolidate these processes which in turn will minimize new curricular difficulties and promote student's success.

Future research could be based on the use of longitudinal designs to establish at which moments of the teaching and learning process the EFs has a higher level of prediction and in which types of subjects there is a more significant relationship. It is considered relevant to replicate this

SEM with larger sample size and use other geographic locations to determine whether there may be significant differences. Besides, three executive factors were included.

However, it would be relevant to include other variables such as planning, verbal fluency, and decision-making. In addition, the present study did not include other variables such as age or gender or the social and economic level which have been shown to have a modulating effect on the explanation of AP, nor has there been a randomized se-lection of the study sample.

The brief self-administered cognitive function mobile assessments, conducted in everyday life settings, are a promising complementary tool to traditional assessment approaches (Moore et al., 2017). The application of these tools guarantees ecological validity to evaluate aspects inherent to attention, WM and EFs (Schweitzer et al., 2017).

In relation to the purity of the EFs assessment test, the task is activated by various executive components, in addition to other non-executive functions, which makes it difficult to measure the specific variance in these functions. In this regard, the latent variables approach was used, based on the selection of tasks and variables through the SEM that in-crease purity (Miyake & Friedman, 2012).

Baggetta, and Alexander (2016) used different tests and variables to measure the WM, IC, and CF components, avoiding a one-dimensional perspective of the EFs with a higher level of reliability in the results. For future evaluations, the authors of this research recommend the inclusion of a greater number of tests with different approaches, coinciding with the criterion of Spiegel, et al. (2021).

In the research context, the findings allow us to conclude that the assessment of EFs using WM, IC, and CF has a limited level of prediction of AP in university students.

5. Thanks

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References

Ali, S., Haider, Z., Munir, F., Khan, H., & Ahmed, A. (2013). Factors Contributing to the Students Academic Performance: A Case Study of Islamia University Sub-Campus. *American Journal of Educational Research*, *1*(8), 283-289. Doi: 10.12691/education-1-8-3.

Amador, J., Krieger, V. (2013). TDAH, funciones ejecutivas y atención. Universidad de Barcelona.

Baddeley, A.D., & Hitch, G.J. (1974). Working memory. In BGA Editor (Ed.), *The psychology of learning and cognition* (pp. 1-13). Academic Press.

Baggetta, P., Alexander, P.A. (2016). Conceptualization and Operationalization of Executive Function. *International Mind, Brain, and Education Society and Wiley Periodicals*, *10*(1), 10–33. Doi:10.1111/mbe.12100

Ball, K. K., Wadley, V.G., Vance, D.E., & Edwards, J.D. (2004). Cognitive skills: training, maintenance and daily usage. In SCD Editor (Ed.), *Encyclopedia of Applied Psychology* (pp. 387-392). Elsevier Academic Press.

Barceló, E., Lewis, S., & Moreno, M. (2006). Funciones ejecutivas en estudiantes universitarios que presentan bajo y alto rendimiento académico. *Psicología desde el Caribe*, (18), 109-138.

Besserra-Lagos, D., Lepe-Martínez, N., & Ramos-Galarza, C. (2018). Las Funciones Ejecutivas Del Lóbulo Frontal Y Su Asociación Con El Desempeño Académico De Estudiantes De Nivel Superior. *Revista Ecuatoriana de Neurología*, *27*(3), 51-56.

Bjorklund, D.F., & Harnishfeger, K.K. (1995). The evolution of inhibition mechanisms and their role in human cognition and behavior. In D.F.N., & B.C.J., Editor (Eds.), *Interference and inhibition in cognition* (pp. 142-169). Academic Press.

Casas-Ortiz, S. (2013). *Relación entre las Funciones Ejecutivas y el Rendimiento Académico en la educación de Adultos*. [Tesis de Máster, Universidad Internacional de la Rioja]. https://reunir.unir.net/bitstream/handle/123456789/1982/2013_07_23_TFM_ESTUDIO_DEL_TRABAJO.pdf?sequence=1%26isAllowed=y.

Castillo-Parra, G., Gómez, E., & Ostrosky-Solis, F. (2009). Relación entre las funciones ejecutivas y nivel de rendimiento académico en niños. *Revista Neuropsicología, Neuropsiquiatría y Neurociencias*, 1, 41-54. Doi: 10.17151/hpsal.2016.21.2.4.

Conners, C.K. (2004). Conners` Continuous Performance Test (CPT II). Version 5 for Window, Technical Guide and Software Manual. Multi-Health Systemes Inc.

Corsi, P.M. (1972). *Human memory and the medial temporal region of the brain*. McGill University.

Dubuc, M.M., Aubertin-Leheudre, M., & Karelis, A.D. (2020). Relationship between interference control and working memory with academic performance in high school students: The Adolescent Student Academic Performance longitudinal study (ASAP). *Journal of Adolescence*, 80, 204-213. Doi: 10.1016/j.adolescence.2020.03.001

Edwards, J.D., Delahunt, P.B., Mahncke, H.W. (2009). Cognitive speed of processing delays driving cessation. *J Gerontol A Sci Med Sci, 64*, 1262-67. Doi: 10.1093/gerona/glp131.

Espy, K., McDiarmid, M., Cwik, M., Stalets, M., Hamby, A., & Senn, T. (2004). The contribution of executive functions to emergent mathematics skills in preschool children. *Developmental Neuropsychology*, 26, 465-486. Doi: 10.1207/s15326942dn2601_6.

Gardner, J.K. (2009). Conceptualizing the Relations between Executive Functions and Self-Regulated Learning. *J Psychol, 143* (4), 405–426. Doi: 10.3200/JRLP.143.4.405-426.

Graham, S. (1997). Executive Control in the Revising of Students with Learning and Writing Difficulties. *Journal of Educational Psychology*, 89, 223-234. Doi:10.1037/0022-0663.89.2.223

Grant, D.A., & Berg, E.A. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of Experimental Psychology, 38*(4), 404-411. Doi: 10.1037/h0059831.

Gutiérrez-Ruiz, K., Paternina, J., Zakzuk, S., Méndez, S., Castillo, A., Payares, L., Peñate, A. (2020). Las funciones ejecutivas como predictoras del rendimiento académico de estudiantes universitarios. *Psychology, Society & Education, 12* (3), 161-174. Doi:10.25115/psye.v12i3.2103.

Kail, R., Salthouse, T.A. (1994). Processing speed as a mental capacity. *Acta Psychol*, 86, 199-225. Doi: 10.1016/0001-6918(94)90003-5.

Lezak, M. (2004). Executive Functions and Motor Performance. In M.D., Lezak, D.B., Howieson & D.W., Loring (Eds), *Neuropsychological Assessment* (4th ed., pp. 611–646). Oxford University Press.

May, R.W., Bauer, K.N., Fincham, F.D. (2015). School burnout: Diminished academic and cognitive performance. *Learning and Individual Differences*, 42, 126-131. Doi:10.1016/j.lindif.2015.07.015.

Mclean, K., & Hitch, J. (2001). Executive functions in student with and without mathematics disorder. *J. Learn. Disabil*., 30, 214–225.

Metatrans Apps SA. (2020). *Wisconsin Card Sorting Test (WCST) Variant: Cards.* [mobile app]. Google Play. https://play.google.com/store/apps/details?id=com.wisconsin&hl=es_419.

Mirmehdi, R., Alizadeh, H., & Seifnaraghi, M. (2009). The efficacy of executive functions training on mathematics and reading performance of children with learning disabilities. *J. Res. Except. Child*, 1, 1–12.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science 21*(1), 8–14. Doi: 10.1177/0963721411429458.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A. & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognitive Psychology, 41*(1), 49-100. Doi: 10.1006/cogp.1999.0734.

Mokhtar, M., & Aghababaei, S. (2013). The effect of executive functions training on the rate of executive functions and academic performance of students with learning disability. *International Journal of Developmental Disabilities*, 59, 145-155. Doi:10.1179/2047387712Y.0000000004.

Moore, R.C., Swendsen, J., Depp, C.A. (2017). Applications for self-administered mobile cognitive assessments in clinical research: A systematic review. *Int J Methods Psychiatr Res, 26*(4). Doi: 10.1002/mpr.1562. Epub 2017 Mar 31.

Neurorehabilitation and Brain Research Group. (2019). *Test de Atención Continua*. [mobile app]. Google Play. https://play.google.com/store/apps/details?id=com.NRHB.CAT&hl=es_419.

Neurorehabilitation and Brain Research Group. (2019). *Test de Memoria Visuoespacial*. [mobile app]. Google Play. https://play.google.com/store/apps/details?id=com.NRHB.SST&hl=es.

Pérez, K. (2019). Influencia de la función ejecutiva en el rendimiento académico de estudiantes universitarios. Caso Fundación Universitaria Tecnológico Comfenalco. *Revista Espacios, 40* (8), 1-7.

Petersen, R., Lavelle, E., Guarino, A.J. (2006). The Relationship Between College Students' Executive Functioning and Study Strategies. *Journal of College Reading and Learning, 36* (2), 59-67. Doi:10.1080/10790195.2006.10850188.

Pineda, D.A., Merchán, V., Rosselli, M., Ardila, A. (2000). [Factorial structure of the executive functions in young university students]. Rev Neurol,*16-31;31*(12):1112-1118.

Prosen, S., & Vitulić, H. (2014). Executive function in different groups of university students. *Review of Psychology, 21*(2),137-143.

Rial, A., Varela, J., Abalo, J., & Lévy, J. (2006). El Análisis Factorial Confirmatorio. In J.P., Lévy & J., Varela (Eds.), *Modelización con estructuras de covarianza en ciencias sociales*. *Temas esenciales, avanzados y aportaciones especiales.* Netbiblo.

Ramos, C., Jadán-Guerrero, J., & Gómez-García, A. (2018). Relación entre el rendimiento académico y el autorreporte del funcionamiento ejecutivo de adolescentes ecuatorianos. *Avances en Psicología Latinoamericana, 36*(2), 405-417. Doi:10.12804/revistas.urosario.edu.co/apl/a.5481.

Ríos, M., Perianez, J.A., & Muñoz-Céspedes, J.M. (2004). Attentional control and slowness of information processing after severe traumatic brain injury. *Brain Injury, 18*(3), 257-272. Doi:10.1080/02699050310001617442.

Sánchez, G., García, J. (22 de junio de 2014). *Predicción de la deserción escolar*. https://www.semana.com/educacion/articulo/prediciendo-la-desercion-escolar/392724-3/.

Sánchez, J. (2020). *Stroop Effect - Juego de colores*. [mobile app]. Google Play. https://play.google.com/store/apps/details?id=com.josesanchez.stroopeffect.

Schmidt, F.L. (2017). Beyond questionable research methods: The role of omitted relevant re-search in the credibility of research. *Archives of Scientific Psychology*, 5, 32-41. DOI:10.1037/arc0000033.

Schweitzer, P., Husky, M., Allard, M., Amieva, H., Pérès, K., Foubert-Samier, A., Dartigues, J., Swendsen, J. (2017). Feasibility and validity of mobile cognitive testing in the investigation of age-related cognitive decline. *Int. J. Methods Psychiatr. Res.,* 26, 1-8. Doi: 10.1002/mpr.1521.

Sherwood, M.S., Kane, J.H., Weisend, M.P., & Parker, J.G. (2016). Enhanced control of dorsolateral prefrontal cortex neuro-physiology with realtime functional magnetic resonance imaging (rt-fMRI) neurofeedback training and working memory practice. *Neuroimage, 1*, (124) (Pt A), 214- 23. Doi: 10.1016/j.neuroimage.2015.08.074.

Simmonds, D. J., Pekar, J. J., & Mostofsky, S. H. (2008). Meta-analysis of Go/No-go tasks demonstrating that fMRI activation associated with response inhibition is task-dependent. *Neuropsychologia, 46*(1), 224-232. Doi: 10.1016/j.neuropsychologia.2007.07.015.

Simone, A.N., Marks, D.J., Bédard, A.C., & Halperin, J.M. (2018). Low working memory rather than ADHD symptoms predicts poor academic achievement in school-aged children. *Journal of abnormal child psychology, 46*(2), 277-290. Doi: 10.1007/s10802-017-0288-3.

Spiegel, J.A., Goodrich, J.M., Morris, B.M., Osborne, C.M., & Lonigan, C.J. (2021). Relations Between Executive Functions and Academic Outcomes in Elementary School Children: A Meta-Analysis. *American Psychological Association,147*(4), 329–351. Doi: 10.1037/bul0000322.

St. Clair-Thompson, H.L., & Gathercole, S.E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology*, 59, 745-759. Doi: 10.1080/17470210500162854.

Stelzer, F., & Cervigni, M.A. (2011). Desempeño académico y funciones ejecutivas en infancia y adolescencia: Una revisión de la literatura. *Revista de Investigación en Educación, 1* (9), 148-156.

Strauss, C.C., Lahey, B.B., Jacobsen, R.H. (1982). The relationship of three measures of childhood depression to academic underachievement. *J Appl Dev Psychol,* 3, 375–380. Doi: 10.1016/0193-3973(82)90009-0.

Stroop, J.R. (1935). Studies of interference in serial verbal reaction. *J Exp Psicol,* 18, 643-62. Doi: 10.1037/0096-3445.121.1.15.

Stuss, D.T., & Alexander, M.P. (2007). Is there a dysexecutive syndrome? *Philosophical Transactions of the Royal Society of London Serie B Biological Science*, 362(1481), 901- 915. Doi: 10.1098/rstb.2007.2096.

Taylor, S. F., Stern, E. R., & Gehring, W. J. (2007). Neural systems for error monitoring: recent findings and theoretical perspectives. *Neuroscientist, 13*(2), 160-172. Doi: 10.1177/1073858406298184.

Van der Ven, S.H., Kroesbergen, E.H., Boom, J., & Leseman, P.P. (2012). The development of executive functions and early mathematics: A dynamic relationship. *British Journal of Educational Psychology, 82*(1), 100-119. Doi: 10.1111/j.2044-8279.2011.02035.x.

Wechsler, D. (2004). Escala de Memoria de Wechsler-III. TEA Ediciones, S.A.

Wiest, D.J., Wong, E.H., Bacon, J.M., Rosales, K.P., & Wiest, G.M. (2020). The Effectiveness of Computerized Cognitive Training on Working Memory in a School Setting. *Applied Cognitive Psychology, 34(*2), 465-471. DOI: 10.1002/acp.3634.