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Research Article

Effects of the Use of Different Digital Media on the Assessment of Executive Functions Using the Tower of London, a Randomized Cross-over Trial

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Abstract

In the field of education and training, the use of new information and communication technologies (ICTs), particularly educational technologies (EdTech), has increased significantly in recent years. Among these, the adoption of Virtual Reality (VR) is expanding rapidly. While recent studies emphasize the importance of considering individual differences in executive functions (EFs)-a set of cognitive processes involved in planning and regulating thoughts and actions-the aim of our study was to examine the impact of various digital media (digital tablets, VR with joystick, VR with hand-tracking, and conventional support) on EFs using the Tower of London task implemented on both tablet and VR platforms. A total of 48 participants (32 women and 16 men) completed the Tower of London test in all four conditions. Most participants were apprentices in the fields of sales and hairdressing, with no prior exposure to instruction using tablet-based or VR-based tools. Statistical analyses (t-test and Bayes repeated measurement) were conducted on several indicators, including the number of movements, problem-solving time, and the time-to-movement ratio. Among these, the latter emerged as the most informative, as it normalizes performance across the four experimental conditions. Data analysis revealed that performance with VR supports (both joystick -20.21- and hand-tracking -21.75) was lower compared to tablet use (13.33), Cohen's d = 1.613 and 2.01. This difference may be explained by participants' lack of familiarity with VR, which imposes greater cognitive demands (cognitive load) than the more conventional tablet interface. These findings suggest that, before integrating VR into educational settings, it is essential to ensure that students are sufficiently familiar with and comfortable using this technology. In other words, while VR represents a promising opportunity to enhance training, its implementation must carefully consider the limitations associated with learners' executive functions.

Keywords

Executive Functions, Tower of London, Tablet, VR Joystick, VR Hand-tracking

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1. Introduction

The use of new information and communication technologies, and more specifically educational technologies, has revealed its full potential transforming the ways of learning and teaching. Information and communication technologies encompass a wide range of tools, technologies and infrastructures for the creation, processing, storage and communication of information in a variety of fields. Educational technologies are all digital tools designed to support, enrich and transform teaching practices. These tools promote personalized learning pathways, provide access to a variety of resources, and facilitate interaction between teachers and learners. However, if their effective integration requires careful consideration of educational choices, adequate teacher training, and critical reflection on equity of access, the learners' experience -e.g., computer skills and computer self-efficacy [51]; student profile -e.g., sex, spatial ability [15] and digital literacy levels [52] cognitive abilities -e.g., inhibition control [21] must be taken into account. This work aims to contribute to this body of knowledge by studying the impact of digital media (digital tablets and Virtual Reality) on Executive Functions (EFs) - a set of cognitive processes involved in planning and regulating thoughts and actions - using the Tower of London test.

2. Literature Review

Educational technologies aim to transform learning and teaching by integrating innovative, user-centered approaches for learners, teachers, and trainers. By personalizing educational experiences, these technologies help reduce inequalities in access to knowledge and enhance learner engagement.

The use of devices such as digital tablets exemplifies their potential to make education more accessible, interactive, and tailored to individual needs [13, 28, 43, 52, 53] Tablets provide quick and easy access to a wide range of educational resources, facilitate interactive learning that increases engagement and motivation, enable real-time feedback from teachers through educational apps and platforms, allow for the customization of learning paths, and are lightweight and portable, allowing students to carry their learning materials easily [25, 66] However, tablet use in educational settings is not without drawbacks. Potential issues include distraction and excessive screen time, which can lead to health problems such as eye strain, headaches, sleep disturbances, and poor posture [7, 23, 62].

In recent years, virtual reality (VR), has emerged as a promising technology in education. Indeed, VR offers immersive and interactive learning experiences that are transforming traditional pedagogical approaches [49]. The meta-analysis by Lara-Alvarez et al. [32] shows that students in VR learning conditions achieved better outcomes than those using other approaches. These findings are consistent with other studies conducted across various educational levels [34]. VR enables students to fully immerse themselves in interactive environments, fostering increased motivation, improved memory retention, and personalized learning opportunities. It can also support collaborative learning [4, 9, 10, 19, 29, 38, 39, 41, 42, 50].

However, despite the widespread recognition of VR's potential, empirical findings regarding its actual impact remain mixed, particularly in relation to cognitive load. For example, Sari et al. (2023) demonstrated the importance of considering the cognitive demands induced by immersive technologies such as VR (see also [47]). In their literature review, Poupard, Larrue, Sauzéon, and Tricot [48] explore the effects of immersive technologies on learning by focusing on two critical variables: cognitive load and intrinsic motivation. Cognitive load refers to the limited capacity of working memory. It is generally divided into three types: intrinsic load (i.e., related to the complexity of the content); extraneous load (i.e., related to the way information is presented); and germane load (i.e., the effort devoted to processing, constructing, and activating schemas [63] Their findings suggest differentiated effects based on learner profiles: augmented reality appears more effective for novice learners by helping to optimize cognitive load, whereas VR, though more cognitively demanding, may offer greater benefits for experienced learners who are better equipped to handle complex virtual environments. Furthermore, their review examines the link between immersive technologies and intrinsic motivation. Intrinsic motivation refers to the drive to engage in an activity for its inherent satisfaction, interest, or enjoyment [55]. While immersive environments are often assumed to enhance engagement and motivation, their analysis does not yield a definitive conclusion regarding the impact on intrinsic motivation. The literature reviewed in the critical analysis by Lin et al. [35] reinforces the importance of VR in fostering comprehensive student engagement: cognitive (understanding and memory), behavioral (active participation), and affective (motivation and positive emotions). Chen et al.'s [10] meta-analysis further confirms the significant impact of VR on student engagement, particularly highlighting its strong influence on cognitive engagement. The study also finds that immersive VR is more effective than non-immersive VR, especially in teaching procedural knowledge. While this meta-analysis emphasizes VR's strong potential to enhance motivation and active participation, it also stresses the importance of aligning VR applications with learner profiles and instructional goals. However, methodological limitations-such as the lack of statistical data in several studies-restrict the generalizability of these findings.

Like tablets, the use of VR is not without drawbacks. Prolonged exposure can have adverse effects on vision, spatial awareness, and balance. It may also induce what is known as "cybersickness," which can include symptoms such as nausea, dizziness, headaches, eye fatigue, and disorientation [6, 31, 60]

Nevertheless, VR continues to attract considerable interest from educators, researchers, and healthcare professionals because of its unique capacity to immerse individuals in rich, interactive, and stimulating environments. Numerous studies have highlighted its benefits, including applications in cognitive rehabilitation [8, 65] the enhancement of cognitive abilities [24] and the development of more ecologically valid methods for assessing cognitive functions [16, 30].

The work presented in this article originated from the growing demand among training centers to integrate VR into their instructional practices. More specifically, it is based on the developers' perspective within the StartUp "Epistème" that, although VR undeniably holds great promise for learning, its implementation in classrooms must consider learners' cognitive capacities. The findings reported by Lawson and Mayer [33] supported this perspective. They highlight the importance of considering individual differences in EFs in the context of learning through VR. Indeed, students with weaker executive functions are more likely to be negatively impacted by perceptually rich environments, such as those found in VR, compared to students with stronger executive functions.

EFs are a set of high-level cognitive processes that allow individuals to plan, organize, and control their thoughts and actions, thus playing a crucial role in learning. The concept of EFs was first introduced by Luria [36] and has since been developed by many scholars [5, 3, 18, 20, 61, 69]. Although there are several models of EFs [14], that of Miyake et al. [44] remains the most widely accepted. These authors identified three main components of EFs: mental set shifting (''Shifting''), information updating and monitoring (''Updating''), and inhibition of prepotent responses (''Inhibition''). These components work simultaneously and are essential for learning [1, 22, 40, 54] and in visuo-spatial tasks [17]. Moreover, there is a relationship between EFs and Cognitive Load. Several studies have demonstrated that individuals with impaired executive function are more susceptible to cognitive overload in complex, immersive environments [26] For example, learners with stronger executive function capabilities are better equipped to filter out irrelevant information, sustain attention, and adapt strategies, which allows them to manage cognitive load more efficiently ([11]. So, high cognitive load can overwhelm learners with weaker executive control, leading to reduced learning outcomes [46].

In line with Lawson and Mayer [33], who emphasize the importance of considering individual differences in EFs, the aim of our study was to examine the impact of digital media-specifically digital tablets and VR-on the executive functions of apprentices in training who had no prior experience with VR. For that, we used a test recognized in the field: the Tower of London [2, 58, 59]. The long version of the Tower of London was used in this work [12].

The Tower of London task involves a manipulation exercise in which participants must move colored balls between three rods of varying heights to reproduce a given target configuration. Balls must be moved according to two rules: only one ball can be moved at a time, and no rod may hold more balls than its capacity allows. The objective is to solve the problem using the fewest possible moves. Accordingly, the task assesses anticipatory planning (predicting the consequences of one's actions when placing a ball), cognitive flexibility (adjusting actions based on previous moves), and inhibition of impulsive responses (resisting the influence of ball colors).

To evaluate the possible effects of digital media on EFs, we compared the results of the classic version of the test (wooden configuration) with those obtained on a digital tablet. Since VR allows for a variety of approaches, we used two versions to manipulate the balls: one with a joystick and the other with hand tracking.

3. Experiment

3.1. Method

3.1.1. Participants

All participants were volunteers. They had all received an information letter and a consent form. Informed consent was obtained from all individual participants included in the study.Moreover, the training supervisors assured the students that participation in the experiment was not mandatory and that they could refuse to take part without any consequences for them. All participants were apprentices, from the training center SKOOL n'JOB, located 145 Chemin. de la Passio Vella, 66100 Perpignan. Most participants were apprentices in the fields of sales and hairdressing, with no prior exposure to instruction using tablet-based or VR-based tools. In addition, we ensured that they had no previous experience with VR. A total of 48 participants (32 women and 16 men) completed the Tower of London test in all four conditions (classic support, tablet support, VR with joystick, VR with hand tracking). Participants were randomly assigned to one of the four conditions using a counterbalanced cross-over design, ensuring that each participant experienced all four conditions in different orders. The allocation sequence was generated in advance to avoid order effects, and its implementation was concealed from participants. Because of the nature of the intervention, blinding of participants was not feasible. Nevertheless, outcome assessment was standardized across all conditions to minimize bias: data from the tablet and VR conditions were recorded automatically, while performance in the classic condition was evaluated according to a predefined scoring grid. Participation was voluntary, and individuals were informed that they could withdraw at any point without consequences. At the end of each session, participants were invited to report any discomfort or comments regarding the tasks. A licensed psychologist supervised the administration of the classic task and was available to provide support or referral if needed; no participants required such intervention. The study was approved by the Ethics Committee of Paul

Valéry University (n°2022-17 CER UPVM) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

3.1.2. Material

Classic support (see Figure 1). The material consists of two identical configurations placed on a Table 1 meter long and 60 cm wide, positioned 30 cm from the experimenter and 20 cm from the participant. It is a rectangular board (30 cm long and 10 cm wide) with three vertical rods of 1 cm in diameter each. The tallest stem is 9 cm high and can hold three balls. The central stem is 6 cm high and can hold two balls, and the shortest stem is 3 cm high and can only hold one ball. Three hollow balls, each with a diameter of 3 cm, complete the installation. The balls are colored in blue, green, and red.

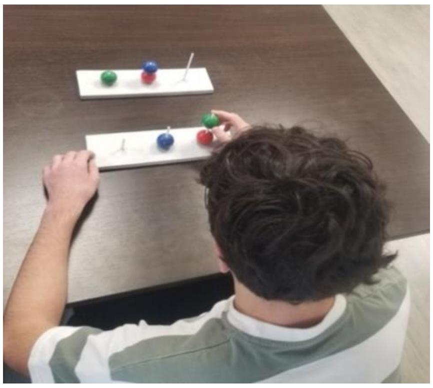

Figure 1. *Classic version.*

Tablet support (see Figure 2). Tablet Specs: Operating System: Android™ 10; Processor: MediaTek MT 8167A/B; 4 ARM Cortex cores, 1.3 GHz; RAM: 2GB / 3GBSTORAGE: 32GB / 64GB; Dimensions: 21.39 x 29.46 x 1.15 cm; Weight: 800g (including built-in case and foldable stand); Screen Size: 10.1" - Touch Technology: 10-point capacitive touchscreen; Resolution: 1280 × 800 px, WXGA, 16:10 aspect ratio.

The device was developed under Android. It consists of a base and three rectangular rods. Each rod has a size equivalent to 1, 2 and 3 balls. The first rod (the tallest) can hold three balls, the second rod (central rod) can hold two balls, and the third rod (the smallest) can only hold one ball. Three spheres represent the hollow balls, which are colored in blue, green, and red. A "Validate" button has also been added to allow detection when the participant confirms their action. The digital elements have been designed to be proportionally accurate to the original physical test. To simulate the effect of perspective and foreground and background as shown in the original test, the base of the model is 50% smaller than the working base. Model Base Dimensions: Base: 383 px x 18 px; Rod 1: 198 px x 10 px; Rod 2: 132 px x 10 px; Rod 3: 66 px x 10 px; Balls: 66 px in diameter. Work Base Dimensions: Base: 573 px x 26 px; Rod 1: 297 px x 10 px; Rod 2: 198 px x 10 px; Rod 3: 99 px x 10 px; Balls: 99 px in diameter.

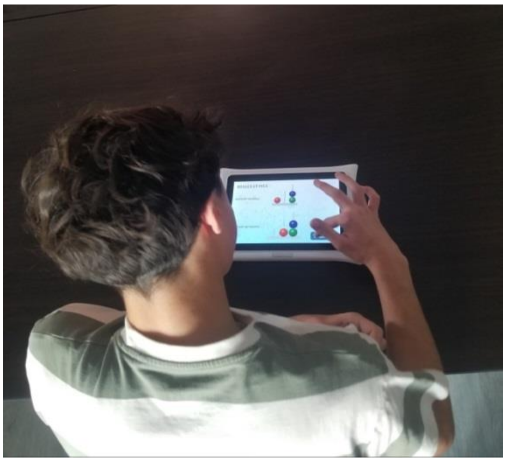

Figure 2. *Tablet version.*

VR joystick and VR hand tracking supports (see Figures 3, 4). Virtual reality headset specs: Meta Quest Pro (1800×1920 pixels per eye; Screen refresh rate: 72Hz / 90Hz; Field of view: 106° horizontally, 96° vertically; Storage: 256 GB; RAM: 12 GB; Battery life: 1-2 hours; Eye tracking; Joysticks included with the headset). The app was created using the Unity 3D engine and places the user in a neutral environment with a large table. There are then two configurations in front of the participant: the furthest one, which is the basis of the model; The closest one, which is the working base of the task.

The environment and virtual elements were designed to match the size and proportions of the original physical trial. The rods have been made thicker to facilitate interaction, especially for inserting the beads. A "Validate" button has also been added to allow detection when the participant confirms their action. The participant can also adjust the size of the table using a handle on the left side. Finally, there is a validation button located on the right, allowing the participant to move to the next level of the task. The only difference between the joystick version and the hand tracking version is that the controller display looks like either hands or VR joysticks.

Figure 3. *VR Joystick support.*

Figure 4. VR Hand Tracking support.

3.2. Procedure

The classic, tablet, VR with joystick and VR with hand tracking supports were counterbalanced among the participants. The instructions were provided orally by the experimenter in the classic condition, while they were displayed on the device's screen for the tablet and VR supports. It should be noted that with the digital media, the experimenter was present but not in the participant's line of sight. The experimenter was present if the medium malfunctioned, but did not interact with the participants during the test, which was not the case with the traditional medium. In the classic condition the experimenter faces the participant, who sees him recording his responses.

As we used the extended version of the Tower of London, the participants had to solve two practical tests, and then the 18 problems in the order established by Shallice. Participants were told that each issue should be resolved in less than a minute.

3.3. Results

Since the purpose of the experiment was not to assess the effectiveness of participants' executive functions, but rather to determine whether the type of support used to assess these functions influenced participants' performance, we retained only those participants who completed all tasks in less than one minute (Table 1). This time was chosen with reference to the study by Anderson et al. (2001), which reports average times ranging from 45 to 90 seconds in children and adolescents.

Table 1. Number of participants who completed all tasks in less than one minute.

Classic support	44
Tablet support	41
VR joystick support	38
VR Hand Tracking	43

Statistical analysis indicates that there is no difference between the types of support used: Chi-square = 3.74, p = 0.29.

We first present the average number of movements needed to solve the tasks, followed by the average time needed to solve them, and finally, we calculated the time/movement ratio to provide an index regardless of the heterogeneity of the support in the execution of the movements to solve the problems.

Statistics were compiled using JASP software [67, 68]. We performed frequentist repeated measurements, Student Test (t), followed by a Bayesian repeated measurement (BF_{10}). In line with the recommendations of [57] a $BF_{10} \geq 10$ will be interpreted as strong evidence for the alternative hypothesis (null), $3 \leq BF_{10} < 10$ as moderate evidence for the alternative hypothesis (null), and a $BF_{10} < 3$ as anecdotal evidence for the alternative hypothesis (null), with a BF_{10} close to 1 considered as no evidence.

3.3.1. Number of Movements (Table 2)

Table 2. Average number of movements required to solve tasks concerning the different devices (Classic support, Tablet support, VR Joystick, VR Hand-Tracking supports).

	n	*M*	*SD*
Classic support	42	7.709	1.425
Tablet support	40	9.642	2.186
VR Joystick support	37	10.448	4.122
VR Hand-Tracking support	42	8.896	1.851

Table 3. Statistical analysis for movements.

		t	*Df*	*p*	*d (Cohen)*	*BF10*
Classic	Tablet	4.796	40	<.001	0.243	941.78
Classic	VR_Joystick	4.150	37	<.001	0.212	139.44
Classic	Follow-up VR_Hand	3.431	42	0.001	0.216	22.68
Tablet	VR_Joystic	1.228	37	0.227	0.175	0.35
Tablet	Follow-up VR_Hand	1.683	40	0.100	0.219	0.61
VR_Joystic	Follow-up VR_Hand	2.157	37	0.038	0.217	1.37

3.3.2. Time (Table 4)

Table 4. Average time (seconds) to solve tasks (Classic support, Tablet support, VR Joysticksupport, VR Hand-Tracking support).

	n	*M*	*SD*
Classic support	43	14.934	3.361
Tablet support	40	13.334	3.959
VR Joystick support	36	20.211	5.250
VR Hand-Tracking support	42	21.751	4.692

Table 5. Statistical analysis for time.

		t	*Df*	*p*	*d (Cohen)*	*BF10*
Classic	Tablet	2.103	40	0.042	0.333	1.23
Classic	VR Joystick	-4.108	36	<.001	-0.685	118.15
Classic	VR Hand Tracking	-8.997	42	<.001	-1.388	$3.23\times10^{+8}$
Tablet	VR Joystick	-7.149	36	<.001	-1.191	554088.45
Tablet	VR Hand Tracking	-9.425	40	<.001	-1.490	$6.948\times10^{+8}$
VR Joystick	VR Hand Tracking	-1.629	36	0.112	-0.271	0.52

3.3.3. Time-to-movement Ratio (Table 6)

Table 6. Average Time-to-movement Ratio for supports (Classic support, Tablet support, VR Joystick support, VR Hand-Tracking support).

	n	*M*	*SD*
Classic support	43	2.076	0.500
Tablet support	38	1.537	0.394
VR Joystick support	38	2.494	0.664
VR Hand-Tracking support	41	2.615	0.436

Table 7. *Statistical analysis for Time-to-movement Ratio.*

		t	*Df*	*p*	*d (Cohen)*	*BF10*
Classic	Tablet	5.984	38	<.001	0.958	27604.78
Classic	VR Joystick	2.776	38	0.008	0.445	4.73
Classic	VR Hand Tracking	5.734	41	<.001	0.885	16390.19
Tablet	VR Joystick	10.074	38	<.001	1.613	3.106×10+9
Tablet	VR Hand Tracking	12.601	38	<.001	2.018	1.726×10+12
VR Joystick	VR Hand Tracking	1.240	38	0.222	0.199	0.039

4. Discussion

The use of digital media in education has expanded rapidly over the past decade. While tablets were once the dominant tool, VR is increasingly taking their place. VR offers possibilities that tablets cannot, particularly by immersing learners in environments that foster collaboration and active engagement. However, as with tablets, the use of VR is not without drawbacks, notably in relation to vision, spatial representation, and balance. Furthermore, research suggests that VR implementation may increase cognitive load, a factor closely linked to the effectiveness of executive functions.

The aim of this study was to investigate the impact of digital media-specifically digital tablets and VR-on executive functions (Efs). To this end, we employed a widely recognized assessment tool: the Tower of London task. The test was implemented on both tablets and in a VR supports. Participants were young adult apprentices engaged in a learning program, all of whom volunteered for the study and had no prior experience with VR. Since our objective was not to evaluate the participants' baseline executive functioning, but rather to examine whether the medium used influenced their performance, we analyzed only the results of those who successfully solved all problems within one minute. However, as one reviewer pointed out, excluding slower participants could compromise the validity of the results by reducing the variability in executive functions and potentially eliminating those who are most affected by the medium (particularly VR).

Statistical analyses were conducted on several indicators, including the number of movements, problem-solving time, and the time-to-movement ratio. Statistical analysis (see Table 2) shows that participants solve problems with fewer movements when using the conventional medium than other media. Also, the other supports are not distinguished from each other by the number of strokes to solve problems. Statistical analysis (Table 4) shows that participants solve problems with similar times with the classic and tablet support. In addition, they show that these two mounts achieve faster times than the other two mounts – i.e., VR Joystick and VR Hand-Tracking. However, these two media are not distinct. The statistical analysis (Table 7) indicates that the time-to-movement ratio is lower with tablet support than with any other support. Furthermore, the classic support yields a lower ratio than both the VR Joystick and VR Hand-Tracking supports. No significant difference is observed between these two VR-based supports. The Bayesian analysis provides a more nuanced perspective: it confirms that tablet support is the least demanding, whereas VR supports are the most taxing. However, the difference between the VR Joystick and the classic support, while statistically reliable, remains moderate. By contrast, the effect observed for the VR Hand-Tracking condition is substantially more pronounced.

To summarize, among these three indicators, the latter emerged as the most informative, as it normalizes performance across the four experimental conditions. Results indicated that tablet-based support was the least demanding, followed by the classic support. In contrast, the two VR conditions yielded comparable outcomes and were associated with the greatest performance costs. Put differently, the VR settings appeared to hinder EFs such as planning, cognitive flexibility, and inhibition.

Nonetheless, several limitations of this study must be acknowledged, which constrain the extent to which these findings can be generalized. While this study highlights that participants perform worse using VR compared to tablets, this result should be interpreted with nuance. The lower performance may be attributed to the high initial cognitive cost (i.e., cognitive load) associated with adopting VR-a technology still unfamiliar to most users [63, 64]. This cost, inherent in learning any new tool, can temporarily divert learners' attention [27], particularly when mastering the use of Hand-Tracking. In addition, the cognitive processes involved in using VR - e.g. visual-spatial-motor coordination - may compete with the cognitive processes involved in the task [45] For future research, it would be necessary to include self-reported measures of cognitive load. Indeed, as Jiang, Mizobuchi and Chignell [26] show there is a close link between cognitive load and Efs, with the latter affecting the former. With gradual practice and appropriate adaptation, it can be assumed that this cognitive load will diminish, thereby allowing the full pedagogical potential of VR to be realized. However, the present findings suggest that before integrating VR into educational contexts, it is essential to ensure that students are sufficiently proficient in using the technology-a point consistent with prior research (see, e.g., [48]). Otherwise, the use of VR may impede rather than facilitate the learning process.

Another limitation of this study is that certain distinctive features of VR-such as immersion, contextualization, and the ability to explore environments inaccessible in the real world-were underutilized in this experimental setting. Consequently, the motivational advantages associated with these features did not outweigh the cognitive costs stemming from participants' lack of VR proficiency. These characteristics are essential for fostering collaborative and experiential learning by placing learners in meaningful and interactive contexts. When these elements are effectively integrated into well-designed educational settings, VR has the potential to provide benefits that substantially exceed those offered by traditional media, such as tablets. Future studies of this nature should assess participants' intrinsic motivation and engagement, as these factors have been shown to mitigate cognitive load and offset the cognitive demands associated with VR use (see, e.g., [48]).

Finally, it could be argued that the sample was not fully representative, as all participants were apprentices from the same training center and only two occupational fields. This limits the generalizability of the findings. Nevertheless, because the majority of participants were apprentices with no prior VR experience, these results should alert educators and trainers to the potential adverse effects of introducing VR into tasks that require the engagement of multiple executive functions.

5. Conclusion

Despite the limitations mentioned, our findings align with existing research highlighting the impact of VR on cognitive functioning, particularly in relation to cognitive load [47, 48, 56]. Most importantly, the study showed that performing a task involving EFs within a VR environment negatively affected the performance of individuals with no prior experience using VR for learning. This result is significant, as previous research has demonstrated that reduced executive function efficiency increases cognitive load, with individuals experiencing greater mental workload when faced with demanding tasks [26].

This issue is particularly relevant for populations such as our sample of sales and hairdressing apprentices, who-despite their motivation to participate in the experiment-had no prior exposure to VR. Introducing them to an environment that simultaneously mobilizes multiple executive functions may therefore have amplified the cognitive cost. While VR immersion can indeed foster motivation [37, 47], it simultaneously requires the effective mobilization of EFs.

Accordingly, these findings call for deeper pedagogical reflection: the integration of VR into education and training should not be regarded merely as a technological innovation, but as a modality that necessitates specific preparation. It appears essential to design accompanying measures, such as gradual immersion progressions or adaptive systems capable of regulating cognitive load in real time. Ultimately, VR represents a promising opportunity to enrich training, provided that the limitations linked to learners' executive functions are carefully addressed. A more precise understanding of these constraints will not only optimize the pedagogical benefits of VR but also help prevent the risks associated with cognitive overload, thereby ensuring a more effective and sustainable integration into educational practice.

Author Contributions

Denis Brouillet: Conceptualization, Formal Analysis, Methodology, Supervision, Validation, Writing – original draft

Daniela Popescu: Funding acquisition, Investigation, Resources, Software

Virgile Thiriot: Investigation, Software

Arthur Alain: Investigation, Software

Adrien Parietti: Investigation, Software

Conflicts of Interest

The authors declare that they have no conflict of interest.

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