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NEUROPSYCHOLOGICAL PROFILES AS A FRAMEWORK FOR A CURRICULAR INTERVENTION USING LOGIC AND READING ALOUD IN HIGH SCHOOL STUDENTS

Abstract

The implementation of the new general high school curriculum in the Upper Secondary Education System (SEMS) demands self-management and complex reasoning competencies from students, which require specific neurobiological maturity. The objective of this study was to diagnose the state of Executive Functions (EF) in high school students and, based on this evidence, to propose a situated pedagogical intervention. Through a quasi-experimental design, a sample of 20 students was evaluated using the Neuropsychological Battery of Executive Functions (BANFE-3). The results revealed a significant maturational asynchrony: while the orbitofrontal area (behavioral regulation) is preserved in the majority, 70% of the sample presents alterations in the dorsolateral prefrontal area, a region critical for planning, working memory, and cognitive flexibility, in view of this finding, which suggests a biological barrier to autonomous learning, a systematized curricular intervention strategy is presented. This proposal integrates exercises in formal logic—to specifically stimulate the deficient dorsolateral area—and reading aloud (RA)—for the maintenance of inhibitory control—aligning with the learning unit of Mathematical Knowledge. It is concluded that high school should serve as an explicit cognitive training environment to close the gap between curricular demands and adolescents' neurofunctional capacity.

Keywords: Executive functions, dorsolateral area, formal logic, reading aloud, upper secondary education.

Introduction

The Upper Secondary Education System (SEMS) of the University of Guadalajara faces significant challenges in responding to students' cognitive, emotional, and social demands in a global context that demands complex, multifaceted skills [1], [2], [3]. High school plays a fundamental role in the development of adolescents aged 14-18, as it serves a bridge between basic education and higher education or entry into the workforce [3.-15]. During this stage, students are required to process increasingly complex information, plan and make decisions, and regulate their behavior in line with academic objectives [4].

These demands depend on executive functions (hereinafter EF), a multidimensional and complex set of basic cognitive processes and skills such as attention, memory, perception, and language [5], [6], as well as higher-orderl skills such as planning, inhibitory control, working memory, cognitive flexibility, decision-making, task supervision, emotional control, verbal fluency, initiative, and organization of materials [7]. Importantly, adolescence not only represents a period of vulnerability but also a critical window of neuroplasticity and EF [8], [9]. At the neural level, EFs are primarly supported by the prefrontal cortex, which during adolescence undergoes its final stages of myelination and synaptic pruning [8. – 648], [10], meaning that educational interventions implemented at this stage may have a more profound and mor enduring structural impact than those applied later in development.

In this sense, good executive functioning is associated with improvements in academic performance, so it is imperative to emphasize that stimulating these functions is necessary, given students' growing difficulties with attention, following instructions, perseverance, and emotional regulation [6, - 114].

As is well known, adolescence is a crucial stage for the consolidation of thought processes; therefore, to navigate these demands, the student depends on their EFs and their capacity for formal operational thought. Given this, the close relationship between formal logic and EFs is highlighted,

where structured thought requires a solid semantic memory and cognitive control mechanisms [11]. In other words, when these functions are not intentionally stimulated, recurrent failures in reasoning and abstraction capacity are observed.

In this scenario, the need arises to implement systematized pedagogical interventions that leverage the rapid maturation of the prefrontal cortex characteristic of adolescence. In this regard, the literature identifies specific curricular practices that can serve as neurocognitive training. On the one hand, logical verbal training has been shown to improve abstract reasoning, suggesting that systematic exposure to logical exercises can enhance the transferability of cognitive skills to other domains [12]. Moreover, recent neuroimaging evidence reinforces this link; specifically, fMRI studies comparing inductive and deductive reasoning have demonstrated that deductive tasks recruit the fronto-parietal network exclusively. This activation is concentrated in the dorsolateral prefrontal cortex (DLPFC), a region essential for error monitoring and for manipulating complex mental models during rule-based processing [9. - 135].

On the other hand, Reading Aloud (RA) has been identified as a powerful tool that, beyond decoding, involves attention and monitoring processes, fundamental for cognitive development [13]. Furthermore, recent neuroscientific evidence supports the view that RA is a core element of neuroplasticity, as interventions integrating reading with executive function training significantly enhance functional connectivity between sensory networks and the frontoparietal control network, recruiting the inferior frontal gyrus to exercise inhibitory control mechanisms actively [14].

In this context, this study starts from a fundamental premise: high school must transition from being a space of mere instruction to one of training in higher cognitive capacities. This premise is significant because it aligns with the programs of the new curricular plan of the SEMS of the University of Guadalajara, such as "Mathematical Knowledge I".

Therefore, the objective of this research is to diagnose the current state of EFs in students. In addition, recent studies in the Eurasian context have also highlighted the importance of stimulating academic performance in mathematics [15]. Based on this evidence, the present study proposes an intervention that integrates logic and RA as guiding principles to strengthen academic performance and cognitive maturity.

Materials and methods of research

The research is framed within a quantitative approach defined as a descriptive study with a proposed intervention design. Its methodological structure focuses on an initial diagnostic phase that establishes the neuropsychological profile of the students, enabling, based on this empirical evidence, the design of a specific pedagogical intervention that will be assessed in a subsequent phase.

1. Participants

The sample consisted of 20 students from High School No. 7 of the University of Guadalajara (Mexico). The selection was non-probabilistic by convenience, under the following inclusion criteria:

1.Students enrolled in upper secondary education in the semester corresponding to the study, without a history of failing and/or repeating subjects.

2.Age between 14 and 18 years.

3.Homogeneous characteristics regarding socioeconomic and demographic levels.

4.That the student and their parents or guardians have signed the informed consent to participate.

5.Not having a diagnosis of any disorder.

2. Diagnostic Instrument

The Neuropsychological Battery of Executive Functions and Frontal Lobes (BANFE-3), standardized for the Mexican population, was used. This instrument was selected because, in addition to offering a Global Executive Function Index (IFEG), it has the capacity to disaggregate executive functioning into specific areas (orbitomedial, anterior prefrontal, and dorsolateral),

allowing not only to determine if there is an alteration in these areas but also to locate exactly which neurocognitive circuit requires stimulation. The EFs corresponding to the evaluated areas are as follows:

1. Orbitofrontal Cortex: inhibition, emotional control, decision-making.
2. Medial Prefrontal Cortex: sustained attention, behavioral regulation.
3. Dorsolateral Prefrontal Cortex: planning, working memory, cognitive flexibility, problem-solving.
4. Anterior Prefrontal Cortex: meta-functions (metamemory, understanding of sayings/proverbs).

This battery was chosen for its high internal consistency and foundation in neuropsychology and neuroimaging studies. Furthermore, it is a standardized tool for the Mexican population, sensitive to detecting changes following interventions in adolescents, and suitable for the age range of high school students.

3. Procedure and Design of the Proposal

The study was articulated in three strategic stages, with the first two being the focus of this article:

Phase 1: Diagnosis (Pre-test): Participants were individually assessed to establish a baseline. The objective was not only to classify performance but to detect the real neurocognitive needs of the student body before any intervention.

Phase 2: Justification of the Pedagogical Intervention: Based on the diagnostic findings, an intervention proposal was structured based on two guiding axes: Formal Logic exercises and RA. The choice of these tools was not arbitrary but was based on a precise neuropsychological justification.

Phase 3: Design of the Intervention Proposal. Consequently, this phase focused on structuring a specific curricular intervention protocol. This proposal presents a theoretical model intended for future implementation and empirical validation.

Table 1 – Structure and Timeline of Neuropsychological Intervention Proposal

Intervention Component	Timeline	Neuropsychological Objective	Activity Description
Diagnosis	Week 1	Pre-Test Evaluation All Prefrontal Areas	Administration of BANFE-3 (complete battery)
Axis 1: Formal Logic	Weeks 2- 13	Dorsolateral: Stimulate Working Memory and Planning by manipulating abstract sequences	Exercises on propositional logic, truth tables, and symbolization of natural language sentences into logical notation 3 sessions per week 45 minutes per session
Axis 2: Reading Aloud		Orbitofrontal and Anterior: Maintain Inhibitory Control and Metacognition through tone modulation and error monitoring	Reading texts aloud with emphasis on intonation, followed by self-correction of reading errors. Start of each session 10-15 minutes
Evaluation	Week 14	Measure cognitive changes after intervention All Prefrontal Areas	Administration of BANFE-3 (complete battery)
Note: Own elaboration			

The intervention is designed to last 14 weeks in total: an initial week was dedicated exclusively to diagnostic assessment (pre-test), followed by a 12-week core intervention phase to

ensure sufficient time for neuroplastic consolidation, and concluding with a final week for post-intervention assessment (post-test).

Results and their discussion

The data presented below correspond to the initial assessment of the sample (N=20). These results focus on assessing the maturity of prefrontal areas to determine the relevance of a targeted pedagogical intervention.

In a first approximation, the IFEG of the BANFE-3 indicates a concern about academic performance at the upper secondary level.

1. 55% of the sample presents alterations in their general executive functioning (45% with mild-moderate alteration and 10% severe).
2. Only 45% of the students fall within the normal range for their age.

This initial finding confirms that more than half of the students attend high school without the consolidated neurocognitive tools to face the standard academic load, highlighting the need for external scaffolding. However, when classifying results by functional regions of the prefrontal cortex, a pattern of maturational asynchrony emerged, constituting the central finding of this study and the foundation of the intervention proposal.

Table 2 – Distribution of Executive Function Alterations by Prefrontal Area (N=20)

Prefrontal Area	Function	Preserved (Normal Range)	Altered (Mild to Severe)
Anterior Prefrontal	Metacognition	95%	5%
Orbitofrontal	Inhibitory Control / Social Regulation	85%	15%
Dorsolateral	Planning / Working memory	30%	70%
Note: Own elaboration based on BANFE-3 results.			

Specifically, the preserved areas are the orbitofrontal cortex, which is responsible for inhibitory control and social regulation. This is within the norm in 85% of the students. Also, the Anterior Prefrontal area shows no alterations in 95% of the sample. These areas indicate that students possess the biological capacity to regulate their social behavior and to follow basic classroom rules.

In contrast, the dorsolateral area presents a 70% prevalence of alteration. This indicates a prevalent weakness in planning, working memory, verbal fluency, and cognitive flexibility functions.

These results by area gain relevance when conducting a cross-analysis of the data, as they allow establishing a direct link with the proposed pedagogical strategy. For example, given that 70% of students fail in the dorsolateral area—which is necessary for sequencing steps and mentally manipulating information—the intervention through logic exercises is highly relevant because these students' brains require explicit training in sequencing to mature this specific area.

On the other hand, although the orbitofrontal area (necessary for inhibitory control and social regulation) is preserved to a greater extent, the percentage of students with global alterations suggests fragility in attention systems. This is why RA is sustained as a maintenance strategy to ensure this inhibitory control.

In summary, this first diagnosis shows that students have behavioral "brakes" (orbitofrontal cortex) but lack a cognitive "steering wheel" (dorsolateral cortex). This metaphor illustrates how these functions allow individuals to consciously guide their thoughts, suppress impulsive reactions, and navigate complex environments towards specific goals, just as a steering wheel directs a vehicle. Along this same line, it is possible to argue that these results validate the instructional design centered on the development of logic and RA activities.

The findings of this study offer a first empirical approach that allows for contrasting the expectations of the new general high school curriculum promoted by the University of Guadalajara with the neurobiological reality of the classroom. The discussion of these results focuses on the tension between the curricular demand itself and the necessary development of students' EFs to enable a better academic trajectory.

In this regard, it is necessary to note that the new general high school of the SEMS establishes the development of critical and autonomous thinking as a goal for the student. However, the diagnosis reveals that 70% of the sample lacks the functional maturity to sequence steps and mentally manipulate information. This discrepancy suggests that the educational system may be in a contradiction: it requires the adolescent student to plan and manage their learning (dorsolateral functions), treating it as a matter of will, whereas the data from this research indicate that it is a biological constraint. The results confirm a developmental asynchrony: students possess a relatively functional socio-emotional (orbitofrontal) system for social interaction, but a cognitive (dorsolateral) system that is still immature for organizing complex thought [16].

Furthermore, the high prevalence of alterations in the dorsolateral area (planning, working memory, and flexibility) has significant academic implications. Common difficulties in high school—such as not understanding long instructions, losing track of mathematical problems, or the inability to correct one's own errors— are consistent in similar educational systems [15.- 365]; however, they are not necessarily signs of disinterest, but symptoms of a possible alteration in an EF. Thus, as students have not consolidated this area, the retention of information in their minds is not sustained long enough for manipulation. Therefore, traditional teaching that merely exposes content is insufficient and requires external scaffolding [17] to compensate for and train these functions.

For this reason, given this specific diagnostic profile, the intervention proposal designed in this study is validated not as a complementary activity, but as a corrective necessity. Therefore, the choice of Formal Logic exercises directly responds to the dorsolateral deficit observed, because logical thinking requires formalism and a structured semantic memory [11.- 449]. In other words, working memory is exercised when it forces the student to keep multiple rules active in the mind simultaneously and to manipulate them to reach a conclusion.

Moreover, the selection of exercises based on formal logic is validated by recent neuroimaging findings, which confirm that deductive reasoning tasks are superior to inductive ones for recruiting the DLPFC [9. - 168], which means that this type of reasoning demands a unique activation of the fronto-parietal network, making it an ideal pedagogical tool for targeting the specific deficits identified in the student profile. Thus, by inserting this type of exercise into the curriculum, we are forcing the student's brain to perform precisely the tasks it struggles with (sequencing and validating), acting as intensive training for working memory and cognitive flexibility.

In turn, RA is justified as a maintenance strategy for the attentional system. Mechanistically, this practice engages the phonological loop and requires continuous auditory self-monitoring to suppress impulsive errors. This specific design indicates that training requiring such sensory-motor integration strengthens the functional coupling between visual systems and the frontoparietal control network [13. - 37]. Therefore, the proposed daily RA practice does not merely improve fluency, but actively recruits executive circuits to modulate behavior, preventing cognitive fatigue from degrading performance during the school day.

Finally, it is crucial to clarify the scope of this work. Although this study focuses on the diagnostic phase and the theoretical design of the intervention, the ultimate validation of this model lies in the future post-test phase. The implementation of this protocol is expected to provide empirical data quantifying whether curricular training in logic and RA successfully reduces the prevalence of dorsolateral alteration specifically in this population.

Limitations It is important to acknowledge that this study presents several limitations. First, the sample size (N=20) is small and was selected through convenience sampling, which limits the generalizability of the findings to the broader high school population. Second, as a diagnostic and propositional study, the effectiveness of the designed intervention remains hypothetical; empirical validation through a pre-test/post-test design with a control group is required in future research to establish causal links between the proposed activities and neurocognitive improvements. Finally, the study does not address the long-term sustainability of the potential cognitive gains.

Conclusion

It has been found that the neuropsychological profile of the upper secondary student is characterized by uneven development. While 85% of the student body maintains a preserved orbitofrontal area—allowing them to regulate their social conduct—70% present significant alterations in the dorsolateral prefrontal area. This implies that observed academic failures (disorganization, difficulty planning) do not necessarily reflect a lack of attitude, but rather a specific biological immaturity in the circuits responsible for working memory and sequencing.

Likewise, these results highlight a critical disparity between the demands of the new SEMS general high school and students' actual EFs, since the educational model requires self-management and complex thinking competencies for which more than half of the students (55% with a global alteration) are not neurologically ready. Thus, without explicit training, the curricular goals of autonomy risk being unattainable.

For this reason, the intervention proposal of this study is not arbitrary. Still, it constitutes a technical response to the profile found, as it is determined that Formal Logic is the ideal curricular tool to compensate for the dorsolateral deficit, acting as scaffolding to structure the sequential thought that students cannot generate on their own. Furthermore, RA is recognized as a necessary strategy for maintaining attentional tone and inhibitory control in the classroom through auditory feedback and prosody regulation, thereby ensuring comprehensive stimulation from verbal fluency to complex problem-solving.

In sum, this research proposes promoting an educational model that not only assesses competencies but also trains the EFs necessary to acquire them, establishing an integrated intervention protocol that combines activities of progressive complexity under constant performance monitoring.

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ЖОҒАРЫ СЫНЫП ОҚУШЫЛАРЫНЫҢ НЕЙРОПСИХОЛОГИЯЛЫҚ ПРОФИЛІНЕН ТУЫНДАЙТЫН, ЛОГИКА МЕН ДАУЫСТАП ОҚУҒА НЕГІЗДЕЛГЕН ПЕДАГОГИКАЛЫҚ ИНТЕРВЕНЦИЯ БОЙЫНША ҰСЫНЫС

Аңдатпа

Жоғары орта білім беру жүйесінде (ЖОБЖ) енгізілген жаңартылған жалпы білім беру бағдарламасы оқушылардан өзіндік оқу әрекетін ұйымдастыруды, жоспарлау мен рефлексияны талап етеді. Алайда бұл талаптар жасөспірімдердің атқарушы функцияларының нейробиологиялық жетілу деңгейімен әрдайым сәйкес келе бермейді. Осы зерттеудің мақсаты – жоғары сынып оқушыларының атқарушы функцияларының даму деңгейін анықтау және алынған нәтижелер негізінде оқу үдерісіне енгізілетін нақты педагогикалық интервенцияны негіздеу.

Зерттеу квазиэксперименттік дизайнда жүргізіліп, 20 оқушының атқарушы функциялардың нейропсихологиялық батареясы (BANFE-3) арқылы бағаланды. Диагностика нәтижелері оқушылардың басым бөлігінде мінез-құлықты реттеуге жауапты орбитофронтальды аймақтың сақталғанын, алайда жоспарлау, жұмыс жадысы және когнитивтік икемділікпен байланысты дорсолатералды префронтальды аймақтың функцияларында 70% жағдайда жеткіліксіз даму бар екенін көрсетті.

Осы нейропсихологиялық деректерге сүйене отырып, «Математикалық білім» оқу пәнінің оқу үдерісіне бағытталған жүйеленген педагогикалық интервенция ұсынылады. Аталған интервенция сабақ барысында формальды логика элементтері бар есептерді кезең-кезеңмен талдау арқылы жоспарлау мен когнитивтік икемділікті дамытуға, сондай-ақ мәтіндерді дауыстап оқу (reading aloud) әдісін қолдану арқылы зейін мен тежеу бақылауын тұрақтандыруға бағытталған. Ұсынылған тәсілдер күнделікті сабақ құрылымына енгізіліп, арнайы қосымша пәнді талап етпейді.

Зерттеу нәтижелері жоғары мектептегі оқу үдерісін тек білім берумен шектемей, атқарушы функцияларды мақсатты түрде дамытатын когнитивтік жаттығу ортасы ретінде ұйымдастырудың педагогикалық маңызын көрсетеді.

Негізгі сөздер: атқарушы функциялар, дорсолатералды аймақ, формальды логика, дауыстап оқу, орта білім

ПРЕДЛОЖЕНИЕ ПО ПЕДАГОГИЧЕСКОЙ ИНТЕРВЕНЦИИ НА ОСНОВЕ ЛОГИКИ И ЧТЕНИЯ ВСЛУХ, РАЗРАБОТАННОЕ С УЧЕТОМ НЕЙРОПСИХОЛОГИЧЕСКОГО ПРОФИЛЯ СТАРШЕКЛАССНИКОВ

Аннотация

Внедрение новой программы общего среднего образования в Системе среднего образования (SEMS) требует от учащихся компетенций самоорганизации и сложного мышления, которые предполагают наличие определенной нейробиологической зрелости. Цель данного исследования заключалась в диагностике состояния исполнительных функций (ИФ) у учащихся старших классов и разработке, на основе полученных данных, ситуативной педагогической интервенции. В рамках квазиэкспериментального дизайна была проведена оценка выборки из 20 учащихся с использованием Нейропсихологической батареи лобных долей и исполнительных функций (BANFE-3). Результаты выявили значительную асинхронию созревания: в то время как орбитофронтальная зона (поведенческая регуляция) сохранна у большинства учащихся, у 70 %

выборки наблюдаются нарушения в дорсолатеральной префронтальной зоне — области, критически важной для планирования, рабочей памяти и когнитивной гибкости. В свете этого открытия, указывающего на биологический барьер для автономного обучения, представлен проект стратегии систематизированной учебной интервенции. Данное предложение объединяет упражнения по Формальной логике — для специфической стимуляции дефицитарной дорсолатеральной зоны — и Чтение вслух (RA) — для поддержания ингибиторного контроля, что согласуется с учебным модулем «Математические знания». Сделан вывод о том, что старшая школа должна служить средой для целенаправленного когнитивного тренинга, чтобы сократить разрыв между требованиями учебной программы и нейрофункциональными возможностями подростков.

Ключевые слова: исполнительные функции, дорсолатеральная зона, формальная логика, чтение вслух, среднее образование

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