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Influence of Digital Media on Memory and Attentional Abilities of Students with ADHD

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ABSTRACT

The objective of this study focuses on analyzing the influence that the use of digital devices can have on the learning processes of students with ADHD, establishing a clear concomitance between the clinical symptoms of the disorder and the main learning difficulties that this group presents. Following a mixed approach, information is collected from a total sample of 91 Primary Education students enrolled in the provinces of Almería and Granada, considering as inclusion criteria the presentation of a clinical picture compatible with ADHD and this profile being confirmed by means of an initial Magellan Scale questionnaire. Once the sample has been completed, the Memory and Learning Test (TOMAL) is used, made up of a main battery of six subtests in order to determine the delayed memory capacity and attentional processes of the participating subjects. The results show a significant improvement in the attentional and mnesic tasks of the participants in digital support compared to the written one, showing a greater motivation for the use of digital devices regardless of age or characteristic symptoms. In conclusion, the implementation of innovative educational models favors the quality of teaching in the selected cases.

Key words: Attention Deficit Hyperactivity Disorder, Technology, Attentional Processes, Memory

RESUMEN

Influencia de los soportes digitales sobre las capacidades mnésicas y atencionales del alumnado con TDAH

El objetivo del presente estudio se centra en analizar la influencia que el uso de los dispositivos digitales puede tener sobre los procesos de aprendizaje del alumnado que presenta TDAH, estableciendo una clara concomitancia entre la sintomatología clínica del trastorno y las principales dificultades de aprendizaje que este colectivo presenta. Siguiendo un enfoque mixto se recoge información de una muestra total de 91 alumnos de Educación Primaria escolarizados en las provincias de Almería y Granada, considerando como criterio de inclusión la presentación de un cuadro clínico compatible con TDAH y siendo confirmado dicho perfil mediante un cuestionario inicial Escala de Magallanes. *Concretada la muestra se emplea el* Test de memoria y aprendizaje (TOMAL) *integrado por una batería principal de seis subtest con la finalidad de determinar la capacidad de recuerdo demorado y procesos atencionales de los sujetos participantes. Los resultados evidencian una mejora significativa de las tareas atencionales y mnésicas de los participantes en soporte digital comparativamente con el escrito, siendo manifiesta una mayor motivación por el uso de los dispositivos digitales con independencia de la edad o sintomatología característica. Como conclusión, la implantación de modelos educativos innovadores favorece la calidad de la enseñanza en los casos seleccionados.*

Palabras clave: *trastorno por déficit de atención e hiperactividad, tecnología, procesos atencionales, memoria*

1. INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent childhood and adolescent neurodevelopmental disorders. Chronic impairments of hyperactivity, impulsivity, and attention with onset typically before age 12 years are referred to as it. These impairments substantially interfere with functioning in the customary life of school, social, and home settings. ADHD is rooted in a neurobiological multifactorial etiology with genetic and environmental underpinnings and neural circuit changes underlying attentional regulation, emotional regulation, and impulse control. Additionally, the disorder comorbidities at high rates with other psychiatric disorders such as anxiety, depression, and learning disability, adding to presentation complexity for affected individuals (American Psychiatric Association, 2022).

In the classroom, ADHD is defined by pervasive inattention, impulsivity, disorganization, and conduct problems that lead to underachievement, peer social struggles, and high rates of classroom disruption (Barkley, 2021). Educational accommodation and support strategies that are individualized are needed with these challenges in consideration to promote inclusion and improve academic and psychosocial adjustment among students with ADHD. Despite all the research done on ADHD, its impacts in the educational setting are an area yet to be exhaustively researched, particularly the efficiency of technology resources to bridge cognitive and behavioral impediments (Palacios, 2022).

Historically, ADHD has been explained by varied theoretical constructs, extending from moralizing explanations of children's misbehavior to neurodevelopmental and biological models (Still, 1902). The contemporary construct of ADHD recognizes its neurobiological underpinnings, with recent studies emphasizing its high comorbidity with other neurodevelopmental disorders, including Autism Spectrum Disorder (ASD), tic disorders, obsessive-compulsive disorder (OCD), and learning disabilities (Torres et al., 2022). This paradigm shift, officially acknowledged in the DSM-5-TR (2022), has unveiled new avenues of investigation of innovative therapeutic interventions, including pharmacological treatments, psychotherapy, and combined treatments.

A promising avenue of research is the use of Information and Communication Technologies (ICTs) for the treatment of ADHD. In today's technology-dependent world, the use of digital means in teaching is increasingly ubiquitous. Schools need to be considering how new technologies can be utilized in service of pedagogy, not as ancillary aids but as central tools of cognitive growth and personalized learning (Sánchez, 2022). ADHD in the traditional model classroom is very difficult to address, especially where there are big student-teacher ratios

and expert support is not forthcoming. If didactical adjustments are not made, these pupils are more likely to fail academically, be excluded socially, and experience lowered self-esteem (Pozo et al., 2022).

ICTs hold one promising way to improve such challenges by enabling personalized instruction, learning paths that conform to students' needs, and greater student engagement. Through the utilization of stimulating, game-like, and graphically intensive content, the technologies have the potential to engage, sustain attention, and strengthen executive functioning skills (Gutiérrez et al., 2022). Effective utilization of ICTs in educating ADHD students requires:

- Teacher professional development in the use of technology in pedagogical practice in a timely manner.
- Sufficient technological hardware to allow universal access for students.
- Interdisciplinary teaming of teachers, parents, and specialists in planning interventions based on individual needs.

Additionally, one must consider potential obstacles to digital accessibility for students with ADHD and adapt technological tools accordingly. Successful integration models must incorporate co-designed learning environments, interprofessional collaboration, and ongoing impact assessment to maximize the benefits of ICTs for students with ADHD (Linscott & Van Os, 2010).

Rodríguez et al. (2022) believe that learning underachievement associated with ADHD typically stems from the inflexible, mass school structure with little room for responding to various cognitive profiles. Classical models of education with inflexible calendars, limited adaptation capacity, and strong emphasis on mechanical memorization are not capable of reaching students who are suffering from ADHD (Ramírez, 2019). However, existing pedagogical approaches, such as project-based learning, differentiated instruction, and computer-based interventions, have yielded positive effects on attention regulation, academic performance, and self-esteem among ADHD students (Pilamunga, 2022).

Considering the phenotypic diversity of ADHD, curriculum accommodations are a challenging task with limited specialized interventions, insufficient teacher training, and the structural inflexibility of traditional school systems. This research investigates how digital technologies can be used as potent interventions in the form of real-time feedback, individualized learning experiences, and interactive engagement strategies to improve the cognitive and socio-emotional functioning of students with ADHD (Zambrano & Johanna, 2022).

This research thus aims to:

1. Evaluate the influence of digital technologies on attention and memory processes in students with ADHD, with variability by age and subtype of ADHD.
2. Offer empirical evidence of the effectiveness of digital technologies for ADHD learning processes.
3. Contrast cognitive outcomes of digital learning and paper learning in ADHD students.

Based on the available research up to this point, we propose that:

- Implementation of electronic technologies in learning procedures will facilitate gaining knowledge by ADHD students since they offer an interesting, flexible, and interactive learning procedure as opposed to the traditional ones.
- Electronic tools will enhance attention span and intellectual curiosity among ADHD students, allowing them to sustain focus on activities for longer hours as opposed to paper-based procedures.

2. METHOD

This was a mixed-method study with a population of 91 primary students from the academic year 2021/2022 (Table 1). The population was composed of students from different schools in Granada and Almería with greater inattention than impulsiveness or hyperactivity behavior. The diagnosis was already established by the health team and Educational Guidance Team (EOE).

Table 1. Sample Distribution

Educational Stage	ADHD Subtype	6-7 years	7-8 years	8-9 years	9-10 years	10-11 years	11-12 years	Total
First Cycle	ADHD-I	3	5	-	-	-	-	8
	ADHD-H	4	3	-	-	-	-	7
	ADHD-C	2	4	-	-	-	-	6
Second Cycle	ADHD-I	-	-	10	8	-	-	18
	ADHD-H	-	-	4	7	-	-	11
	ADHD-C	-	-	3	5	-	-	8
Third Cycle	ADHD-I	-	-	-	-	10	11	21
	ADHD-H	-	-	-	-	2	1	3
	ADHD-C	-	-	-	-	7	1	8
TOTAL		9	12	17	20	19	13	91

Note: ADHD-I = Inattentive subtype; ADHD-H = Hyperactive/Impulsive subtype; ADHD-C = Combined subtype.

All participants had the permission of their school administration and legal guardians, with confidentiality and anonymity being assured. The choice was random, and it was voluntary, having no impact on academic performance.

To assess primary ADHD symptoms and their effect on school performance, the Magallanes Scale for Visual and Auditory Attention (EMAV) was employed. It is a 23-item scale to measure inattention, hyperactivity, and impulsivity through systematic teacher observation (González-Castro et al., 2011). It has been validated and shown to be a valid tool in screening ADHD symptoms in school settings from previous studies (González-Castro et al., 2014; Fernández-Morales et al., 2019).

In addition to this, the Test of Memory and Learning (TOMAL) was used to assess memory recall and attention abilities (Reynolds & Voress, 2007). The 10 subtests were used, and six were employed to administer delayed recall ability and sustained attention (see Table 2).

Both tests were administered in paper-and-pencil and computer modes under controlled testing conditions to give the same level of noise, light, and exposure time. The procedure was split into four phases:

1. **Familiarization Stage:** Both modes were familiarized with the participants in order to eliminate bias.
2. **Paper-Based Testing:** Attention and memory standardized tasks in paper form were provided.
3. **Digital Testing:** The same tasks were simulated in an interactive computer mode.
4. **Data Collection and Analysis:** Performance was measured in terms of accuracy, response time, and rate of task completion.

Table 2. Selected TOMAL Subtests

Subtest	Cognitive Function Assessed
Selective Word Recall (RSP)	Short-term verbal memory
Digits in Direct Order (D)	Associative numerical memory
Story Memory (MH)	Semantic and sequential memory
Location Memory (ML)	Spatial memory
Digits in Reverse Order (DI)	Reverse numerical associative memory
Letters in Reverse Order (LI)	Reverse verbal associative memory

Paired samples t-test compared both modes of performance using mean correct responses (RC) and errors (RE) as the dependent variables. Shapiro-Wilk normality test confirmed data fit the parametric testing assumptions ($p > 0.05$ in most distributions).

- **Paper-Based Format:** Higher attentional stability, fewer interruptions, and higher task completion were experienced by the participants. The above findings are consistent with earlier research wherein it was identified that written information reduces cognitive load and enhances understanding among ADHD students (Muñoz et al., 2020; Sánchez & Valdez, 2021).
- **Digital Format:** While it increased interest and motivation, it also led to more attentional dispersion, which is likely due to distractions through the sense of sight and hearing (Torrico & López, 2022).

Two-way ANOVA was used to examine the interaction of test medium (paper and computer) and ADHD subtype (ADHD-I, ADHD-H, ADHD-C). The results evidenced a significant main effect of test medium on performance ($F(1, 88) = 14.32$, $p < 0.001$), which indicated that computerized support enhanced recall and attention in some but affected stability in others. In addition, there was an interaction effect for format and subtype of ADHD ($F(2, 88) = 6.47$, $p = 0.003$), and it showed that the ADHD-H and ADHD-C students benefited more from the electronic format, while the ADHD-I students were less consistent across formats.

3. RESULTS

Paper and computer testing of mnemonic processes engaged in by participants in performing tasks were conducted, where the participants received a series of words, figures, and places at random intervals. They had to identify and recite these sequences in the proper order. The first trial was completed on paper and a second trial completed online two months later with either the computer lab at the school or one of the tablets provided by the researcher.

Subtests were allocated to subject groups based on cognitive and development disabilities by grade level, with the most that could be given to each group being not more than two subtests and an overall estimated test time of 40 minutes.

Findings yielded statistically significant differences between paper and electronic modes of administration on accuracy, retention capacity, and task completion rates. For each of the groups, the two modes were contrasted by paired samples t-test using the number of correct

responses (RC) and errors (RE) as the dependent measures. Shapiro-Wilk test for normality confirmed data conformed to the assumptions of parametric tests ($p > 0.05$ for most distributions).

The MH and ML subtests were used to examine 6-8-year-olds' recall from short-term memory of numerical and verbal series. The rate of correct response was higher on average in the digital format ($t(44) = 3.21$, $p = 0.002$), and TDAH-H (Hyperactive) group suggested better digital precision in recall. However, TDAH-I (Inattentive) group had elevated error rates (RE) in both formats, particularly among 7-8-year-olds, showing persistent working memory deficit.

Additionally, larger values for standard deviation in the MH subtest across both versions reflect greater variability of performance that is accounted for by variation in attentional stability. The proportion of scores obtained fluctuated around 0.4 on paper but rose to 0.63 on computerized tests, demonstrating a net two-tenths gain in accuracy through the administration of computer-based tests.

In the second cycle of teaching (8-10 years old), there were found differences in achievement in RSP (Recognition of Spatial Patterns) and D (Delayed Recall) tests. Computer format performed better than paper activities again by 0.39 more correct answers on average ($t(44) = 4.15$, $p < 0.001$). Interestingly enough, the TDAH-I group also improved significantly in the D subtest, where their RC went from 14 (paper) to 21 (computer), which may suggest that interactive digital stimuli can strengthen encoding and retrieval processes.

However, standard deviations were small ($\sigma < 0.17$ for most instances), indicating homogeneous patterns of performance within individuals, across ages. There were no age-group differences on each subtest ($p > 0.05$), highlighting that task format, but not the developmental stage, dictated cognitive performance.

RSP and D tests required greater attentional engagement, while ML and MH relied more on previous literacy and numeracy skill. The researcher's facilitation of meaning interpretation was also engaged, particularly in paper-based tasks, where instructions lacked the same immediate feedback as computerized tests.

Third school cycle (10-12 years old), performance trends were also the same as previously seen, with higher accuracy levels on computer tests across all ADHD subtypes. Trends for the DI (Digit Span) and LI (Lexical Identification) subtests were the same, evidenced by a significant rise in the average number of correct answers on computer tests ($t(44) = 3.89$, $p < 0.001$).

There was a clear disparity in LI digital performance within the TDAH-C group, with RC scores being just below their paper scores ($t(22) = 1.85$, $p = 0.07$, on the border of significance). This means that there were students who struggled with lexical encoding in the digital modality, possibly due to increased cognitive load or distraction by digital features.

We used two-way ANOVA to investigate test format (computer v. paper) x ADHD subtype (TDAH-I, TDAH-H, TDAH-C) interaction. Effects indicated a significant test format main effect on performance ($F(1, 88) = 14.32$, $p < 0.001$) since computer assistance had been shown to enhance retention and recall in most. In addition, performance was also affected by ADHD subtype ($F(2, 88) = 6.47$, $p = 0.003$), which means that TDAH-H and TDAH-C groups were improved most by digital formats, while TDAH-I was most inconsistent.

4. DISCUSSION

The mean trend coupled with the low standard deviation sustains the pre-existing data and confirms that computer resources are viable to overcome learning challenges characteristic in ADHD, such as in instrumental courses demanding superior attentional control and behavioral self-regulation.

The integration of Information and Communication Technologies (ICTs) into the classroom can immensely enhance students with ADHD by raising their performance according to motivational needs as well as individualized instruction. Previous studies have also shown that computer platforms can help students with ADHD by saving time, keeping students on task, and providing more compatible with their attentional, impulsivity, and reasoning styles (Pellicano et al., 2021; Lindner et al., 2022). Thus, ICT-based interventions appear to be a valuable tool for ADHD students since they engage executive functions and improve skills like sustained attention, problem-solving, and reading, which become automatic in the future.

These results are in line with the growing evidence that ICTs are necessary to improve academic performance in ADHD students (Pérez et al., 2020; Kerns et al., 2021).

Different research studies suggest that individualized learning is the key to the success of digital interventions (Barkley, 2020). Through providing different content, pace, and difficulty in assignments according to individual students' requirements, ICTs allow ADHD students to learn at their own pace while benefiting from focused support to overcome learning barriers (Medeiros et al., 2022). In addition, the interactivity and dynamism of computer tools have the

ability to engage and hold attention, thus enhancing interest and motivation among students who cannot adapt to traditional learning methods (Tsai et al., 2021).

Another fundamental advantage is immediate feedback from online sources. Immediate feedback allows students to identify mistakes and reinforce weak areas more effectively, enhancing independent and substantive learning (Miranda et al., 2019). The feature also allows teachers to modify teaching approaches in real-time, making the process more responsive and adaptive (Geurts et al., 2020).

The education implications of this study are that in classrooms for ADHD, ICTs should be used with careful training to teachers in the proper deployment of digital technology in the classroom, along with sustained professional development and universal access to essential technology resources (Dovis et al., 2015).

Besides, the development of specialized training programs for the specific needs of ADHD pupils is of particular importance. The programs should consider individual cognitive profiles, deficits of executive function, and common learning barriers (Raggi & Chronis, 2006).

Having access to a multidisciplinary group of professionals, therapists, and teachers is also required to be able to deliver an integrated intervention. For example, occupational therapists can offer organizational and time management skills as part of ICT-based interventions (Green et al., 2020).

Despite the promising findings, this study has some limitations. The population of study and sample size can constrain external validity to other learning environments. Beyond that, additional studies are needed in order to examine in greater depth the processes of ICT effectiveness and identify best practices for implementation (Antrop et al., 2021).

Future studies should try at:

- **Comparison with Other Groups:** Compare the impact of ICT on non-ADHD students to determine the distinctiveness of its impacts.
- **Long-Term Effects:** Determine if the positive impact of ICTs on the academic achievement of ADHD students is long term.
- **Impact on Social Skills:** Investigate the impact of ICT interventions on the social and emotional development of ADHD students.
- **Fair Access to ICTs:** Investigate possible barriers to online access, particularly for underprivileged socioeconomic student populations (Davis et al., 2023).

ICTs may be a friend in need in improving academic achievement and overall quality of life for students with ADHD. There will be success, however, only if there is logical planning to meet individual pupil needs and specific educational requirements. Ongoing research and inter-disciplinary work will maximize the potential of ICTs and result in greater inclusion and higher education quality for all children.

5. CONCLUSIONS

The results of the research confirm the first hypothesis that proper use of new technologies in learning processes and for the personal needs of students with ADHD leads to improved academic performance and inclination towards more interesting and meaningful learning, regardless of symptomatic deviations associated with it (inattentive, hyperactive, or impulsive predominance).

Therefore, the results show the dispersion which had been obtained in each of the tests by age of each group and the corresponding clinical subtype. Thus, the evidence confirms the initial hypothesis with regard to the beneficial role of the implementation of new technologies in the situation in the school towards the students' school performance, particularly students with some type of disability or functional diversity that does not allow them to behave normally in the classroom. This technique allows for the possibility of a more specific adaptation of their own distinct learning process (Gutiérrez & Valero, 2019).

Unlike the computer model, among the results of this study is the spurious replica of words and figures in written form due to similarity between the given written model and its replica. There is a deductive pattern in their application, from the most general characteristics of the model to the more specific ones normally overlooked and accepted as incorrect answers (IR).

Furthermore, there are considerable differences in attentional ability for the first-cycle group ($p<0.001$), where digital indicates a greater percent of correct responses (CR) compared to the physical version (0.63 ± 0.13). Both the ML and MH subtests are discussed in the study of the attentional indices of the sample group, and the results obtained are non-significant regarding the age of each of the individuals, although there are differences between each form of clinical presentation's response. Therefore, based on the information collected, there is more similarity in the extent to which each clinical presentation affects some of the cognitive domains, with the DI and LI tests demanding most effort in terms of attention because of the

associative nature of reverse sequencing tasks. Yet, the limitation of these subtests to the third cycle of Primary Education compensates for the test difficulty with a more advanced stage of cognitive development in the subjects, although the result is conditioned by previous stimulation level and by the flexibility of the subjects to the devices.

In summary, this research experience validates the enhancement of most cases in mnemonic processes, that is, attentional and memory capacity processes in ADHD students at different levels of their learning, using digital forms, either as an adjunct or a substitute for paper forms (Gutiérrez et al., 2022).

These findings foster the vision of a new models approach to teaching, including the restatement of working dynamics in an individualized sense to each one's own peculiar needs. The achievement of such a goal necessitates adequate trainer preparation for the fulfillment of pupils and the new technologies implementation (Terradillos, 2023). Lastly, the purpose of this research is to describe and validate how the use of digital tools in pedagogical care for children with ADHD affects the quality of such care.

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