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Relationship between episodic memory and executive functions in university students

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Abstract

Executive functions play a key role in the strategic processing of episodic memory, but their interaction with this system in young adults without cognitive impairments is not yet fully understood. This study aimed to determine the contributions of five executive functions (planning, cognitive flexibility, working memory, verbal fluency, and inhibition) to the encoding, storage, and retrieval processes of episodic memory in university students. A total of 52 physiotherapy students from a Colombian university participated. The results show that cognitive flexibility and verbal fluency are significantly related to these processes. These findings provide evidence of the role of executive functions in the episodic memory performance of young adults and suggest that stimulating them could support both learning and intervention processes in educational and clinical settings.

Keywords

Executive functions; episodic memory; neuropsychological assessment; college students.

Thesaurus

DeCS/MeSH thesaurus

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Relación de la memoria episódica con las funciones ejecutivas en jóvenes universitarios

Resumen

Las funciones ejecutivas desempeñan un papel clave en el procesamiento estratégico de la memoria episódica, pero su interacción con estas en adultos jóvenes sin alteraciones cognitivas aún no se comprende del todo. El estudio tuvo como objetivo determinar los aportes de cinco funciones ejecutivas (planificación, flexibilidad cognitiva, memoria de trabajo, fluidez verbal e inhibición) a los procesos de codificación, almacenamiento y recuperación de la memoria episódica en jóvenes universitarios. Participaron 52 estudiantes de Fisioterapia de una universidad colombiana. Los resultados muestran que la flexibilidad cognitiva y la fluidez verbal se relacionan significativamente con dichos procesos. Estos hallazgos aportan evidencia sobre el papel de las funciones ejecutivas en el desempeño mnésico de adultos jóvenes y sugieren que estimularlas podría favorecer tanto el aprendizaje como los procesos de intervención en contextos educativos y clínicos.

Palabras clave

Funciones ejecutivas; memoria episódica; evaluación neuropsicológica; jóvenes universitarios.

Relação da memória episódica com funções executivas em jovens universitarios

Resumo

As funções executivas desempenham um papel fundamental no processamento estratégico da memória episódica, mas sua interação com esse sistema em adultos jovens sem alterações cognitivas ainda não é totalmente compreendida. Este estudo teve como objetivo determinar as contribuições de cinco funções executivas (planejamento, flexibilidade cognitiva, memória de trabalho, fluência verbal e inibição) para os processos de codificação, armazenamento e recuperação da memória episódica em estudantes universitários. Participaram 52 estudantes de Fisioterapia de uma universidade colombiana. Os resultados mostram que a flexibilidade cognitiva e a fluência verbal estão significativamente relacionadas a esses processos. Esses achados fornecem evidências sobre o papel das funções executivas no desempenho mnésico de adultos jovens e sugerem que sua estimulação pode favorecer tanto a aprendizagem quanto os processos de intervenção em contextos educacionais e clínicos.

Palavras-chave

Funções executivas; memória episódica; avaliação neuropsicológica; jovens universitários.

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Introduction

Understanding how human beings remember past experiences—events located in time and space—has been a central interest of cognitive psychology. This ability, known as *episodic memory*, makes it possible to encode, store, and retrieve contextualized information (Danieli *et al.*, 2023; Tulving, 2005), and it is the basis for acquiring semantic and procedural knowledge (Santiago, 2006). However, this system does not work in isolation; to operate efficiently, it depends on the ability to focus attention, control interference, and apply strategies during information processing (Porras, 2016). These abilities are grouped under the concept of *executive functions*, which regulate and coordinate cognitive activity for complex requests (Cifuentes-Castañeda & Marín-Gutiérrez, 2024; Miyake *et al*., 2000; Tirapu-Ustárroz *et al.*, 2002).

A wide range of studies have shown that executive function impairments affect the quality of episodic memory, due not so much to damage to the memory system itself, but rather because of difficulty in efficiently organizing, encoding, and retrieving information (Shimamura, 2000, 2002; Wang *et al.*, 2024). As a result, subjects with lower executive functioning tend to also demonstrate a decrease in the strategic processing of episodic memory (metamemory; Brand & Markowitsch, 2008; Chino *et al.*, 2023; Cunha *et al.*, 2023; Freedman & Cermak, 1986; Kirchhoff, 2009; Persson & Nyberg, 2008). This indicates that executive function impairments slow down the ability to encode and retrieve information in a controlled manner, rather than damaging memory *per se*. Given the impact that executive functions have on episodic memory, it is clear why, in most cases, the use of memory strategies explains the inter-individual performance of this memory system (Abellán, 2022; Laine *et al.*, 2023; Schneider, 2000; Schneider & Bjorklund, 2003).

From a neurobiological perspective, these cognitive functions do not work in isolation; rather, they are supported by interconnected brain systems. Episodic memory is primarily related to the hippocampus, a key structure for the encoding and retrieval of contextualized experiences (Zheng *et al.*, 2025). In turn, executive functions depend largely on the prefrontal cortex, especially the dorsolateral, orbitomedial, and anterior regions (Flores *et al.*, 2014). The interaction between these two structures makes it possible to strategically organize information and direct its retrieval, which is the basis for the operational relationship between the two cognitive systems (Zheng *et al.*, 2025).

Along similar lines, some studies indicate that the frontal lobes, directly involved in executive functions, are activated during temporary memory ordering (action specific to episodic memory; *v. g.*, Buckner *et al.*, 1999; Goldman-Rakic, 1988) and the execution of metamemory tasks (*v. g.,* Addis & McAndrews, 2006; Blumenfeld & Ranganath, 2007; Buckner *et al*., 1999; Goldman-Rakic, 1988; Miotto *et al.*, 2006; Staresina & Davachi, 2006; Summerfield *et al.*, 2006). This highlights the intrinsic connection between the frontal lobes and episodic memory.

Although the impact of executive dysfunction and the role of the frontal lobes is clear in episodic memory performance, the relationship between this memory system and different executive functions has scarcely been explored in populations considered "healthy", especially young adults. This gap in the research was noted in the systematic literature review conducted by Quiñones-Bermúdez (2024). In fact, the author indicates that there are no studies on this topic in the Colombian context. Therefore, research in this vein is required to understand how these variables interact in the population of young people without cognitive impairments, nationally.

Analyzing the link between episodic memory and executive functions in young, "neurotypical" adults is of significant interest. Most cognitive processes reach their maximum point of development in this population (Hochberg & Konner, 2020; Salthouse, 2009). Clarifying the scaffolding between episodic memory and executive functioning in this group will thus make it possible to explore ways of optimizing even further the different processes involved in the formation and recovery of memories, such as encoding, storage, and retrieval (Craik & Tulving, 1975; Savarimuthu & Ponniah, 2024).

The university environment is a promising stage for this study, not only given the cognitive requirements it involves but also due to the kind of self-regulatory skills demanded of students for successful performance. University life requires planning, flexibility to adapt to changes in study methods, inhibitory control regarding distractions, and the efficient use of learning strategies (Enrico, 2023), which, to some extent, are also related to episodic memory, given that many of these strategies involve elaborate encoding processes, meaningful organization of information, and the use of contextual clues that facilitate retrieval (Wenger & Shing, 2016). Studies like those by del-Valle *et al.* (2024) and Ramos-Galarza *et al.* (2023) have shown a close relationship between executive functions and academic performance in university students. Further, in the Colombian context, empirical studies analyzing these relationships are still rare, which strengthens the relevance of this study.

What do studies on the relationship between episodic memory and executive functions in young, "neurotypical" adults say?

As mentioned, the systematic literature review (Quiñones-Bermúdez, 2024) indicates that, up to now, studies exclusively analyzing the relationship between episodic memory and executive functions in young, "neurotypical" adults are rare. However, some studies that have explored this link at different stages of development in healthy subjects or that have examined control groups composed of young adults without mental impairments have also contributed to understanding this link.

Correlational analyses conducted by Burger *et al.* (2017) in France show that subjects with greater visuospatial working memory capacity benefit more from imagination-based strategies to encode verbal information when they are assessed at long time intervals between stimuli. In contrast, those with lower visuospatial working memory capacity, assessed under the same conditions, have a greater tendency to use the strategy of repetition to encode this kind of information. However, despite these findings, the authors did not find that visuospatial working memory predicted the performance of verbal episodic memory. Likewise, Gombart *et al.* (2021), also in France, did not find that verbal working memory predicted the performance of verbal episodic memory.

The study conducted by Porras (2016) in Spain showed that working memory, in both verbal and visuospatial modalities, has predictive ability for the encoding and retrieval of verbal episodic memory. Along similar lines, Lugtmeijer *et al.* (2019), in the Netherlands, found a positive correlation between visuospatial working memory, incidental encoding, and recognition of visual elements. Further, experimental research by Rudebeck *et al.* (2012) in the United Kingdom showed that, after intensive training of visuospatial working memory, episodic memory of the same modality improved significantly.

Regarding inhibition, the study by Dias *et al.* (2018) in Brazil showed that while there is a correlation between this executive function and visuospatial episodic memory, the level of association is weak. However, studies conducted by Bouazzaoui *et al.* (2014) and Burger *et al.* (2017) in France, as well as by Porras (2016) in Spain, found no connection between verbal episodic memory and inhibition. Likewise, in the studies that examined the relationship between verbal episodic memory and cognitive flexibility, no meaningful relationship was found (*see* Bouazzaoui *et al.*, 2013, 2014; Porras, 2016; Taconnat *et al.*, 2010 [France]). Bouazzaoui *et al.* (2013, 2014) and Taconnat *et al.* (2010) concluded that verbal fluency has no relationship to verbal episodic memory. However, Porras (2016) reports that planning does predict both encoding and retrieval from this memory system.

In conclusion, the evidence shows that working memory has a moderately consistent impact on episodic memory processing in young adults without cognitive impairments. In terms of the other executive functions, with the exception of planning, studies suggest that they may not be related to this memory system in the specified group. However, given that there are few studies addressing the link between episodic memory and executive functions in young, "neurotypical" adults, and considering that there is a theoretical relationship between these executive functions and episodic memory processes, more studies are required in this regard (Quiñones-Bermúdez, 2024). Along these lines, and considering that the university environment sets high cognitive demands involving executive functions and memory, the following research question was proposed: What are the contributions of planning, cognitive flexibility, working memory, verbal fluency, and inhibition on the encoding, storage, and retrieval of episodic memory in university students without cognitive impairments?

The general hypothesis guiding this study holds that executive functions (particularly planning, cognitive flexibility, working memory, verbal fluency, and inhibition) contribute meaningfully to episodic memory encoding, storage, and retrieval processes in university students without cognitive impairments.

Methodology

Study design and type

This research uses the empirical-analytical approach, which is appropriate for examining relationships between executive functions and episodic memory in populations without cognitive impairments, as it makes it possible to operationalize these constructs using standardized tests and to analyze their links based on quantifiable evidence. This approach is consistent with the objective of identifying functional patterns in a specific context, without intervening in the conditions of the phenomenon. Within this framework, a cross-sectional design with a correlational scope was chosen, appropriate for exploring relationships between variables at a specific point in the life cycle. Although this design does not allow establishing causality, it does offer a useful empirical basis to guide future research with longitudinal or experimental approaches.

Sampling and sample

Fifty-two (52) undergraduate students majoring in Physical Therapy from a university in the city of Manizales, Colombia participated. Non-probabilistic convenience sampling was used, according to direct access to the population and the voluntary availability of the participants. The sample size was defined based on practical and comparative criteria, considering prior studies with similar sizes that have analyzed relationships between executive functions and episodic memory in young adults. While a prior statistical power analysis was not conducted, the number of participants was sufficient to run correlational and regression analyses with a moderate number of independent variables, without compromising the models' stability.

The subjects' ages ranged from 20 to 24 years (*Avg.* = 21.63; *SD* = 1.35). Women represented 80.8% and men represented 19.2%. All participants are from Colombia; 62% are from the Caldas Department and 38% from other departments. Fifty per cent (50%) belong to the lower middle class (Stratum 3), 19.2% to poverty level (Stratum 1), 17.4% to the lower class (Stratum 2), 9.6% to the middle class (Stratum 4), and 3.8% to the upper class (Stratum 6). Nineteen point two per cent (19.2%) are in the ninth and sixth semesters, 17.3% in eighth, 15.4% in seventh, 13.5% in tenth, 4.8% in third and fourth, and 5.8% in second.

Selection criteria

The following inclusion criteria were defined to select the subjects: 1) being between 20 and 34 years old;[1] 2) being a native Spanish speaker; and 3) signing an informed consent form. The exclusion criteria were: 1) having a psychiatric diagnosis; 2) presenting a likely psychiatric disorder; 3) diagnosed with a medical condition, not psychiatric, that significantly degrades cognitive functioning; 4) presenting a likely neurocognitive disorder; 5) presenting moderate or high risk of suffering health problems due to use of psychoactive substances; 6) consuming prescribed hypnotics, sedatives or opioids; 7) presenting sensory or motor impairments that interfere with the application of the assessment instruments; and 3) not signing the informed consent form.

Instruments

Sample filtering instruments

Self-Reporting 24-item Questionnaire (SRQ-24). This was developed by the World Health Organization as part of its collaborative study on strategies for mental health services extension (Harding *et al.*, 1980, 1983). It was created to identify the likelihood of suffering psychiatric disorders (Pan-American Health Organization [PAHO], 1983). Harding *et al.* (1980) validated the SRQ-24 with the populations of Colombia, India, the Philippines, and Sudan, keeping in mind transcultural differences. Variability has been found in its sensitivity (78% – 83%) and specificity (72% – 85%) in these contexts (Harding *et al.*, 1980). The WHO (1983) suggests the following cut-off points: anxiety/depression ≥ 11 and psychosis ≥ 1.

Adult ADHD Self-Report Scale, version 1.1 (ASRS-V1.1). This was developed by Kessler *et al.* (2005) based on DSM-IV-TR criteria. For this study, the screening version adapted for Mexican Spanish was used (World Health Organization, 2004). In the original study, this version demonstrated 68.7% sensitivity and 99.5% specificity in adults (Kessler *et al.*, 2005). In Spain, the reported values are 78.3% and 86%, respectively (Pedrero & Puerta, 2007). Up to now, there have been no studies in Latin America analyzing the sensitivity and specificity of this test,

[1] Episodic memory shows its maximum performance level at between 20 and 34 years of age, after which it starts to show decline that is increasingly pronounced by aging (Wechsler, 2004).

although its effectiveness in diverse contexts supports its use. In Peruvian youth, its reliability is similar to that of the original version (α = .655; ω = .664; Merino & Ariza-Cruz, 2021).

Montreal Cognitive Assessment (MoCA). This is a cognitive ability screening instrument developed by Nasreddine *et al.* (2005). For this study, the Spanish version 8.2 was used, as adapted for the Latin American context by Ledesma (2020). The MoCA shows better performance than other, similar screening tools for general cognitive functioning (Aguilar-Navarro *et al.*, 2018). Further, the study by Pike *et al.* (2017) reported 96% sensitivity and 67% specificity for identifying neurocognitive dysfunction in youth of different ethnicities, including Hispanics, using a cut-off point of < 26.

Clinical-Demographic Survey. This is a tool designed by the authors to collect demographic information and medical history. It was evaluated by four clinical neuropsychology experts who analyzed the validity, relevance, clarity, and relevance of the items. To measure agreement among the evaluators, the Kendall coefficient of concordance (Kendall's W) was calculated, obtaining values between .68 and .71 ($p < .05$), which indicates a moderate to strong affinity among scores (Schmidt, 1997).

Alcohol, Smoking and Substance Involvement Screening Test, version 3.1 (ASSIST-V3.1). This is a test developed and adapted into Spanish by the World Health Organization and the Pan-American Health Organization ([WHO] & [PAHO], 2011) to assess the risk of suffering health and other problems linked to psychoactive substance use. Its design is culturally neutral, enabling its application in various countries. In the Colombian context, it has shown high reliability (α = .809 for the total scale; α = .804 in typified aspects; Ferrel *et al.*, 2016). The cut-off points for cannabis, cocaine, amphetamines, inhalants, sedatives, hallucinogens, opioids, and other drugs are 0–3 (low risk), 4–26 (moderate risk), and ≥ 27 (high risk); for tobacco, 0–3 (low risk), 4–26 (moderate risk), and ≥ 27 (high risk); and for alcohol, 0–10 (low risk), 11–26 (moderate risk), and ≥ 27 (high risk; WHO & PAHO, 2011).

Instruments for assessing study variables

Neuropsychological Battery of Executive Functions and Frontal Lobes, version 2 (BANFE-2). This was validated and standardized with Latin American populations ages 6 to 80 by Flores *et al.* (2014). The tests comprising the BANFE-2 were selected based on their neuropsychological validity: they are widely used by the international academic community to assess executive functions and they have broad support in the scientific literature, specifically for areas of the brain identified by studies with neuroimaging and subjects with neuronal damage (Flores *et al.*, 2014). This ensures the generalization and comparison of results between different groups under study (Flores *et al.*, 2014). Likewise, a concordance of .80 among evaluators has been established, which means that the qualifications of this battery are consistent (Flores *et al.*, 2014). The BANFE-2 tests used included Mazes and Tower of Hanoi for assessment of planning; Card Classification for assessment of cognitive flexibility; Stroop Effect for assessing perceptual inhibition; a verb fluency task for assessing verbal fluency; Alphabetical Word Ordering, Consecutive Subtraction and Addition, Visuospatial Working Memory, and Self-Ordered Pointing for assessment of working memory. In addition, the number of times the walls were crossed in the Mazes test was considered as an indicator of motor inhibition.

Phonological and Semantic Verbal Fluency Test from the Brief Neuropsychological Assessment in Spanish (NEUROPSI). From this battery, whose concordance level among evaluators ranges from .89 to .95 and whose validation and standardization processes were also conducted in the Latin American context with individuals aged 16 to 85 (Ostrosky-Solis *et al.*, 1999), the phonological and semantic verbal fluency test was used to complement assessment of this executive function, given that the BANFE-2 has only one task for evaluating it. Table 1 presents the indicators analyzed for each sub-test, organized by the executive functions considered in this study.

Table 1

Operationalization of executive functions

Executive function/Subtest	Indicators
Planning/Mazes	Number of errors and average execution time (in seconds).
Planning/Tower of Hanoi	Number of errors, quantity of movements to reach the goal, and execution time (in seconds).
Cognitive flexibility/Card Classification	Number of correct answers, mismatch errors, maintenance errors, perseverations, and deferred perseverations, as well as execution time (in seconds).
Working memory/Alphabetical Word Ordering	Number of trials in which a correct reproduction is done and quantity of perseverations, ordering errors, and intrusions.
Working memory/Consecutive Subtraction and Addition	Number of correct answers and errors, as well as execution time (in seconds).
Working memory/Visuospatial Working Memory	Number of perseverations, ordering errors, and substitution errors, as well as level reached.
Working memory/Self-Ordered Pointing	Number of correct answers, omissions, and perseverations, as well as execution time (in seconds).
Verbal fluency/BANFE-2 and NEUROPSI	Number of correct answers, errors, and perseverations.
Perceptual inhibition/Stroop Effect	Number of Stroop and non-Stroop correct answers and errors, as well as execution time (in seconds).
Motor inhibition/Mazes	Number of times the maze walls were crossed.

Spain-Complutense Verbal Learning Test (TAVEC). This is the Spanish version of the California Verbal Learning Test developed by Delis *et al.* (1987). The TAVEC was validated and standardized by Benedet and Alejandre (1998) with the Spanish population over 16 years old. The test is based on learning lists of words, a classic test for evaluating verbal episodic memory (Perry & Hodges, 2000). It has three lists: List A (for learning), List B (for interference), and a recognition list. Lists A and B can be grouped in semantic categories. List A is presented in five consecutive trials. List B is then shown in a single trial. Later, the subject is asked to remember the words from List A (short-term free-recall task). In the following task, the evaluator asks the subject to remember the words by category (short-term recall with semantic keys task). After 20 minutes, these two final tasks are repeated, representing the long-term free-recall and long-term recall with semantic keys tasks. The test ends with a recall task in which the subject must identify, from a list composed of different words, those belonging to List A.

The structure of this test surpasses the multi-store memory model and is integrated into modularity of mind theories (Benedet & Alejandre, 1998). It includes effective control of what is known as "ecological validity", by presenting the word lists as "shopping lists". This makes the TAVEC a task that reflects as closely as possible situations in daily life that involve episodic memory operations (Benedet & Alejandre, 1998). The validity analysis shows a factorial structure composed of nine factors that explain 66.7% of the total variance (Benedet & Alejandre, 1998). In total, the reliability analysis shows α values of between .80 and .86 (Benedet & Alejandre, 1998).

The TAVEC enables assessment of the learning curve, the use of memory strategies, short- and long-term free recall and recall with keys, primacy and recency effects, learning stability, discriminability of stored information, memory intrusions and perseverations, response bias, and susceptibility to proactive and retroactive interference (Benedet & Alejandre, 1998). However, in this study only the indicators of episodic memory encoding, storage, and retrieval processes were considered, along with those assessing inhibition of proactive and retroactive interferences. Table 2 shows the operationalization of these processes.

Table 2

Operationalization of episodic memory encoding, storage, and retrieval processes and inhibition of proactive and retroactive interferences

Process	Indicators
Encoding	Number of correct answers on the short-term and long-term recall with semantic keys tasks, frequency with which serial and semantic strategies are used across the five List A learning trials, as well as discriminability index (measure of the subject's capacity to discriminate words from List A on the recognition list).
Storage	Number of correct answers on the fifth List A learning trial and number of correct answers on the recognition task.
Retrieval	Number of correct answers on the short- and long-term free-recall tasks, as well as the frequency with which serial and semantic strategies are used on the short- and long-term free-recall tasks.
Proactive interference	Comparison between the number of correct answers on the immediate free-recall task of the first List A learning trial and the number of correct answers on the List B immediate free-recall task.
Retroactive interference	Comparison between the number of correct answers on the fifth List A learning trial and the number of correct answers on the short-term free-recall task.

Given that the original version of the TAVEC includes words that are uncommon in the Colombian lexicon, a linguistic and cultural adaptation was done following the stimulus selection procedure proposed by Benedet and Alejandre (1998). This process, developed by Quiñones-Bermúdez (2024), included the application of a lexical frequency and familiarity survey to 90 students of another university in the same city, who were native Spanish speakers and had similar characteristics to those of the study sample. Non-prototypical words were selected (that is, the three most frequently appearing words in each category were excluded and the following four and eight were chosen for the exclusive and shared categories for Lists A and B, respectively) which were recorded in the *Diccionario de la lengua española*. The immediate repetition of words from the same semantic category and the presence of serial patterns were also avoided. In addition, the original proportion of singular and plural words was maintained, as well as the structure of the recognition list, which included phonetic, semantic, prototypical, and neutral distractors, in line with the original TAVEC format. In a later stage, 30 students from the same university were selected—applying the same exclusion criteria as used to filter the main sample—to whom the adapted TAVEC version was administered. In this preliminary application an omega coefficient (ω) of .80 was obtained for the set of raw scores that reflect general performance on the test, indicating an acceptable level of reliability (Campo-Arias & Oviedo, 2008). Afterwards, the data on the 52 students making up this study's sample were incorporated, for a total of 82 observations in which a ω value of .80 was also obtained.

Procedure

Authorization was obtained from the university where the sample was recruited, as well as approval from the CINDE Ethical Research and Development Committee to conduct the study with students from the Physical Therapy program. The participants were informed of the project in a session organized by the program coordinator. Of the 86 students interested, 59 were selected after applying the screening instruments (MoCA, SRQ-24, clinical-demographic survey, ASRS-V1.1, and ASSIST-V3.1). In the same session, the selected students were administered the NEUROPSI semantic and phonological verbal fluency tests, as well as the BANFE-2 alphabetical word ordering test, in order to reduce potential interference in the later application of the remaining tests. In the final stage of the study, the 59 participants were assessed using the remaining neuropsychological tests, of whom 52 satisfactorily completed the process and received their results, along with personalized recommendations. The students who met one or more exclusion criteria (except for not having signed the informed consent form) were suggested for referral to the University Well-being Unit or for activating a healthcare route via their health promotion center. In addition, they received recommendations corresponding to the specific reasons for their exclusion.

Analysis

Since no meaningful differences were found in neuropsychological performance by age, the statistical analyses were done with the full set of 52 participants.

Correlational analyses were performed using Spearman and Pearson coefficients, according to the nature of the variables: Spearman to assess relationships between discrete variables, as well as between discrete and continuous variables, and Pearson exclusively for continuous variables. However, the latter did not show significant correlations. In addition, the coefficient of determination was calculated to estimate the explained variance.

To reduce data dimensionality, five main component analyses were performed, one for each executive function, in which compliance with criteria was verified using Bartlett's test of sphericity ($p < .05$) and the Kaiser-Meyer-Olkin index (KMO ≥ .50).

Based on the factorial loads obtained—which explained at least 50% of the variance—cluster analyses were performed using Ward's method and Euclidean distance. The only exception was working memory, for which an independent analysis was performed due to an insufficient value on the KMO test.

The clusters made it possible to identify two groups, which were compared using Student's and Welch's *t*-tests, as well as Mann-Whitney *U* test, depending on fulfillment of statistical assumptions (normality and homoscedasticity). To evaluate the magnitude of the differences, effect size was calculated using Cohen's *d* in the cases where the differences were analyzed with *t*-tests and using the bi-series range correlation coefficient when Mann-Whitney *U* test was applied.

Likewise, multiple, step-by-step linear regressions were run, including as predictors those measures of executive functions that showed the greatest relationship to episodic memory in prior analyses. Statistical assumptions (absence of multicollinearity, normality of residuals, linearity, and homoscedasticity) were verified and, following Cohen's (1988) proposal, the adjusted coefficient of determination was used as a statistician to estimate the percentage of explained variance, correcting positive overestimates generated by the sample size. Finally, statistical power was calculated for all tests and methods used, establishing a minimum threshold of .75, considering the limitations of the study's sample size.

Various programs were used for statistical analysis. A set of tools comprising SPSS 29, Jamovi 2.4, XLSTAT 25.2 and G*Power 3.1 was used.

Results

Correlations among measures of episodic memory and executive functions

Table 3 shows the correlations identified between the indicators of episodic memory encoding and executive functions. The TAVEC short- and long-term recall with semantic keys indicators were found to correlate negatively with the number of maintenance errors on the card classification test, and positively with the number of correct answers on the phonological verbal fluency test.

Table 3

Correlational statistics between indicators related to episodic memory encoding and executive functions

Encoding indicators	Executive function indicators	r_s	p	r_{s2}	1 - β
Tavec_RCCP	Cartas_Mant	-.374**	.006	.13	.79
	FLU_FON_Acierto	.380**	.005	.14	.80
Tavec_RCLP	Cartas_Mant	-.373**	.006	.13	.79
	FLU_FON_Acierto	.411**	.002	.16	.87
Tavec_Discrim	Cartas_Mant	-.425**	.002	.18	.89

Note. r_s = Spearman's coefficient of correlation; p = statistical significance; r_s^2 = coefficient of determination; 1 - β = statistical power; Tavec_RCCP = number of correct answers on the TAVEC short-term recall with semantic keys task; Tavec_RCLP = number of correct answers on the TAVEC long-term recall with semantic keys task; Tavec_Discrim = TAVEC discriminability index; Cartas_Mant = number of maintenance errors on card classification test; FLU_FON_Acierto = number of correct answers on the phonological verbal fluency test. *$p < .05$; **$p < .01$.

In addition, the TAVEC discriminability index was negatively associated with the number of maintenance errors on the card classification test. However, the only moderate correlations occurred between the number of correct answers on the TAVEC long-term recall with semantic keys task and the number of correct answers on the phonological verbal fluency test, as well as between the TAVEC discriminability index and the number of maintenance errors on the card classification test. These results indicate that encoding supported by semantic keys is associated with a lower number of errors by maintaining active rules in contexts of cognitive flexibility, as well as with better verbal organization. This suggests a possible interaction between retrieval processes, lexical selection and error inhibition.

Table 4, whose values reflect the correlation between episodic memory storage and executive functioning, shows a moderately negative correlation between the number of correct answers on the fifth TAVEC List A learning trial and the number of maintenance errors on the card classification test. This finding suggests that a higher level of storage could be related to better ability to maintain rules in contexts of cognitive flexibility, reflecting more efficient executive control.

Table 4

Correlational statistics between indicators associated with episodic memory storage and executive functions

Storage indicators	Executive function indicators	r_s	p	r_s^2	$1 - \beta$
Tavec_A5_RLI	Cartas_MANT	-.433**	.001	.18	.90

Note. r_s = Spearman's coefficient of correlation; p = statistical significance; r_s^2 = coefficient of determination; $1 - \beta$ = statistical power; Tavec_A5_RLI = number of correct answers on the fifth TAVEC List A learning trial; Cartas_Mant = number of maintenance errors on card classification test. *$p < .05$; **$p < .01$.

Finally, Table 5 presents correlations between the episodic memory retrieval and executive functions indicators. Although there was a positive association between the number of semantic strategies used on the TAVEC long-term free-recall task and the maximum level reached on the visuospatial working memory test, the correlation was weak. A moderately negative correlation was also observed between the number of correct answers on the TAVEC short-term free-recall task and the retroactive interference rate of the same test. The occurrence of this correlation was expected since a higher score on the short-term free-recall task decreases the retroactive interference rate. This is because the formula for calculating the rate conditions the result. Therefore, it is not considered an important finding.

Table 5

Correlational statistics between indicators associated with episodic memory retrieval and executive functions

Retrieval indicators	Executive function indicators	r_s	p	r_s^2	$1 - \beta$
Tavec_RLCP	Tavec_Retroac	-.462**	.001	.21	.97
Tavec_SEM_RLLP	MT_Nivel	.369**	.007	.13	.78

Note. r_s = Spearman's coefficient of correlation; p = statistical significance; r_s^2 = coefficient of determination; $1 - \beta$ = statistical power; Tavec_RLCP = number of correct answers on the TAVEC short-term free-recall task; Tavec_SEM_RLLP = frequency with which semantic strategies are used on the TAVEC long-term free-recall task; Tavec_Retroac = retroactive interference rate; MT_Nivel = maximum level reached on the visuospatial working memory test. *$p < .05$; **$p < .01$.

It is noteworthy that, while retrieval is a process dependent on encoding (Tulving, 1983; Tulving & Thomson, 1973), the same associations were not found with executive functioning as identified in the case of encoding. However, later analyses made it possible to confirm the relationship between cognitive flexibility and verbal fluency with the retrieval process.

Identification of differences in episodic memory based on clusters defined by executive functions

The first cluster analysis, performed with the planning and episodic memory indicators, identified two groups of subjects: one with 22 individuals and another with 30 individuals. However, on comparing the neuropsychological performance of each group, planning was not found to characterize the episodic memory processes.

The second cluster analysis, which included the cognitive flexibility and episodic memory indicators, also found two groups of individuals, each with 26 subjects. Subsequent comparative analysis revealed significant variations in the neuropsychological performance of each group (Table 6). The participants who had a higher number of correct answers on the card classification test and showed fewer perseverations on it were observed to achieve higher scores on various TAVEC indicators, with large effect sizes and adequate statistical power. In this case, the indicators related to encoding included short- and long-term retrieval with semantic keys, as well as the frequency of use of semantic strategies over the five List A learning trials.

In addition, the indicators associated with retrieval covered short- and long-term free recall, as well as the use of semantic strategies on short- and long-term free-recall tasks. These data show that better performance on cognitive flexibility is associated with greater efficiency in both encoding and retrieval, particularly when semantic strategies are used.

The third cluster analysis, which was performed with working memory and episodic memory indicators, also identified two groups of subjects: one of 21 individuals and another of 31. However, the comparative analysis indicated that working memory cannot characterize any episodic memory process.

Table 6

Comparison of neuropsychological performance of episodic memory processes between the two groups characterized by cognitive flexibility indicators

Indicators	Tests	*p*	*ES*	1 - *β*	Conclusions
Cognitive flexibility indicators					
Cartas_Acierto	Student's *t*	.002**	0.92	.95	Performance of Group 2 is greater than Group 1
Cartas_PER	Student's *t*	.004**	0.82	.90	Performance of Group 1 is greater than Group 2
Encoding indicators					
Tavec_RCCP	Mann-Whitney *U*	< .001**	0.77	.76	Performance of Group 2 is greater than Group 1
Tavec_RCLP	Mann-Whitney *U*	< .001**	0.88	.85	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLIA	Welch's *t*	< .001**	14.91	1	Performance of Group 2 is greater than Group 1
Retrieval indicators					
Tavec_RLCP	Mann-Whitney *U*	< .001**	0.78	.77	Performance of Group 2 is greater than Group 1
Tavec_RLLP	Mann-Whitney *U*	< .001**	0.57	.76	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLCP	Student's *t*	< .001**	21.81	1	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLLP	Student's *t*	< .001**	17.17	1	Performance of Group 2 is greater than Group 1

Note. *p* = statistical significance; *ES* = effect size; 1 - *β* = statistical power; Cartas_Acierto = number of correct answers on the card classification test; Cartas_PER = number of perseverations on the card classification test; Tavec_RCCP = number of correct answers on the TAVEC short-term recall with semantic keys task; Tavec_RCLP = number of correct answers on the TAVEC long-term recall with semantic keys task; Tavec_SEM_RLIA = frequency with which semantic strategies are used over the five TAVEC List A learning trials; Tavec_RLCP = number of correct answers on the TAVEC short-term free-recall task; Tavec_RLLP = number of correct answers on the TAVEC long-term free-recall task; Tavec_SEM_RLCP = frequency with which semantic strategies are used on the TAVEC short-term free-recall task; Tavec_SEM_RLLP = frequency with which semantic strategies are used on the TAVEC long-term free-recall task. $^*p < .05$; $^{**}p < .01$. *ES* for Student's *t* and Welch's *t* = small if .20, medium if .50, and large if ≥ .80 (Cárdenas & Arancibia, 2014); *ES* for Mann-Whitney *U* = small if .10, medium if .30, and large if ≥ .50 (Oltra-Cucarella *et al*., 2020).

The fourth cluster analysis, performed with verbal fluency and episodic memory indicators, also revealed two groups: one with 32 participants and another with 20 participants. Subsequent comparative analysis showed significant differences between the two groups, with large size effects and adequate statistical power (Table 7).

Table 7

Comparison of neuropsychological performance of episodic memory processes between the two groups characterized by verbal fluency indicators

Indicators	Tests	*p*	ES	*1 - β*	Conclusions
Verbal fluency indicator					
Flu_Verb_Acierto	Student's *t*	.009**	0.81	.79	Performance of Group 2 is greater than Group 1
Encoding indicators					
Tavec_RCCP	Mann-Whitney *U*	< .001**	0.77	.75	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLIA	Welch's *t*	< .001**	132.73	1	Performance of Group 2 is greater than Group 1
Retrieval indicators					
Tavec_RLCP	Mann-Whitney *U*	< .001**	0.74	.75	Performance of Group 2 is greater than Group 1
Tavec_RLLP	Mann-Whitney *U*	< .001**	0.59	.77	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLCP	Student's *t*	< .001**	197.34	1	Performance of Group 2 is greater than Group 1
Tavec_SEM_RLLP	Student's *t*	< .001**	182.77	1	Performance of Group 2 is greater than Group 1

Note. *p* = statistical significance; *ES* = effect size; 1 - *β* = statistical power; Flu_Verb_Acierto = number of correct answers on the verb fluency test; Tavec_RCCP = number of correct answers on the TAVEC short-term recall with semantic keys task; Tavec_SEM_RLIA = frequency with which semantic stragegies are used over the five TAVEC List A learning trials; Tavec_RLCP = number of correct answers on the TAVEC short-term free-recall task; Tavec_RLLP = number of correct answers on the TAVEC long-term free-recall task; Tavec_SEM_RLCP = frequency with which semantic strategies are used on the TAVEC short-term free-recall task; Tavec_SEM_RLLP = frequency with which semantic strategies are used on the TAVEC long-term free-recall task. *$p < .05$; ** p < .01. *ES* for Student's *t* and Welch's *t* = small if .20, medium if .50, and large if ≥ .80 (Cárdenas & Arancibia, 2014); *ES* for Mann-Whitney *U* = small if .10, medium if .30, and large if ≥ .50 (Oltra-Cucarella *et al*., 2020).

In particular, participants who had a greater number of correct answers on the verb fluency test were observed to get higher scores on various TAVEC indicators. Those related to the encoding process included short-term recall with semantic keys and the frequency of use of semantic strategies over the five List A learning trials. In terms of the indicators associated with retrieval, short- and long-term free recall stood out, as well as the frequency of use of semantic strategies during these tasks. Thus, more efficient verbal access is seen to be associated with better organization of information in the different stages of episodic memory, which could reflect more integrated cognitive functioning.

As in the prior cases, the fifth and final cluster analysis, which included the inhibition and episodic memory indicators, made it possible to identify two groups of subjects: one with 27 individuals and another with 25. However, on performing the comparative analysis of these groups, inhibition was not found to characterize the episodic memory processes.

Predictive models for episodic memory based on executive functions

Table 8 shows that the number of maintenance errors on the card classification test inversely predicted episodic memory encoding. Although not all the indicators associated with this process were predicted by this indicator, three were successfully predicted using significant models: the number of correct answers on the short-term recall with semantic keys task, the number of correct answers on the long-term recall with semantic keys task, and the TAVEC index of discriminability.

Table 8

Executive functioning indicators that predict episodic memory encoding

Predictors	*F*(df)	Adj. R^2	*β*	*SE*	*B*	*p*	1 - *β*	CI 95%
				Tavec_RCCP				
Cartas_MANT	12.03(1,50)	.17	-.65	.18	-.44	.0001**	.92	-1.02 – -0.27
				Tavec_RCLP				
Cartas_MANT	13.71(1,50)	.20	-.67	.18	-.46	.001**	.95	-1.04 – -0.30
				Tavec_Discrim				
Cartas_MANT	15.77(1,50)	.22	-1.43	.36	-.49	< .001**	.97	-2.15 – -0.70

Note. *F*(df) = statistical F (degrees of freedom); Adj. R^2 = adjusted coefficient of determination; *β* = coefficient of regression; *SE* = standard error; *B* = standardized coefficient of regression; *p* = statistical significance of the model; 1 - *β* = statistical power; CI 95% = confidence intervals at 95% for the non-standardized coefficients of regression; Cartas_Mant = number of maintenance errors on the card classification test; Tavec_RCCP = number of correct answers on the TAVEC short-term recall with semantic keys task; Tavec_RCLP = number of correct answers on the TAVEC long-term recall with semantic keys task; Tavec_Discrim = TAVEC discriminability index. *$p < .05$; ** $p < .01$. Adjusted R^2 is small if .10, medium if .50, and large if ≥ .80 (Cohen, 1988).

The adjusted coefficients of determination indicate that the explained variability rages from 17% to 22%. These results suggest that lower cognitive control during the maintenance of rules in cognitive flexibility contexts may affect both the efficiency with which information is encoded and the ability to adequately discriminate it.

According to Table 9, the number of maintenance errors on the card classification test and the number of correct answers on the verb fluency test predicted, in a significant model, performance on an episodic memory storage indicator: the number of correct answers on the fifth TAVEC List A learning trial. The first indicator was inversely related and the second directly related. According to the adjusted coefficient of determination, between the two indicators, 21% of the variability on this measure of storage is explained. This pattern indicates that a lower number of errors on maintaining active rules in contexts of cognitive flexibility, together with more efficient verbal access, predicts greater storage of information, possibly by favoring more structured, fluent encoding during learning.

Table 9

Indicators of executive functioning that predict episodic memory storage

Predictors	*F*(df)	Adj. R^2	β	*SE*	*B*	*p*	1 - β	CI 95%
			Tavec_A5_RLI					
Cartas_Mant	8.06 (2,49)	.21	-.53	.17	-.38	.001**	.98	-.89 – -.17
Flu_Verb_Acierto			.07	.03	.25			.01 –.15

Note. *F*(df) = statistical F (degrees of freedom); Adj. R^2 = adjusted coefficient of determination; β = coefficient of regression; *SE* = standard error; *B* = standardized coefficient of regression; *p* = statistical significance of the model; 1 - β = statistical power; CI 95% = confidence intervals at 95% for the non-standardized coefficients of regression; Cartas_Mant = number of maintenance errors on the card classification test; Flu_Verb_Acierto = number of correct answers on the verb fluency test; Tavec_A5_RLI = number of correct answers on the fifth TAVEC List A learning trial. *$p < .05$; **$p < .01$. Adjusted R^2 is small if .10, medium if .50, and large if ≥ .80 (Cohen, 1988).

Regarding the retrieval of episodic memory, Table 10 reveals that the number of correct answers on the verb fluency test and the number of maintenance errors on the card classification test predicted the number of correct answers on the TAVEC short-term free-recall test.

Table 10

Executive functioning indicators that predict episodic memory retrieval

Predictors	*F*(df)	Adj. R^2	β	*SE*	*B*	*p*	1 - β	CI 95%
				Tavec_RLCP				
Flu_Verb_Acierto	8.12 (2,49)	.21	.12	.04	.33	.001**	.98	0.03 – 0.22
Cartas_Mant			-.56	.22	-.31			-1.01 – -0.10
				Tavec_RLLP				
Cartas_MANT	9.93 (1,50)	.14	-.61	.19	-.40	.003**	.88	-1.01 – -0.22
				Tavec_SEM_RLCP				
Flu_Verb_Acierto	5.67 (1,50)	.08	.18	.07	.31	.021*	.88	0.02 – 0.34

Note. *F*(df) = statistical F (degrees of freedom); Adj. R^2 = adjusted coefficient of determination; β = coefficient of regression; *SE* = standard error; *B* = standardized coefficient of regression; *p* = statistical significance of the model; 1 - β = statistical power; CI 95% = confidence intervals at 95% for the non-standardized coefficients of regression; Flu_Verb_Acierto = number of correct answers on the verb fluency test; Cartas_Mant = number of maintenance errors on the card classification test; Tavec_RLCP = number of correct answers on the TAVEC short-term free-recall task; Tavec_RLLP = number of correct answers on the TAVEC long-term free-recall task; Tavec_SEM_RLCP = frequency with which semantic strategies are used on the TAVEC short-term free-recall task. *$p < .05$; **$p < .01$. Adjusted R^2 is small if .10, medium if .50, and large if ≥ .80 (Cohen, 1988).

The prediction of the first indicator is direct, while that of the second is inverse. The adjusted coefficient of determination shows that between the two indicators, 21% of the variability in this memory indicator is explained. In addition, the number of correct answers on the TAVEC long-term free-recall task was predicted inversely only by the number of maintenance errors on the card classification test, with an adjusted coefficient of determination reflecting an explanatory ability of 14%. Likewise, the number of correct answers on the verb fluency test directly predicted the frequency with which semantic strategies are used on the short-term free-recall task. However, the adjusted coefficient of determination for the latter model indicates that only 8% of the variability is successfully explained. It bears mentioning that the three models were significant. These results show that difficulties in maintaining active rules in contexts of cognitive flexibility predict less efficient retrieval, while more effective verbal access predicts better performance in this stage of memory.

Discussion

The goal of this study was to determine the contributions of executive functions to episodic memory encoding, storage, and retrieval processes in university students without cognitive impairments. The findings allow partial confirmation of the hypothesis, given that only cognitive flexibility and verbal fluency were significantly related to the way in which information is coded and retrieved, as well as with the storage and retrieval rate.

Although the tests and statistical methods used in this study do not establish causal relationships between the variables themselves, treatment of the variables together with the theoretical backing provides a basis for inferring that the direction of the relationships identified would extend from executive functions to episodic memory, rather than inversely. Despite the fact that episodic memory can influence executive functioning by enabling the latter to operate with episodic content (Tirapu-Ustárroz & Muñoz-Céspedes, 2005), it is unlikely that in this case such a relationship would work in the aforementioned direction. This is because the fundamental characteristic of executive functions is their ability to strategically process information (Chan & Scalise, 2022; Flores & Ostrosky-Shejet, 2012; Miyake *et al.*, 2000); this faculty is not intrinsically linked to episodic memory, but rather to independent executive processes. This fact was corroborated through the study's findings, where a consistent trend was observed: a large part of the relationships identified were established between executive functioning and memory indicators associated with the use of semantic strategies and categories for processing information. Further, the multiple linear regression analyses showed that some executive function indicators successfully predict the performance of certain measures associated with episodic memory encoding, storage, and retrieval processes.

An additional reason supporting this is that the tests used to assess executive functions that showed a relationship to episodic memory—cognitive flexibility and verbal fluency—do not require greater effort by the episodic system. For example, the card classification test, which assesses cognitive flexibility, only requires learning four classification criteria, a cognitive demand that is below the average ability to simultaneously retain elements in memory (Miller, 1956). Regarding the phonological and verb fluency tests, these require the recall of content from the semantic system. While the origin of this content could depend on episodic encoding (Adrover-Roig *et al.*, 2013; Santiago, 2006), the evidence suggests that over time they become decontextualized, losing their anchoring in space and time and enabling a more automatic, fluent retrieval (Adrover-Roig *et al.*, 2013; Krenz *et al*., 2023). This indicates that their retrieval does not involve direct episodic memory processing but rather access to knowledge already consolidated in semantic memory. Similarly, it was observed that a small number of maintenance errors and perseverations on the card classification test was related to better performance on the TAVEC, which suggests a relationship between the reduction of cognitive flexibility task errors and better performance of episodic memory. Therefore, it is more plausible to think that the findings of this study indicate that episodic memory depends, in this context, on the aforementioned executive functions, and not the opposite.

Based on this and keeping in mind the findings of the systematic literature review presented by Quiñones-Bermúdez (2024), we can affirm that this is the first time, as far as we know, that a significant relationship linking cognitive flexibility and verbal fluency with episodic memory has been successfully identified in young adults without psychiatric or neurocognitive disorders. These results are in contrast to those obtained in prior studies in which it was not possible to identify a relationship between cognitive flexibility and episodic memory (*see* Bouazzaoui *et al.*, 2013, 2014; Porras, 2016; Taconnat *et al.*, 2010). Similarly, in the studies conducted by Bouazzaoui *et al.* (2013, 2014) and Taconnat *et al.* (2010), it was not possible to demonstrate an association between verbal fluency and episodic memory processes.

One possible explanation for this discrepancy stems from the methodological differences between the studies. For example, in the previously mentioned studies, executive functions were assessed using specific tasks that do not necessarily permit a robust estimation of general executive functioning, since they did not include diverse subprocesses or offer multiple indicators per function. In contrast, this study used the BANFE-2, a neuropsychological battery that assesses each executive function through various indicators, increasing the sensitivity for detecting significant associations. Likewise, it is possible that the prior studies used statistical techniques or methods that did not take into account reduction of dimensionality of the data or control of statistical assumptions, elements that were rigorously contemplated in this effort. Furthermore, the prior studies were conducted in European contexts whose educational and cultural conditions differ from the Colombian context. These differences could influence the way in which executive functions and episodic memory are related, especially in academic settings requiring high levels of self-regulation, as is the case in university education, a characteristic that is not present in all samples assessed by the prior studies.

The relationship between cognitive flexibility and episodic memory, which was found in this case, could be due to the fact that this executive function enables the individual to adapt to the evolving demands of the context through the modification of mental strategies for efficiently addressing the challenges (Miyake & Friedman, 2012; Sachse & Widge, 2025). Flexible strategy changes will depend on the feedback the person receives from context or on the intrinsic assessment of their own performance (Robbins, 1998; Zühlsdorff *et al.*, 2023). This ability seems to be critical in the context of episodic memory. For example, a person can become aware that the serial encoding of information is not really effective for its later retrieval. Instead of persisting in this unhelpful strategy, cognitive flexibility enables the person to switch to a more efficient strategy, such as grouping by semantic categories. This strategic shift can significantly improve episodic memory performance, since it makes it possible for information to be organized around a clear semantic structure and, therefore, it could be easier to access at any time (Sohlberg & Mateer, 2001). In fact, several authors state that it is strategic information processing that explains differences between individuals in episodic memory performance (for example, Abellán, 2022; Laine *et al*., 2023; Schneider, 2000; Schneider & Bjorklund, 2003). In short, cognitive flexibility could facilitate the adaptation and optimization of memory strategies, which would lead to better performance on cognitive tasks that involve encoding, storing, and retrieving information.

On the other hand, the association identified between verbal fluency and episodic memory could be explained by the close relationship supporting this kind of memory with semantic memory. Verbal fluency represents the ability to retrieve words quickly and efficiently, which provides access to the extensive network of knowledge stored in semantic memory (Kumar *et al.*, 2025; Tirapu-Ustárroz *et al.*, 2017). The connection between these two memories is essential, given that semantic memory acts as an organizing framework for episodic information (Wing *et al.*, 2024; Strikwerda-Brown *et al.*, 2019; van den Bos *et al*., 2020). When remembering past experiences, the associated semantic representations that gave meaning to those experiences are activated and retrieved (Strikwerda-Brown *et al.*, 2019; Tulving, 1987; van den Bos *et al*., 2020). Semantic memory establishes the parameters needed for efficient encoding of information in episodic memory. For example, thanks to the semantic system, an individual can group information in categories, given that these representations are already consolidated in their semantic memory. By providing context and meaning to events and experiences, this memory system influences the way in which memories are organized and then stored. As has been mentioned, this efficient encoding process facilitates access to stored information, simplifying its later retrieval. In brief, the semantic component seems to be essential in the processing of episodic content, as proposed by Tulving (1987) in the context of the hierarchical organization of memory theory.

The findings presented here indicate that cognitive flexibility and verbal fluency are two important factors in learning among university students, particularly as regards episodic memory processing. This can be interpreted from a neurobiological perspective, in which functional interaction is recognized between the prefrontal cortex and the hippocampus, structures involved in executive control and contextual processing of information in memory, respectively (Zheng *et al*., 2025). Verbal fluency and cognitive flexibility could facilitate encoding and retrieval strategies that depend on this functional connectivity, which would explain their relevance in episodic memory performance.

Therefore, stimulating these executive functions during professional training could lead to significant benefits for students' memory performance (Ramos-Galarza *et al.*, 2023; Yoldi, 2015). From an educational perspective, this opens up the possibility of designing teaching strategies that integrate the conscious use of memory strategies, flexible planning, and fluent verbal retrieval in favor of more efficient information processing. In the clinical setting, these results can also guide neuropsychological intervention programs targeting young people with mild episodic memory difficulties, focused on strengthening the strategic processes that support it. However, it is necessary to keep in mind that controlled experimental studies are required to more precisely identify the causal relationship between the mentioned variables.

Although most executive functions reach their maximum development in late adolescence (Tervo-Clemmens *et al*., 2023), making it possible to assume that university students already have adequate executive performance, it is important to recognize that this does not prevent the ongoing stimulation of these functions. Brain plasticity, also known as *neuroplasticity*, enables the remodeling of neurosynaptic maps, which leads to optimization of neural networks and, therefore, improvement in cognitive functions (Duffau, 2006; Marzola *et al.*, 2023). This adaptive ability of the brain is maintained even into adulthood, facilitating the formation of new neural circuits as a response to learning and to the maintenance of existing networks (Newton *et al.*, 2013). As a result, the ongoing stimulation of these functions in university students can significantly benefit their cognitive performance and all that it involves.

Now, although several prior studies have reported a significant relationship between episodic memory and working memory in young, "neurotypical" adults (*see* Burger *et al.*, 2017; Lugtmeijer *et al*., 2019; Porras, 2016; Rudebeck *et al.*, 2012), the results of this study do not support this association, as no significant links were found between these variables. Only a weak correlation was found that is noteworthy due to its statistical power between an indicator of episodic memory retrieval and a measure of visuospatial working memory. This finding matches the study by Gombart *et al.* (2021), in which no important link between working memory and episodic memory was found. Further, and despite the fact that the study by Porras (2016) suggests that planning affects episodic memory, the findings of this study disagree, given the lack of relationships. In addition, while the study by Dias *et al.* (2018) revealed a slight association between episodic memory and inhibition, in this case, although weak correlations were found between episodic memory and perceptual inhibition, the statistical power was under the minimal accepted limit. Therefore, no relationship is assumed in this regard. The latter agrees with the results of some studies that also suggest a lack of connection (*see* Bouazzaoui *et al.*, 2014; Burger *et al*., 2017; Porras, 2016).

In sum, the findings of this study suggest that, although not all the executive functions assessed were associated with episodic memory, two of them (cognitive flexibility and verbal fluency) emerged as factors related to its performance in young adults. Although episodic memory performance cannot be explained solely by executive functioning variables, it can be affirmed that as cognitive flexibility and verbal fluency increase, episodic memory functioning improves. This highlights the importance of abilities for strategically adapting to the demands of a memory task and fluently accessing the content of semantic memory during the encoding and retrieval of memories.

Although in this study planning and inhibition are not directly associated with episodic memory, and working memory did not show a consistent relationship with this system, this does not rule out the possibility that these executive functions have direct or indirect impact on encoding, storage, and retrieval of episodic footprints in the group evaluated. This lack of association can be interpreted as evidence of the functional specificity of certain executive processes in episodic memory performance. However, it is possible that such specificity is also conditioned by methodological factors, such as the differential sensitivity of the instruments used or the relative cognitive homogeneity of the sample, which was composed of university students in a narrow age range without neuropsychological impairments. In contexts with greater individual variability or in clinical populations, these functions may show a clearer link to memory processes, which is a line for future research.

In addition, it is critical to conduct future studies with young adults from different regions to explore the nature of relationships between executive functioning and memory processes in specific cultural contexts. On comparing the findings of this study with those obtained in research developed in different countries, it was not possible to identify a consistent tendency regarding the relationship among the variables studied here. A situated research perspective could reveal unique aspects on how executive functions influence episodic memory based on the cultural context, which could have important implications for understanding and optimization of episodic memory in different populations.

Finally, it is important to consider that this study's findings cannot be generalized to the whole youth population. While it did work with university students, the sample was limited to just one academic program (Physical Therapy), and it was mostly composed of women from the same region in the country. This homogeneity limits extrapolation of the results to other sociocultural and academic contexts. Further, non-probabilistic convenience sampling was used, which limits the statistical representativity of the sample. Thus, it is suggested that future research incorporate broader, more diverse samples, including participants from different academic programs, geographic regions and with greater gender balance, which would allow validating and comparing the patterns found in this study. Likewise, it would be relevant to conduct longitudinal or experimental studies that make it possible to more precisely examine the directionality and possible causal effects of executive functions on episodic memory.

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