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ADHD and Text Comprehension: Comparing Virtual Reality and Real-Life Multitasking in an Academic Context

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Abstract: *The impact of digital environments on academic performance, particularly among students with ADHD, has become a significant area of study, especially in the wake of increased online learning during the pandemic. This study evaluates how ADHD symptoms affect text comprehension -including accuracy, retention of quantitative and qualitative data, and logical and working memory - within multitasking academic settings in Virtual Reality (VR) and Real Life (VIVO).*

In our pilot experimental study, we have assessed 30 students (20 in VR and 10 in VIVO) from Greece and Romania. Participants were divided into four groups: a Control and an Experimental group for both VR and VIVO settings. The students were tasked with one (text), two (text and audio), or three (text, audio, and content creation) simultaneous activities to simulate multitasking. We utilized the Adult ADHD Self-report Scale (ASRS) and a grid of text comprehension to measure the impacts.

The findings, analyzed through descriptive statistics and non-parametric tests, revealed significant differences ($p=.000$, $\chi^2=33.036$) in text comprehension based on the environment (VR vs. VIVO), and the presence of ADHD symptoms. Notably, two-thirds of the participants scored above average for ADHD symptoms. Additionally, a comparison of ADHD symptoms scores from pre-tests to post-tests showed a decreasing trend, aligning with existing literature that supports managing ADHD symptoms through psychoeducation.

These results underscore the varying effects of multitasking in academic settings on students with ADHD, and highlight the distinct challenges and benefits presented by VR and VIVO learning environments.

Keywords: *comprehension text; ADHD symptoms; multitasking; Virtual Reality (VR); Real Life (VIVO).*

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Introduction

The current academic environment, heavily influenced by technological advancements, has seen significant shifts in educational practices, especially in how learning and comprehension are facilitated. The integration of Virtual Reality (VR) and the conventional Real Life (VIVO) settings have become prominent platforms of study, particularly in understanding their impact on students with Attention Deficit Hyperactivity Disorder (ADHD). Rogers & MacLean (2023) note that the severity of these symptoms has significantly increased during disruptive events, like the COVID-19 pandemic, as analyzed by Chiorean (2023).

This paper aims to delve into how ADHD symptoms influence text comprehension within VR and VIVO environments, specifically under conditions of multitasking. Previous research has shown that ADHD significantly impairs academic performance across various subjects, with a profound impact on text comprehension skills such as retention, accuracy, and logical processing (Arnold et. al., 2020; Avramovich & Yeari, 2023). Additionally, the cognitive load and the distractions inherent in multitasking scenarios further complicate the learning processes for individuals with ADHD, making this an important area of investigation.

The current study's objective is to comparatively analyze the effects of multitasking on text comprehension between VR and VIVO settings among students diagnosed with ADHD. By employing a structured experimental design with control and experimental groups across both settings, this research intends to provide a detailed understanding of the environmental impacts on learning outcomes.

Hypotheses posited in this study include:

H1: We assume that there exists a difference in text comprehension between Virtual Reality (VR) and traditional in-person learning environments (VIVO) when students perform one, two, or more tasks.

H2: Psychoeducation improves text comprehension under three-task multitasking in VR and VIVO.

H3: The presence of ADHD affects text comprehension to a greater extent under multitasking conditions than under single-task conditions.

H4: The impact of ADHD symptoms on text comprehension is lower after psychoeducation regardless of the reception conditions (VR/VIVO).

Literature review

The modern academic context involves complex interactions among students, professors, and emerging technologies. Multitasking in academic settings impacts text comprehension across various modalities, including written and audio formats, as noted by scholars such as Holland (1968), Ricoeur (1973), Eco (1979), and Fish (1980).

Multitasking in an academic environment leaves its mark on text comprehension, both at the written and audio or text-conceived level (Ricoeur, 1973; Eco, 1979; Holland, 1968). Exploring the impact of variables such as ADHD symptoms, virtual reality, and real-time interactions on text comprehension, can provide insights into how these elements interact and affect the academic experience (Tran et al., 2013; Li et al., 2024).

ADHD is defined by the American Psychiatric Association in the DSM-5 (2013) as a neurodevelopmental disorder marked by significant inattention, disorganization, and/or hyperactivity-impulsivity that are inappropriate for a person's age or developmental level. It is the most thoroughly researched and diagnosed behavioral disorder in children and adolescents, with global prevalence rates ranging from 2% to 7%, and an average of about 5% (Polanczyk et al., 2007; Sayal et al., 2018). ADHD occurs more frequently in boys (5.2%) than in girls (2.7%), and is generally more common in younger individuals and those living in urban areas (Mohammadi et al., 2021).

A meta-analysis aiming to understanding changes in ADHD symptoms for children and youth before and during the Covid-19 pandemic revealed a significant exacerbation of inattention, hyperactivity, and/or impulsivity during the pandemic. Although the overall effect size was small, the findings support emerging evidence that the mental health and behavioral functioning of children and adolescents have been adversely affected by the pandemic (Rogers & MacLean, 2023). According to multi-level models, Sibley et al. (2021) found that individuals with ADHD and higher IQ levels faced more severe symptom exacerbations during the onset of the COVID-19 pandemic.

The most noticeable impact of ADHD symptomatology on students is linked to their overall academic performance (Macan et al., 1990) and their level of text comprehension, be it written, auditory, or content creation, in particular (Yeari et, al., 2021). Research on the academic performance of students with ADHD has found that they score lower on multiple subjects and exhibit weaker learning abilities (Nikkelen et al., 2014; Arnold et. al., 2020; Henning et al., 2022). However, the foundation of learning abilities lies in efficiently understanding reading and text (Petrova, 2019).

Students with ADHD often face difficulties in text comprehension (Parks et al., 2022; Avramovich & Yeari, 2023) from both a quantitative and qualitative perspective of text retention, text accuracy (Botha & Barnard, 2012), text logic (Petrova, 2019), and working memory (RepovŠ & Baddeley, 2006). Analyzing texts in the light of logical-cognitive paradigms (Oba et al., 2017), highlights their construction according to the laws of logical thinking (Mandersloot, 1996), emphasizing the depth of their meanings.

In the field of working memory (Repovš & Baddeley, 2006), cognitive psychology adopts functional models to explain the capacities of cognitive systems. Baddeley and Hitch (1974) in their working memory model provide a detailed perspective on its operation by fragmenting short-term memory into distinct components.

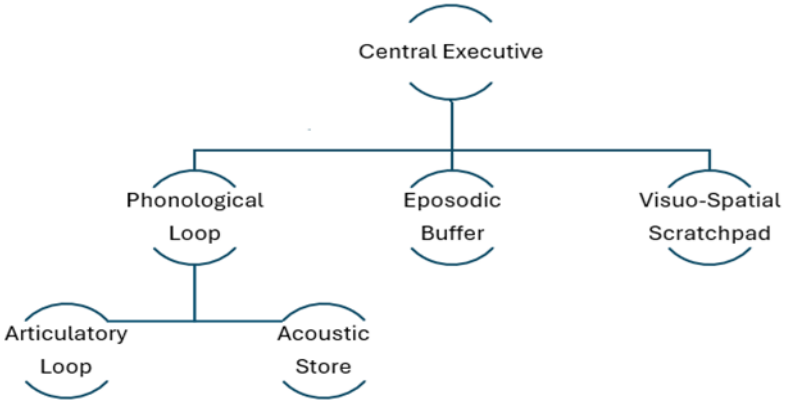


Figure 1. The Working Memory Model (Baddeley & Hitch, 1974)

This cognitive exploration from various perspectives - logical, working memory, and information retention - opens new avenues of

research and contributes significantly to understanding the complexity of the functions of the human mind. Additionally, the precision of language identification through text analysis is contingent on multiple variables, including the length of the text fragment, the training data and algorithms applied, as well as the reading context of the text (Simitsis et al., 2008).

Calvert and Abadia (2020) highlight a distinct contrast between Virtual Reality (VR) environments and traditional real-world settings (VIVO) in terms of text reception. The virtual world, defined by Girvan (2018), and Merchant et al. (2014) as a digital learning environment, possesses unique characteristics: it is computer-mediated, immersive, avatar-represented, interactive, and supports a network of users. Specifically, these VR environments provide immersive experiences by allowing students to observe objects, spaces, or phenomena from multiple perspectives - both externally and internally (Dede et al., 2009). This immersive quality not only makes the virtual world seem rich and authentic, but also enhances learners' engagement by forging a link between virtual and real-world experiences. According to Lin (et al., 2020), such immersion boosts intrinsic motivation factors like interest, task value, perceived competence, and reduces pressure, which Dawley and Dede (2014) argue are critical for enhancing learning outcomes in virtual spaces.

The Cognitive Theory of Multimedia Learning, developed by Mayer in 2005 and further elaborated in 2014, provides a theoretical framework that addresses the initial findings reported in the literature. John Sweller's Cognitive Load Theory (Sweller et al., 2011), argues that learning is more effective when cognitive load is reduced. Constructivist Learning Theory (Piaget, 1971) stresses the importance of constructing new knowledge and meaning through active interaction with the environment and other people. The Sociocultural Theory of Learning, promoted by Vygotsky (1930), emphasizes the role of social interaction in learning (Mălăescu et al., 2024). Anderson's Cognitive Anchor Theory (1976) focuses on the deep and organized cognitive structures that people use to process and retain information. In the context of multimedia learning, this theory can influence the design of materials to facilitate cognitive anchoring processes, and foster the transfer of learning (Anderson, 2007).

Numerous studies have investigated the effects of media multitasking on cognitive functions, with a focus on learning, academic

performance, and multitasking behaviors. Hembrooke and Gay (2002) explored the impact of multitasking, specifically laptop use during lectures, on learning environments. Their study delved into the effects of technology-based distractions on academic performance. Hwang, Kim, and Jeong (2014) examined the underlying motives for media multitasking. The study classified motives as general, medium-specific, and content-specific, illuminating the psychological factors that influence multitasking behaviors. Kirschner and De Bruyckere (2017) challenged the notion of "digital natives" and the multitasking abilities often associated with them. Their study critically analyzed myths surrounding multitasking and digital proficiency. Junco (2012) explored the link between multitasking in class and academic performance. The findings contribute valuable insights into the potential consequences of multitasking behaviors during academic activities. Adler and Benbunan-Fich (2013) examined self-interruptions in discretionary multitasking, offering insights into patterns and behaviors associated with individuals' voluntary interruptions during multitasking activities. Looking at correlations between multitasking and text comprehension, it has been observed that most recent models have near random-chance accuracy (Hendrycks et. al., 2020). The research remains open to discovering and understanding the cognitive implications of multitasking in diverse contexts.

An essential role in the comprehensive management of ADHD is represented by psychoeducational programs recommended by NICE, and the European guidelines recognize them as interventions with great potential for this disorder (National Collaborating Centre for Mental Health, 2009). According to previous studies, little research has investigated the effects of psychoeducation, as defined by Bäuml et al. (2006), on reducing ADHD symptomatology (Montoya et al., 2011; Powell et al. 2022).

Earlier investigations have studied the influence of each of these elements (ADHD symptoms, multitasking conditions, VR or VIVO context) independently, on the comprehension of a written or audio text. Measuring the combined effect of these three elements on text comprehension became the main objective of this study.

Methodology

Participants

In the experimental research design, the participants were 20 students from a postgraduate program in Biomedical Engineering of the School of Medicine, Aristotle University of Thessaloniki (Greece), and 10 students from Babes Bolyai University (Romania). Students were randomly selected on a voluntary and informed basis, and were organized into 4 groups: 10 students in Control Group under VR conditions, 10 students in the Experimental Group under VR conditions, 5 Experimental Group under VIVO conditions, and 5 Control Group under VIVO. The initial criterion for exclusion from the group was ADHD symptomatology. Because 2/3 of the students showed ADHD symptoms in the screening, no students were excluded from the group.

Measures

The Adult ADHD Self-Report Scale (ASRS), designed by Kessler et al. (2005), is an 18-item questionnaire designed to evaluate symptoms of ADHD in adults. This scale, which is based on the World Health Organization's Composite International Diagnostic Interview from 2001, adhering to DSM criteria, consists of two subscales. The Inattentive subscale (9 items), scoring from 0 to 9, measures the individual's ability to focus on details, to organize information, to remember appointments, avoid careless mistakes, and maintain concentration. The Hyperactive subscale (9 items), which scores from 0 to 5, assesses difficulties with sitting still, remaining seated, relaxing, managing speech, interrupting others, and waiting for one's turn.

In a subsequent validation by Kessler and colleagues (2007), the ASRS Screener exhibited internal consistency reliability ranging from 0.63 to 0.72, and test-retest reliability ($r_{Pearson}$) between 0.58 and 0.77. Furthermore, the four-category version of the ASRS Screener exhibited a high level of diagnostic accuracy, as evidenced by its strong agreement with clinician diagnoses and an area under the receiver operating characteristic curve (AUC) of 0.90.

Test of Reading Comprehension Academic Performance. Text comprehension usually refers to accuracy, logic, working memory, and quantitative and qualitative retention (Botha & Barnard, 2012; Petrova, 2019; Repovš & Baddeley, 2006; Oba et al., 2017; Mandersloot, 1996;

Simitsis et al., 2008). The grid evaluates the following coordinates: (1) retention of quantitative data; (2) retention of qualitative data, (3) accuracy of information, (4) logical coherence of events, and (5) working memory by filling in the gaps.

Procedure

Based on "Research Ethics Approval" No. 7480/2/15.06.2023, favorably endorsed by "The Scientific Council of Babeş-Bolyai University" of Cluj-Napoca, the research followed the following coordinates:

- *The data collection*: A pre-test using ASRS, was conducted at the beginning of the experiment, which consisted of four phases. The intervention, involving psychoeducation, was administered to the experimental group between phases three and four. Following this, a post-test using the ASRS was conducted. In this study, we are focusing on the results from the ADHD screening and the Text Comprehension Grid in VR/VIVO.
- After the preliminary briefing of the volunteer students regarding the study and obtaining their informed consent, which included assurances of data confidentiality and the option to withdraw from the research at any stage, they completed the requested pre-evaluation questionnaires.

The intervention:

In *the first stage*, students engage in a 5-minute VR session where they read a news story, followed by a 5-minute interval to respond to related questions. In *the second stage*, they read medical news and listen to an audio lecture in a VR environment for 5 minutes. Subsequently, they spend 10 minutes answering questions about what they have read and heard, in a Google Form document. The *third stage* involves a 5-minute session where students read medical news in VR, listen to a lecture, and reflect on a medical topic they are passionate about. Afterwards, they dedicate 15 minutes to answering questions in Google Forms, and then remove the VR headset. *The psycho-educational intervention* (15 students, experimental group) lasted on average an hour/week, 4 sessions. They included breathing exercises (4 times on inhalation, 4 times pause, 4 times on exhalation, 4 times pause), problem-solving (defining a problem; determining the cause of the problem; identifying, prioritizing and selecting alternative solutions; and implementing a solution), and the acquisition of memorization techniques (acronyms and acrostics, build a

memory palace, mental maps, write it down, and visual connections). The psycho-educational intervention was carried out on another day. *Phase 4* of the experiment was carried out after the psycho-educational sequence. *In the fourth stage*, students spent 5 minutes simultaneously engaging with medical news in VR, an audio lecture, and contemplating a current medical topic. Following this, after removing the VR headset, they invested 15 minutes in answering questions in Google Forms. The *fifth stage* revolved around students completing a post-intervention assessment questionnaire. The experiment was conducted in Greece using VR technology, while in Romania it was conducted without technology.

The medical news was about 250 words long. The optimal time for reading information from a news item of approximately 250 words, regardless of conditions (VR/VIVO), on a first reading for advanced readers (students) was calculated to be around 5 minutes. The audio information in task 2 was little less than 5 minutes. Task 3 for content creation was also 5 minutes, with the volume of information required being generic and restrained. The evaluation time was again 5 minutes for each task.

Data analysis

To demonstrate hypothesis 1, the Freidman nonparametric Test was used. It measured the differences between variables of text comprehension in VR or VIVO conditions. Descriptive statistics provided an overview of data collected in VIVO and VR conditions. Linear regression was employed to identify the correlation between variables of text comprehension and VR/VIVO conditions.

To demonstrate hypothesis 2, we used descriptive statistics to provide an overview of data collected on level of text comprehension before and after psychoeducation, and the Wilcoxon Test measured the before and after psychoeducation levels of text comprehension.

To demonstrate hypothesis 3, after using descriptive statistics to provide an overview of the data collected on ADHD symptoms before and after the experiment, the Kruskal-Wallis test was employed for non-parametric variables to indicate differences among three or more groups.

To demonstrate hypothesis 4, we used the Kruskal-Wallis test to indicate differences among groups, and Spearman's rank correlation test to prove whether ADHD and psychoeducation are inversely correlated.

Results

H1.

The Friedman Test is used to test the correlation between two qualitative variables *Text understanding (Text_understanding_1, Text_understanding_2, Text_understanding_3, Text understanding 4),* and *VR/VIVO conditions*. Following the test, we obtained a significant level of p=.000 and χ^2=33,036. This means that under *VR/VIVO conditions the level of understanding of the text* differs. More specifically, the comprehension level of a text is influenced by the environment in which it is received. In our analysis, we observed an increase in the overall text comprehension in the virtual reality environment compared to the real reality environment, without considering each component of the text comprehension level.

Using descriptive statistics, an increase in values for text comprehension levels, along with all its components, was observed in the VR environment and the VIVO environment across most variables. For a single task (*reading text*), *accuracy* (Mvivo =.90, Mvr=.65) and *working memory* (Mvivo =3.50, Mvr=.95) are higher in VIVO, while *logic* (Mvivo =.90, Mvr=1.00) is better in *VR*. If we have 2 tasks (*reading text and audio text*) at the same time, for *understanding reading text accuracy* (Mvivo =.60, Mvr=.85), *logic* (Mvivo =.80, Mvr=.90) are better in *VR,* and *working memory* (Mvivo =2. 90, Mvr=1.00) is better in *VIVO*, while for *audio text working memory* (Mvivo =.30, Mvr=.65) is better in *VR*, and *text comprehension* (Mvivo =.30, Mvr=.25) is better in *VIVO*. And if we have 3 tasks at the same time (*reading text, audio text, text creation*), performance in *VR* is better than in *VIVO* for all three: *accuracy* (Mvivo =.44, Mvr=.95), *logical* (Mvivo =.60, Mvr=.95), and *working memory* (Mvivo =.50, Mvr=1.00). After the psychoeducation phase in the three simultaneous tasks (*reading text, audio text, text creation*), the students obtained similar results between the two reception conditions (*VR/VIVO*), but also an increase in *accuracy* (Mvivo =.90, Mvr=.65).

Generalized linear model analysis indicates a significant influence of the environment (VR versus VIVO) on text comprehension with 1 task. The corrected model showed that the independent variable, environment (VR_VIVO), had a significant effect on text comprehension ($F_{(1, 28)} = 30.290$, $p < 0.001$). This indicates that there are significant differences between participants exposed to the virtual reality environment and those exposed to real life in regard to the level of text comprehension with a single task. The high intercept (792.067) indicates

that, in the absence of other variables, there is significant text comprehension. In addition, the sum of Type III squares for the (VR_VIVO) environment (35,267) is significant ($p < 0.001$), indicating that there are significant differences in text comprehension between VR and VIVO environments. The adjusted R-squared value is 0.502, suggesting that approximately 50.2% of the variation in text comprehension is explained by our model. This indicates that our model effectively explains a significant proportion of the variation in text comprehension.

Table 1. Tests of Between-Subjects Effects
Dependent Variable: Text_understanding_1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	35,267[a]	1	35,267	30,290	,000
Intercept	792,067	1	792,067	680,303	,000
VR_VIVO	35,267	1	35,267	30,290	,000
Error	32,600	28	1,164		
Total	838,000	30			
Corrected Total	67,867	29			

a. R Squared = ,520 (Adjusted R Squared = ,502)

Also, significant correlations between the *working memory, accuracy, audio memory, audio understanding*, and the examination format:

Table 2. Spearman's correlation

Correlations

			Examination format	working memory 1	working memory2	working memory 3	the accuracy of the information 3	audio 3.1 - memory	audio 3.2 - understand
Spearman's rho	Examination format	Correlation Coefficient	1.000	-.882**	-.772**	.632**	.530**	-.433*	-.544**
		Sig. (2-tailed)	.	.000	.000	.000	.003	.017	.002
		N	30	30	30	30	30	30	30
	working memory 1	Correlation Coefficient	-.882**	1.000	.832**	-.493**	-.471**	.558**	.476**
		Sig. (2-tailed)	.000	.	.000	.006	.009	.001	.008
		N	30	30	30	30	30	30	30
	working memory 2	Correlation Coefficient	-.772**	.832**	1.000	-.398*	-.364*	.536**	.445*
		Sig. (2-tailed)	.000	.000	.	.030	.048	.002	.014
		N	30	30	30	30	30	30	30
	working memory 3	Correlation Coefficient	.632**	-.493**	-.398*	1.000	.671**	-.365*	-.237
		Sig. (2-tailed)	.000	.006	.030	.	.000	.047	.207
		N	30	30	30	30	30	30	30
	the accuracy of the information3	Correlation Coefficient	.530**	-.471**	-.364*	.671**	1.000	-.442*	-.237
		Sig. (2-tailed)	.003	.009	.048	.000	.	.014	.207
		N	30	30	30	30	30	30	30
	audio 3.1 – memory	Correlation Coefficient	-.433*	.558**	.536**	-.365*	-.442*	1.000	.145
		Sig. (2-tailed)	.017	.001	.002	.047	.014	.	.444
		N	30	30	30	30	30	30	30

	audio 3.2 - understand	Correlation Coefficient	-.544**	.476**	.445*	-.237	-.237	.145	1.000
		Sig. (2-tailed)	.002	.008	.014	.207	.207	.444	.
		N	30	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

These results suggest that a VR environment may not be beneficial while memorizing information, however, it may have a positive effect when multitasking. Still, that effect is negative in the case of multitasking with audio understanding.

For the operational elements of the text comprehension concept (*quantitative retention, qualitative retention, accuracy, logical, working memory*), a series of results have been obtained. Comparing the recorded results of the reading comprehension tests based on the medium of the test (*VIVO or VR*) shows the following. The independent variable Mann-Whitney U test shows that there is a significant difference between the results of VIVO and VR in the case of the variables Working memory 1 (U=9.5, p<.001) 2 (U=30, p=.001) and 3 (U=50, p=.028), audio 3.1 (U=55, p=.049) and 3.2(U=40.5, p=.007), and Accuracy 3 (U=55, p=.049) (multitasking conditions).

Table 3. Mann-Whitney U Test

Test Statistics[a]

	working memory 1	working memory 2	working memory 3	audio 3.1 memory	-audio 3.2 understand	-the accuracy of the information 3
Mann-Whitney U	9.500	30.000	50.000	55.000	40.500	55.000
Wilcoxon W	219.500	240.000	105.000	265.000	250.500	110.000
Z	-4.752	-4.158	-3.406	-2.332	-2.931	-2.856
Asymp. Sig. (2-tailed)	.000	.000	.001	.020	.003	.004
Exact Sig. [2*(1-tailed Sig.)]	.000[b]	.001[b]	.028[b]	.049[b]	.007[b]	.049[b]

a. Grouping Variable: Examination format
b. Not corrected for ties.

The VR may have better results for some variables (Working memory for 1, 2, and 3 tasks, audio text for 3 tasks, accuracy for 3 tasks) in multitasking conditions, but not for the whole text comprehension.

H2.

Regarding text comprehension when the subject is exposed to a single task, M=5.07 and SD=1.530. For the stage where the student is exposed to two tasks simultaneously, data differs for reading comprehension (M=5.17, SD=1.577), and audio text comprehension (M=0.83, SD=1.037) in multitasking mode. When the student is exposed to three simultaneous tasks, in the multitasking mode, M=3.27 and SD=0.868 for reading comprehension, M=1.33 with SD=0.959 for audio text comprehension, and M=2.07 with SD=0.785 for creative text.

In stage 4, after psychoeducation, results show for reading text, a mean of 4.27 with a standard deviation of 0.785, for audio text (M=1.33, SD=0.959), and creative text (M=2.37, SD=0.702). All tests were conducted in multitasking mode. These comparisons show that the level of text comprehension after psychoeducation increased.

Table 4. Descriptive Statistics before and after psychoeducation

	Mean	Std. Deviation	N
ADHD 1	3,00	1,414	30
I1	4,50	2,782	20
H1	3,40	2,088	20
ADHD 2	3,05	1,638	20
I2	4,65	2,758	20
H2	3,25	2,124	20
VR vs VIVO	,63	,490	30
Text_understanding_1	5,07	1,530	30
Text_understanding_2	5,17	1,577	30
create content 2	2,30	,702	30
Text_understanding_3	3,27	,868	30
Text_understanding_4	4,27	,785	30
Auidotext_understanding_1	,83	1,037	29
Auidotext_understanding_2	1,33	,959	30
Auidotext_understanding_3	1,33	,959	30
create content1	2,07	,785	30

The Wilcoxon signed pair test shows if there is a change between the two related variables after and before psychoeducation. Significant variable pairs were identified as shown in the following table:

Table 5. Wilcoxon Test

Test Statistics[a]

	working memory 3 - working memory 1	working memory2 - working memory 1	retention of quantitative data 2 - retention of quantitative data 3	retention of quantitative data 2 - retention of quantitative data 4	retention of qualitative data2 - retention of qualitative data 3	audio 2.2. - understand - audio 2.2 - understand	audio 3.2 - understand - audio 2.2. - understand
Z	-2.777[b]	-1.289[b]	-2.950[c]	-2.558[c]	-2.111[b]	-3.424[c]	-1.375[b]
Asymp. Sig. (2-tailed)	.005	.197	.003	.011	.035	.001	.169

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.
c. Based on negative ranks.

The Wilcoxon table shows that there is a significant change in several related variables in different phases of the experiment due to psychoeducation.

The correlations show that there is a positive correlation between *WM1* and *WM2*, while *WM3* is negatively correlated to *WM1*(r(28)=-.503, p=.005) and *WM2* (r(28)=-.400, p=.028), while it is positively correlated to *WM 3, WM 4* (r(28)=.877, p<.001). In general, these results show that as the number of tasks increases, working memory decreases, while people who do well with one task may do well with two, but not to the same extent as with a single task. Multitasking with 3 tasks can have a significant negative impact on outcomes compared to the impact of multitasking with 2 tasks. L1 and L2 (r(28)=.473, p=.008) have a significant positive correlation, and so do L3 and L4. This could show that individuals who perform at the logic level when solving one task are likely to retain this ability on an increased number of tasks (2 or 3). AU2 and AU3 also show a significant difference between the two variables. While they are also positively correlated (r(28)=.368, p=.045), at the level of audio text comprehension, multitasking conditions with 2 or 3 simultaneous tasks do not affect the individual's performance before or after the instructional step.

H3. The results showed that 2/3 of the students scored above average ADHD symptoms.

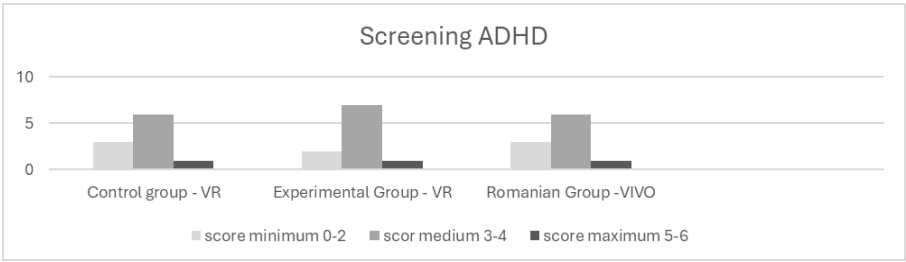


Figure 2. Score ADHD Symptoms

The analysis provided by descriptive statistics revealed an increase in the mean between pre-test and post-test for the *ADHD score* (M pre-test=3.00, SD=1.414), with post-test values of M=3.05 and SD=2.782. In the case of the *Inattention pre-test*, M=4.05 and SD=2.782, and post-test values show an M=4.65 with a SD=2.758. For *Hyperactivity*, in the pre-test, M=3.40 and SD=2.088, and in the post-test, M=3.25 with SD=2.124. This means that after the experiment, ADHD symptoms manifested more intensely.

The Kruskal-Wallis test showed significant differences based on *ADHD1* in the case of *L3* and *WM4*. If grouping by *Hyperactivity*, it showed significant differences in the variables *WM1, A2,* and *QR4*. The participants were separated into groups based on their *ADHD score* (0-6) and *Hyperactivity* score (0-9). This means that the prevalence of ADHD manifestations affected logic and working memory when the student had to solve three tasks at the same time. For those with hyperactivity symptoms, working memory and accuracy for a single work task were affected, as well as the amount of information retained when asked to solve three tasks simultaneously.

Table 6. Correlation between ADHD1 and L3, MW4

Test Statistics[a,b]

	the logical of the information 3	working memory 4
Kruskal-Wallis H	12.350	17.760
df	5	5
Asymp. Sig.	.030	.003

a. Kruskal Wallis Test
b. Grouping Variable: overall score ADHD 1 =6

Table 7. Correlation between H1 and WM1, A1, QR4

Test Statistics[a,b]

	working memory 1	the accuracy of the information 2	retention of quantitative data 4
Kruskal-Wallis H	19.000	13.039	12.920
df	6	6	6
Asymp. Sig.	.004	.042	.044

a. Kruskal Wallis Test

b. Grouping Variable: Hyperactivity/Impulsivity ADHD1 = 9

ADHD1 was proven to have a significant positive correlation only with *L3* (r(28)=.386, p=.035).

Table 8. Correlation between ADHD1 and L3

Correlations

		overall score ADHD 1 =6	the logic of the information 3	working memory 4
overall score ADHD 1=6	Pearson Correlation	1	.386*	.240
	Sig. (2-tailed)		.035	.202
	N	30	30	30
the logic of the information 3	Pearson Correlation	.386*	1	.447*
	Sig. (2-tailed)	.035		.013
	N	30	30	30
working memory 4	Pearson Correlation	.240	.447*	1
	Sig. (2-tailed)	.202	.013	
	N	30	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

H4.

When looking at VIVO results, the Kruskal-Wallis test has not shown any significant differences, however, *ADHD1* was significantly correlated with *L3* (r(8)=.721, p=.019) and *CC1* (r(8)=.784, p=.007).

Particularly *ADHD 1* had a stronger correlation with *L3*, *AU1,* and CC1, compared to its correlation with the entire dataset. This correlation was not identified in the VR data. This suggests that in a VIVO environment, the effect of ADHD on logical comprehension, audio comprehension, and content creation under multitasking conditions had a more consistent impact.

Table 9. Correlation VIVO Data

			ADHD 1	A U 1	L3	C C1
Spearman's rho	ADHD 1	Correlation Coefficient	1,000	,633*	,740*	,788**
		Sig. (2-tailed)	.	,049	,014	,007
		N	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

After the psychoeducation stage, there was no longer identified an impact of ADHD on text comprehension at any level.

When looking at *VR Data*, the Kruskal-Wallis test found significant results in groupings based on *H1*, in the case of *WM1*, *A1*, and *QR4*, which are consistent with the findings on the entire dataset. This suggests that the difference across the dataset might be due to the VR sample.

The Kruskal-Walis test further showed a significant result when looking at *H2*, in the case of *qr4*. When looking at *ADHD 2*, *qr1* was also significant.

Table 10. Test Kruskal-Walis between H2, qr4

Test Statistics[a,b]

	retention of qualitative data 4
Kruskal-Wallis H	19.000
df	6
Asymp. Sig.	.004

a. Kruskal Wallis Test
b. Grouping Variable: Hyperactivity/Impulsivity ADHD 2=9

Table 11. Test Kruskal-Walis between ADHD2, qr1

Test Statistics[a,b]

	retention of qualitative data1
Kruskal-Wallis H	16.000
df	4
Asymp. Sig.	.003

a. Kruskal Wallis Test
b. Grouping Variable: overall score ADHD 2 = 6

The Wilcoxon Test revealed a negative Z value (Z = -1.973), indicating that in the pre-test, ADHD values were lower compared to the post-test (ADHD values increased). There was a significant difference between pre-test and post-test scores for ADHD for p=0,048 level of significance.

Table 12. Wilcoxon Test

Test Statistics[a]

	overall score ADHD 1 =6
Mann-Whitney U	57,000
Wilcoxon W	112,000
Z	-1,973
Asymp. Sig. (2-tailed)	,048
Exact Sig. [2*(1-tailed Sig.)]	,061[b]

a. Grouping Variable: Examination format

b. Not corrected for ties.

In the VR conditions, before psychoeducation, the correlation showed statistical significance (p=.015) for *ADHD2* from the post-test stage and Quantitative Retention 1 (QR1) in the single task condition (reading the text in VR), and score *ADHD2* from the post-test stage and audio understanding 2 (AU2), recorded in the third phase of the experiment, with 3 tasks conditions (reading the text, listening to the different audio, and creating the new text) exist statistical significance (p=.039). This means that the impact of the total ADHD score was felt more at the level of quantitative text retention, when there is a single stimulus, and audio text comprehension under multitasking conditions.

Table 13. VR conditions before psychoeducation

Correlations

			ADHD 2	QR1	AU2
Spearman's rho	ADHD 2	Correlation Coefficient	1,000	-,538*	,465*
		Sig. (2-tailed)	.	,015	,039
		N	20	20	20
	QR 1	Correlation Coefficient	-,538*	1,000	-,341
		Sig. (2-tailed)	,015	.	,141
		N	20	20	20
	AU2	Correlation Coefficient	,465*	-,341	1,000
		Sig. (2-tailed)	,039	,141	.
		N	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

After the psychoeducation stage, there was no longer a significant impact of ADHD on text comprehension at any level.

Discussions

The statistical analysis has demonstrated significant differences in the level of text comprehension based on the reception environment - VR or VIVO. It has demonstrated a difference between the groups exposed to VR or VIVO. Regression coefficients have shown an inversely proportional relationship between the repetition context and the level of text comprehension. The difference also occurs when students are exposed to a single task, two or three tasks concurrently. When comparing the means of the text comprehension levels together with all its components, an increase in values was observed for the VR environment for most variables compared to the VIVO environment. For a single task (writing a text), the VIVO conditions were best suited for text comprehension. The data are consistent with those identified in the previous research (Calvert & Abadia, 2020). Following the application of psychoeducation, it was observed that the level of text comprehension increased.

The results of the experiment suggested that a VR environment is not favorable for a single task, when there is little information to understand, but has a positive impact when students must do several tasks simultaneously. In the case of the results obtained from the descriptive statistical analysis of ADHD symptoms, an increase in values was observed after experimenting at the general score level, an increase in the score at the inattention level, and a decrease in the score at the hyperactivity level. The complexity of the experiment, along with the involvement of students, generated attention demands, but also necessitated better management of hyperactivity levels. From the descriptive statistical analysis, it can be inferred that comprehension of text when a student is exposed to multiple tasks (2 or 3) showed an increase in text comprehension from one task to two tasks, but a decrease from one or two tasks to three tasks. The data is consistent with a series of similar recent studies (Stokes et al., 2022; Cho et al., 2022; Oh et al., 2024).

After the psychoeducation stage, when students were trained to apply memory, concentration, and content prioritization techniques, their results in written/reading text comprehension improved. For audio text comprehension in the multitasking mode, there was an increase in comprehension level from two to three tasks, and a similar situation after psychoeducation. In the case of text creation, an increase in performance was observed after the psychoeducation stage. Similar

results were obtained in the studies conducted by Ferrin et al. (2014), as well as Li, Nair & Naqvi (2024).

Another aspect derived from the statistical analysis shows that in the multitasking mode, scores progressively decreased in 2 or 3 tasks. Subjects exposed to multiple tasks concurrently, achieve lower scores on the tasks proposed.

Conclusions

The present pilot study aimed to test the latest theories suggesting that the influence of technology and the recent pandemic has led to an increase in the frequency of ADHD symptoms among young digital consumers. Additionally, the effect on cognitive performance, the level of comprehension of content, and the ability to create content are also affected by the presence of ADHD symptoms. Another commonly observed trend in today's academic (professional and personal) life is multitasking, which has been proven to have negative effects on text comprehension levels.

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