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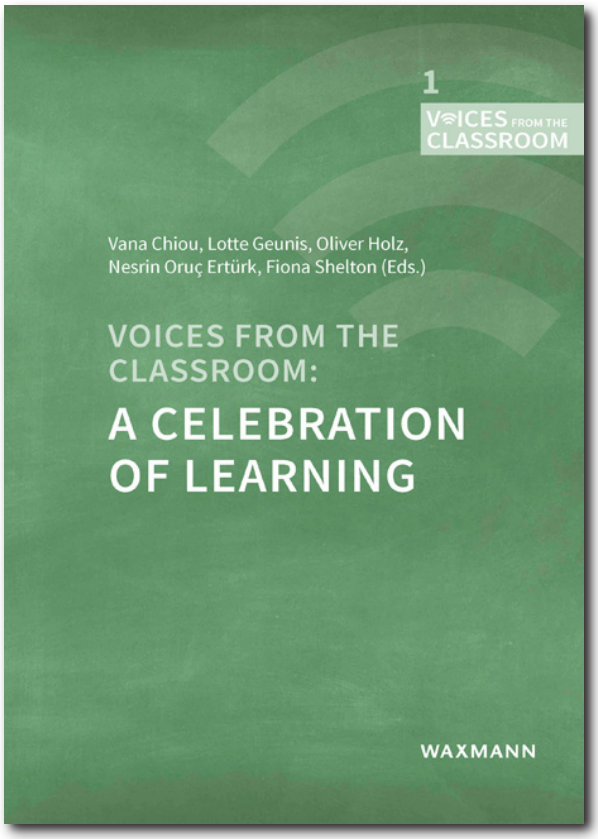

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A 3D Virtual Environment for Easing the Challenging Behaviours of Students with ADHD. A Comparative Case Study

Students with attention-deficit/hyperactivity disorder often display challenging behaviours at school. Given that videos and 3D virtual environments are both considered valuable tools in the context of special education, a study was conducted in order to examine the effects of both on primary school students with the aforementioned condition. Twelve ten-to-eleven years old students were selected, presenting rather severe behavioural problems. Half of them were treated using videos, while to the other half a virtual environment was used. In both cases, a school environment was presented, students observed how they are expected to behave, and had to demonstrate what they have learned. Each student attended a total of four two-hour sessions. An observation protocol was used for collecting data. The subsequent data analysis revealed that students in the second group retained and manifested in the real school environment more acceptable behaviours. Thus, it can be concluded that virtual environments are a promising tool for the behavioural adjustment of students with attention-deficit/hyperactivity disorder.
Keywords: *attention-deficit/hyperactivity disorder, challenging behaviours, Opensimulator, special education, virtual environments*

1 Introduction

Students with special educational needs present a variety of physical and mental impairments, ranging from very mild to extremely severe. In the school context, besides all the other problems these students face isolation, victimisation, dysfunctional social interactions, and the manifestation of behavioural problems are rather common (Nye, Gardner et al., 2016). To counter-balance these challenges, several mechanisms are in place, supporting their academic performance and well-being (e.g., Espelage et al., 2016). Then again, the focus is on students facing severe problems. Students with minor or mild impairments (e.g., with attention-deficit/hyperactivity disorder-ADHD) receive much less attention, to the point of being totally neglected (Office of Special Education and Rehabilitative Services, 2015). Yet, students diagnosed with ADHD often present challenging behaviours at school, rendering their adjustment to this environment problematic (International Statistical Classification of Diseases and Related Health Problems, 2016).

Video-modeling is often used in special education. In essence, the term describes the utilisation of videos for teaching an array of desired behaviours/skills to students with impairments (Mason et al., 2013). In video prompting (a variation of video-modeling), the anticipated behaviour/skill is broken into small segments/steps presented in an equal number of video clips. The child watches the first clip, performs the step that is presented, and continues to the next one (Kellems & Edwards, 2016). Video-modeling is effective, for example, in adjusting students' behaviour (Mason et al., 2013) and in fostering their social skills (Hirsch et al., 2019).

As it will be further elaborated in the coming section, another tool that is commonly used in special education is 3D virtual environments (VEs). VEs are digital representations of imaginary or real environments, allowing users to interact with virtual objects in a realistic manner (Freina & Ott, 2015). As with most technology-based tools, VEs are used for helping students with severe problems (e.g., autism spectrum disorders-ASD) rather than students with milder impairments.

Taking into account that (i) interventions targeting students diagnosed with ADHD are not that common and (ii) VEs can be an effective tool in the context of special education, a project was designed and implemented. The research question that sought to answer was whether VEs are more effective than videos in modifying school-related behaviours of students diagnosed with ADHD. Details for the project are presented in the coming sections.

2 Background

Though the etiology of ADHD is still unclear, it seems to affect around 2.2% of the population (Fayyad et al., 2017). Attentional problems and excessive activity are the main symptoms of this condition. Following instructions or focusing on a task is difficult, as individuals with ADHD are forgetful and easily distracted. When an activity requires intense cognitive involvement, they are bored or have the tendency to give up easily. Most of their activities are left incomplete as they jump from one task to another. Finally, they are hyperactive, disorganised, inattentive, and impulsive (International Statistical Classification of Diseases and Related Health Problems, 2016).

The side-effects of ADHD include functional, emotional, and social problems. For instance, individuals suffering from this condition cannot easily regulate their emotions (Faraone et al., 2019) and their emotional awareness is low (Factor et al., 2016). Moreover, students with ADHD present rather challenging behaviours, resulting in school adjustment and disciplinary problems. That is because they do not take into account the consequences of their behaviour, which is often disruptive and inappropriate for their age (American Psychiatric Association, 2013). In general, their low self-esteem and/or antisocial behaviour result in being isolated or unpopular among their classmates (International Statistical Classification of Diseases and Related Health Problems, 2016). Delays in language development and cases of impaired cognitive functions are commonly reported as well (Dyck & Piek, 2014).

Coming to VEs, they are considered valuable tools in the context of special education. For example, they helped children with Down Syndrome to improve their language skills (Lan et al., 2018) and children with ASD to improve their social (e.g., Stichter et al., 2014) and emotional skills (Craig et al., 2016). What is of interest for this study, VEs simulating school environments enhanced the social understanding of students with ASD (Cheng et al., 2015). They also helped them to understand how to make friends, confront abusers, and deal with social dilemmas (Didehbani et al., 2016).

The value of VEs lies in the fact that they offer a safe and controllable environment in which emotions can be expressed and social skills can be practised (Didehbani et

al., 2016). In fact, it is suggested that VEs not only foster the acquisition of skills, but they also ease the transfer and application of these skills to real-life (Ke & Moon, 2018). There is also evidence that VEs produce equally good results with therapies exposing participants to real-life conditions, as the sensory stimuli are similar to both cases, resulting in similar psychological responses (Bohil et al., 2011).

Another advantage of VEs is that one can experiment with various solutions to a problem for as many times as he/she likes, without any real danger (Freina & Ott, 2015). This is quite important for individuals with ASD as it removes their anxiety for face-to-face interactions (Didehbani et al., 2016). Thus, VEs helped to reduce their social isolation (Craig et al., 2016), as there was a positive impact on social interactions, self-esteem, and confidence. Motivation is also a key advantage of VEs, as they offer a rewarding experience to individuals with special needs (Didehbani et al., 2016; Ke & Moon, 2018). The enjoyment they feel also adds to the above (Ke & Moon, 2018; Lan et al., 2018).

The literature regarding the uses of VEs to students with ADHD is rather limited. Nevertheless, these applications eased their social difficulties (Shema-Shiratzky et al. 2018), improved their working memory and attention (e.g., Schwebel et al., 2008), and reduced their behavioural issues (e.g., Wang & Reid, 2011). Then again, to the best of the authors' knowledge, there are no studies in which VEs were used for demonstrating to students with ADHD how to function or behave in the school environment.

Given that (i) students with ADHD present challenging behaviours and have a poor adjustment to the school environment and (ii) VEs are scarcely used for the treatment of problems students with ADHD face, the study at hand explored the following research hypothesis:

Compared with videos, VEs can ease significantly more the behavioral issues related to the school environment of students with ADHD.

3 Method

A significant problem of studies involving students with special educational needs is that large sample sizes are very hard to achieve. An experimental design that does not require large sample sizes, commonly employed for studying individuals with impairments, is that of a single-subject with a baseline and an intervention phase (A-B design) (Engel & Schutt, 2012). In fact, it allows research to be conducted even with a single subject (typically with three to eight) (Horner et al., 2012). In this type of research, participants serve as their own controls. As the term implies, there are two phases, a baseline (A-phase) and an intervention/treatment phase (B-phase). During the A-phase, data are collected multiple times, until stability is reached (meaning that there is limited fluctuation in the results). Next, the treatment/intervention is introduced, followed by another set of data collection (B-phase). The two sets of data are contrasted, and conclusions can be drawn (Engel & Schutt, 2012). As the study involved the use of two tools (videos and VEs) the A-B design was applied twice.

3.1 Participants

The proper selection of participants was a challenging step. The overall objective was to achieve a sample that included students diagnosed with ADHD having considerable behavioural problems at school. As two tools were used, this necessitated the formation of two groups, with as-much-as-possible equal problems and diagnosis. In order to achieve the above, the following selection criteria were applied: students should (i) be of similar age, (ii) attend public mainstream schools, (iii) have been formally diagnosed with ADHD in accordance to ICD-10 version 2016 (International Statistical Classification of Diseases and Related Health Problems, 2016), (iv) be within the normal range of mental abilities (as assessed by the Greek version of Wechsler Intelligence Scale for Children), and (v) display challenging behaviours and their school-related skills to be dysfunctional.

Two rounds of visits to schools in Athens, Greece, followed. During the first, teachers were interviewed and twenty-five students were selected. During the second, these students were observed for a period of two months (two observations per week), in order to establish the extent of their behavioural problems. As a result, twelve students aged ten to eleven were selected (six boys and six girls) and were split into two groups as presented in Table 1. Students 1 to 6 were assigned to Group1 (videos) and students 7 to 12 were assigned to Group2 (VE).

Table 1. The study's participants

Subjects	Diagnosis*	Behavioral related symptoms
1 and 7	F90.0, ADHD	verbally violent, generalized weakness in social interactions, denial to comply with rules, ignorance of acceptable behaviors
2 and 8	F90.0, ADHD	outbursts of anger, unable to follow simple rules, often engages in socially unacceptable activities, often engages in inappropriate behaviors
3 and 9	F90.0, ADHD	often gets involved in fights with classmates (verbally and physically), indifference to social conventions, outbursts of anger, constant denial to comply with rules
4 and 10	F90.0, ADHD	verbally violent, indifference to social conventions, trouble following rules, often engages in inappropriate behaviors
5 and 11	F90.0, ADHD	physically and verbally violent, indifferent to social conventions, denial to comply with rules, failure to manifest the desired behaviors in their appropriate contexts
6 and 12	F90.0, ADHD	often gets involved in fights with classmates (verbally and physically), indifferent to social conventions, responds with anger and verbal violence when instructed to follow rules, limited manifestation of expected social behaviors

Notes. * = classification and diagnosis according to ICD-10 version 2016 (International Statistical Classification of Diseases and Related Health Problems, 2016).

3.2 Instrument

During the two-month period in which students were observed, several problematic behaviours were recorded and were later classified into four conditions:

- Condition A-in-classroom behaviours (e.g., entering/exiting the classroom, preparing for the lesson, participating in the lesson, responding to disagreements/annoyances).
- Condition B-behaviors during breaks (e.g., entering/leaving the schoolyard, playing with schoolmates, following the rules, responding to disagreements).
- Condition C-behaviours during a school event (e.g., entering/leaving the assembly hall/area, listening/watching the event).
- Condition D-socialisation skills (e.g., addressing teachers/classmates, starting/participating/ending conversations).

The most commonly observed problematic behaviours in each of the above conditions were used for assembling an observation protocol. Observational data (the number of times a wrong behaviour manifested) were collected simultaneously by the class's teacher and a researcher. The two raters were trained by observing the behaviour of students without impairments. The interrater reliability using the Kappa coefficient of agreement was found to be very good [$\kappa = .87$, $p < .001$, 95% CI (.85, .89)] (Landis & Koch, 1977).

3.3 Materials

A VE developed for the needs of a previous study was used in this study as well. It was developed using 'Opensimulator' (http://opensimulator.org/) and, in essence, it simulated a fictional school complex (with classrooms, schoolyard, and an assembly hall) (Figure 1). It was installed as a standalone application on laptops, while the participating students, using their avatars, could freely explore it.

Though the VE was rather simplistic, it was populated with several non-playable characters (NPCs), acting as students or teachers. The NPCs could follow pre-defined paths, change their animation sequences, and converse with each other, in order to demonstrate how one is supposed to behave. Moreover, other NPCs acted as student guides, sensing the proximity of an avatar and prompting students to follow them in areas where the rest of the NPCs were demonstrating the desired behaviours. NPCs acting as "teachers" prompted students (verbally and non-verbally through animation sequences and postures) to perform certain tasks, supplementing the naturalistic prompting presented by the teacher (see "Procedure" section). Finally, a fourth set of NPCs could greet students and could converse with them (through text), responding to a limited set of pre-defined inquiries and responses. It has to be stressed that the NPCs could not correct their paths or animations when the user blocked or derailed them. Consequently, by causing havoc to the VE students could see the consequences of "inappropriate" behaviours.

Figure 1: Screenshots from the application

Four short videos (around 10 minutes each) were recorded, having as actors, real teachers and students. In each, one of the conditions elaborated in the "Instruments" section was presented in two parts. The first, illustrated challenging situations/behaviours in the four conditions, while the second half demonstrated the expected/acceptable behaviours. For example, in a scene, a student was not following the rules of a game. In the first part, another student responded violently starting a quarrel, while both ignored the other students' efforts to stop them. In the second part, the second student, instead of engaging in a quarrel, stopped the game and started to converse with the first one and, at the same time, asked for the teacher's help to resolve the situation. Although these scenarios were unsophisticated, it has to be reminded that it was of the utmost importance to clearly present the problematic situations. Several additional scenes were recorded with just the teachers explaining which behaviours were wrong or right and why. These scenes were later added during the video editing process.

3.4 Procedure

In A-B designs, it is recommended that, during the intervention phase, only one variable can be introduced and studied; afterward, a second one can be introduced and so on (McMillan, 2004). Consequently, the participating students were observed for a period of two weeks (two observation sessions per week, lasting for the whole duration of the school day), for establishing the baseline. Next, one condition was introduced to students (either using the VE or the videos). Intervention observations followed (with

the same duration as in the baseline phase). The above procedure was repeated for four times as there were four conditions.

Coming to the conditions, these were administered during a two-hour session, on an individualised basis (one session per student). The teaching method followed the recommendations of video-modeling (discussed in the "Introduction" section). In detail:

- At the beginning of the session, the researcher discussed with the student, in order to establish what he/she already knew for the given condition and the expected behaviours.
- Using a laptop, the student, either watched the relevant video or explored the VE's area in which the given condition was simulated.
- After the end of the video or after having explored the VE for at least fifteen minutes, the researcher and the student engaged in a discussion, in order to develop an outline of what the latter understood. The researcher drew the student's attention to certain key-points.
- A second round of video watching or use of the VE followed. The researcher or the student could pause the video (or stop exploring the VE) so as to discuss the key-points established in the previous step.
- During the final round of discussions, the researcher presented hypothetical situations (related to the condition that was the session's theme). The student "acted" how he/she would behave or respond. He/she could search the video or go to the area of the VE in which a similar situation was presented and elaborate on the reasoning behind his/her course of action.

4 Results

The rater observations in each session and for each participant were averaged and the resulting data were imputed into SPSS 25 for further analysis. Tables 2a and 2b present the results in detail, while Figure 2 is a graphical illustration of group averages per observation session.

Table 2a. Means and standard deviations of problematic behaviors, baseline phase observations

Group	Condition	Baseline phase									
		1		2		3		4		Cumulative	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Group1	A	19.83	2.14	19.75	1.86	19.75	1.89	20.08	1.59	19.85	1.82
	B	20.33	1.37	20.25	2.25	20.67	2.16	20.58	1.50	20.46	1.73
	C	20.50	1.76	20.17	1.60	20.42	2.06	20.25	2.56	20.33	1.94
	D	19.83	0.86	20.17	1.21	20.00	1.14	20.25	0.82	20.06	0.87
Group2	A	20.33	1.81	20.33	1.37	20.33	1.54	20.33	0.98	20.33	1.40
	B	20.33	1.33	20.25	0.99	20.08	1.36	19.92	1.53	20.15	1.17
	C	20.50	1.82	20.42	1.93	20.42	2.13	20.33	1.99	20.42	1.92
	D	20.25	1.51	20.42	1.86	20.42	2.08	20.33	1.54	20.35	1.68

Notes: Group1 = video; Group2 = VE; Condition A = in-classroom behaviors; Condition B = behaviours during breaks; Condition C = behaviors during school events; Condition D = socialising

Table 2b. Means and standard deviations of problematic behaviors, intervention phase observations

Group	Condition	Intervention phase									
		1		2		3		4		Cumulative	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Group1	A	13.00	1.70	13.00	1.41	13.08	1.56	13.17	1.40	13.06	1.43
	B	12.92	1.72	13.50	1.14	12.83	1.08	12.75	1.17	13.00	1.16
	C	12.75	2.56	13.17	1.91	12.83	2.71	12.50	1.73	12.81	2.11
	D	12.67	1.75	12.92	1.93	13.50	2.28	13.00	1.41	13.02	1.64
Group2	A	10.00	2.28	9.83	1.89	9.67	1.72	9.92	1.46	9.85	1.75
	B	9.00	2.02	8.75	2.19	9.17	1.72	8.92	1.72	8.96	1.87
	C	9.25	1.57	9.42	1.77	9.33	2.04	9.25	2.34	9.31	1.84
	D	9.75	1.21	9.83	1.6	9.83	1.17	10.08	1.32	9.88	1.12

In A-B designs the intervention phase cannot commence if the results of the baseline phase fluctuate a lot. As it is evident in both Table 2a and Figure 2, this requirement was met. It can also be observed that stability was achieved in the results of the intervention phase. Thus, it is quite safe to draw conclusions on the basis of the results. Indeed, considerable positive changes can be noted in all four conditions and in both groups. In fact, Group1 achieved a 52% drop in problematic behaviours regarding Condition A, 57% in behaviours regarding Condition B, 59% in behaviours regarding Condition C, and 54% in behaviours regarding Condition D. On the other hand, the drop in problematic behaviours was even more remarkable in Group2 (106%, 124%, 119%, and 106% respectively). On average, the results of Group2 compared with the results of Group1 were around 59% better. Given the above the study's research hypothesis is confirmed; VEs, compared with videos, can ease significantly more the behavioural issues related to the school environment of students with ADHD.

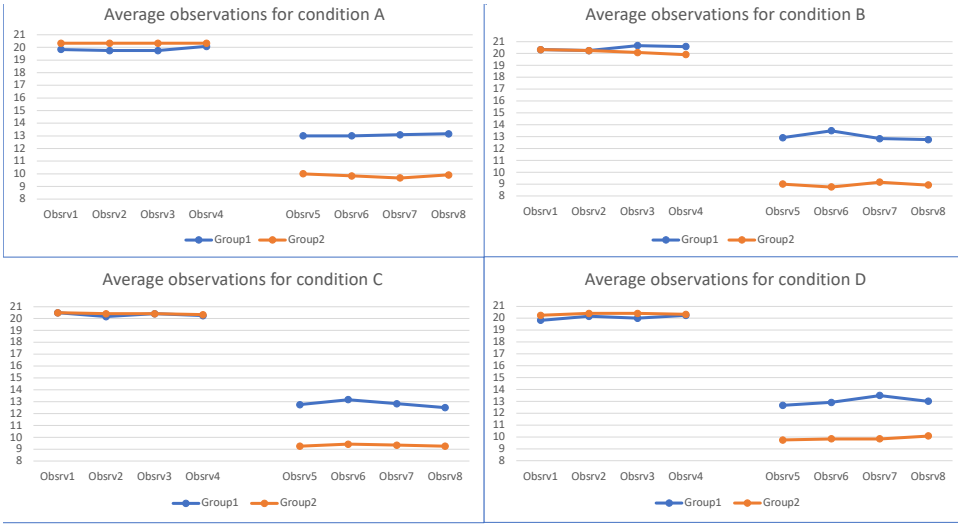

Figure 2: Average observations for the four conditions

5 Discussion

The study examined whether a VE can help students with ADHD to ease their behavioural problems related to the school environment. Data were collected from six students and were compared with that of another six in which videos were used for the same purpose. The results quite clearly demonstrated that all students significantly reduced the number of undesired behaviours they displayed in real school conditions. In this respect, both tools can be considered effective. Yet, by comparing the results, it is more than evident that the outcomes from the use of the VE were better. Therefore, the study's findings give support to previous research suggesting that VEs can ease students' challenging behaviours related to the school environment (e.g., Didehbani et al., 2016; Ke & Moon, 2018; Lan et al., 2018). Given that most of the related studies targeted children with ASD, the study's findings expand the relevant literature, as it provides evidence that VEs are also effective when the target group is students with ADHD.

The results can be attributed to both the affordances of VEs and the teaching framework. It is supported that, in the context of special education, VEs provide controlled, realistic, and secure environments. By allowing the above, they foster the learning of skills/behaviours and their transfer to real-life conditions (Freina & Ott, 2015). It is also suggested that the skills/behaviours learned through VEs, when practiced relatively promptly and regularly, individuals are able to generalise them in similar circumstances (Freina & Ott, 2015). Indeed, in the present study, students in both groups encountered conditions similar to the ones they encounter in their school life, they saw how they are expected to function, and they were asked to apply and demonstrate the target behaviours. Since the results were better in the VE group, it can be supported that VEs are more effective than videos.

It is also suggested that, through VEs, a chain of knowledge-behaviour transformations is initiated to students with special educational needs: (i) the better understanding of concepts leads to the feelings of fulfillment and satisfaction (Didehbani et al., 2016; Freina & Ott, 2015), resulting in a positive influence of students' self-esteem and confidence, (ii) confidence leads to an advancement of their emotional, behavioural, and social status in school (Craig et al., 2016), (iii) seeing that their status is elevated, students are encouraged to manifest more behaviours that are acceptable from their peers and teachers (Lan et al., 2018). On the basis of the study's results, the above sequence of events was confirmed. Table 2a and Figure 2 clearly demonstrate that during the baseline phase students manifested many unacceptable behaviours (in all four conditions). Contrary to that, during the intervention phase, these behaviours were significantly reduced in the VE group. Thus, it is quite safe to assume that what was practiced in the VE and discussed with the researcher/teacher was "transformed" into actual skills/behaviours. More importantly, as students were observed multiple times and the data did not fluctuate much, it is quite safe to assume that students mastered the acceptable behaviours.

5.1 Implications for research and practice

The relevant literature regarding the use of VEs in special education, while not limited, is rather fragmented across diverse objectives, disorders, and settings. What is more, children with ADHD are not the focus of many studies, as researchers put more emphasis on studying ASD or more severe disorders. The study at hand chose to take a research path that is relatively uncharted, namely, to examine the effects of VEs on students with ADHD displaying challenging behaviours in the school environment. On the basis of the results, it can be supported that this research path is worth exploring.

Implications for the educators in special education, as well as for the developers of VEs can also be recognised. As it was elaborated in a preceding section, the study's VE was rather "amateurish;" thus, one might argue that its flaws had a negative impact on the results. Although such a concern is valid, it has to be taken into account that professionally developed suitable for the study's needs are non-existent. The main reason is that students with special educational needs present a large variety of problems and impairments. Therefore, it is impossible to professionally develop applications suitable for each and every case. In fact, Stichter et al. (2014) argued that special education teachers, though not software experts, should be the developers of applications, as they have a better understanding of their students' needs. A plausible solution is the software industry to provide educators with tools that make the process of developing VEs much more efficient and appealing.

5.2 Limitations and future work

There are limitations to the study that are worth mentioning but also provide avenues for future research. The sample size is one such limitation. On the other hand, it has to be stressed that it was within the acceptable range of sample sizes for A-B research designs. In addition, in research related to special education, the target population is smaller than the general one. Not only that, but ADHD is an umbrella term; the severity level differs from individual to individual. Thus, one has to be extremely careful so as to select cases that do not differ lotto much from each other. Nevertheless, it has to be acknowledged that due to the above, concerns about the generalisability of the study's results might be raised. The limited availability of time (due to schools' timetables) also limited the number of interventions. Then again, the number of observations was within the suggested number of observations for an A-B study and enough for establishing result stability. Finally, the long-term retention of behaviours is unknown. Future research can target more students, from different age groups, and with other special needs, so as to provide a clearer picture of VEs' effectiveness. Interviews will allow an in-depth understanding of the impact of both videos and VEs. Finally, professionally developed VEs can be employed for examining whether there are differences in the results.

6 Conclusion

Considering the aforementioned results as well as the study's limitations, it can be concluded that VEs have the potential to support students with ADHD in order to overcome their behavioural problems in the school environment. That is because the study provided evidence that, through the use of VEs, these students positively changed their behaviours which, in turn, were applied in real-life conditions. In conclusion, the study's findings might prove useful to researchers and educators in understanding the affordances of VEs and for exploiting their advantages in the context of special education.

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