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ID Tech: A Virtual Reality Simulator Training for Teenagers with Intellectual Disabilities

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Abstract: People with intellectual disability (ID) should routinely train themselves to carry out a variety of daily challenging tasks while being supervised by one or more supervisors. Virtual reality (VR) technology enables the simulation of certain learning scenarios that would be risky or difficult to set up or repeatedly replicate in the actual world. This paper introduces a VR simulator created for this aim with the assistance of social educators. The purpose is to use VR to conduct learning exercises with teenagers with ID and assess the extent to which the abilities learned in VR can be transferred to the real world. This project focuses mainly on urban mobility with three types of exercise. A study was conducted with 18 students in five institutions for 7 months. Post-tests were also carried out after 1 month with 11 teenagers. In the end, four teenagers are completely autonomous in their travels: two travel on foot and two travel by public transport. Regarding the impact analysis, the results are stable over time regarding self-reported ease, satisfaction, and fatigability. Finally, the system received valuable feedback from the educators.

Keywords: virtual reality; education; training; intellectual disability

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1. Introduction

Intellectual disability (ID) is characterized by significant limitations in intellectual functioning and adaptive behavior. This is discernible in conceptual, social, and practical skills [1]. In this article, we discuss intellectual disabilities using the AAIDD model. The person's level of functioning depends on the intensity of the support received in five areas: intellectual abilities, adaptive behavior, participation, health, and context. We postulate that virtual reality (VR) can support the youth in the areas of cognitive abilities, adaptive behavior, and participation. The other two dimensions of the model are also involved: the use of VR can have an impact on health and it depends on the opportunities offered by the context. These aspects will be discussed later.

Among the various life habits in which young people with ID learn to develop their autonomy and self-regulation, travel in public space occupies an important place. First and foremost, it allows people to safely reach working or recreational places, which both play an important role towards self-determination [2].

However, traveling in public spaces involves a set of cognitive skills (e.g., finding one's way around and identifying visual signals), instrumental skills (e.g., taking the bus and getting off at the right stop), and social skills (e.g., how to interact with other occupants of the public space). On top of that, there are many variables to consider such as possible delays and other always-changing environmental conditions [3].

Training young people with ID to manage these situations is very complex. It implies being able to test whether and how the skills taught in a safe environment (e.g., at school) with the supervision of one or multiple instructors translate to a real environment in full autonomy [4,5]. Training and evaluating such scenarios and competencies in the real world have important stakes in terms of safety and material and human resources [6]. In addition, the need for constant supervision during learning contradicts the objectives of autonomy and self-regulation aimed at by this type of learning [4,7].

Virtual reality allows young people to test situations independently and safely (e.g., taking the bus, behaving appropriately in case of an unexpected event, and managing conversations with strangers). These types of situations can be difficult to reproduce, as they require resources and can involve real risks if supervision is insufficient. New technologies such as VR allow certain conditions to be simulated safely and therefore be used to "train" young people before they face the same situations in real life [8].

The practical goal of this project was to allow young people (12–16 years old) with ID to learn with a "learning by doing" approach to move in public space in safe conditions by using Virtual Reality (VR), while having a variety of experimental situations corresponding to their needs and the needs of the educators. In order to integrate this VR tool into the learning process of the institutions, we developed a research work in collaboration between social educators and engineers. The research goals were (a) to understand how the use of a learning program based on a VR tool promotes the acquisition of cognitive and practical skills in young people with ID and (b) to analyze the user experience from the point of view of teachers and educators using this system.

The acceptability of using VR and the feasibility of our approach have been proved in an exploratory study [9]. In the present study, we wanted to establish and measure to what extent and under which conditions it is possible to transfer skills acquired in VR to the real world for young people with ID.

This paper is structured as follows: Section 2 presents the state of the art; Section 3 describes the conception of the VR tool as well as the developed training scenarios; Section 4 presents the materials and methods used to test and evaluate our approach; Section 5 summarizes the results that are discussed in Section 6; finally, Section 7 concludes the paper.

2. State of the Art

For several years, research has been conducted on the use of VR for the rehabilitation of people with ID. In 2005, Standen and Brown [10] presented a review of the literature highlighting how VR can be used as an intervention and/or assessment tool. They indicate three areas of application: promoting skills for independent living, improving cognitive performance, and improving social skills. The authors state that, apart from studies with people with autism spectrum disorder (ASD), these early experiments showed the possibility of transferring learning from virtual to real.

Yannick Courbois et al. studied learning in virtual environments of navigation tasks (learning new routes, shortcuts, etc.) for people with Down syndrome or Williams syndrome [11–15]. In their work, VR was used as a learning assessment tool without studying the transfer of this learning into reality. Most of their work has shown that individuals with ID are able to learn to orient themselves in VR. The authors argue that VR could be used to identify and educate those individuals most at risk of being involved in dangerous situations.

Another work investigated the crosswalk scenario with six children with ASD [16]. Using an immersive CAVE (Cave Automatic Virtual Environment), results showed that four out of six children were able to achieve the desired learning goal. These results were verified at the end of the 4-day period by having the children. The authors note that these results are encouraging for the children themselves, as they felt a sense of accomplishment, and for their parents, as they felt proud of their children's performance, whereas they were initially skeptical.

Another study conducted with seven adults with ASD showed rather different results [17]. Their treatment protocol included 10 45-minute sessions in a non-immersive virtual environment (participants had a large 2 m $\times$ 2 m screen in front of them). The six subjects who completed the protocol easily learned the body gestures needed to interact with the virtual environment. However, even if during the sessions the participants significantly improved their navigation performance, they did not significantly reduce the errors made when crossing the crosswalk.

In 2021, Wang et al. conducted a study seeking to establish the acceptability of VR for adolescents with intellectual disabilities [18]. They concluded that adolescents with ID had a good level of acceptance of VR and that they were able to interact in a virtual world.

Saredakis et al. [19] conducted a systematic review and meta-analysis of explanatory factors for discomfort potentially related to the use of VR headsets. These factors are related to visual stimuli, motion, exposure time, and user age. Younger users would present more disorders than older ones. An exposure time of more than 10 min significantly increases the risk of experiencing discomfort. For people with ID, barriers to the use of VR can be related to personal factors (motor skills and attention deficits, sensitivity to moving pictures, and excitability) [20,21]. However, lack of access to digital technologies for people with ID is also related to environmental factors, such as low funding and high costs of material, lack of knowledge on VR by teachers, and inadequate assessment of learning [22].

To summarize, the existing studies that concern the use of VR for learning new skills show encouraging findings despite some disadvantages. However, most of these studies focus on a very specific group of participants and the limited number of participants in the studies and sometimes contradictory results indicate the need for further research. In addition, to the best of our knowledge, no study has yet investigated the acceptability, feasibility, and specific benefits of immersive headset-based VR for young adults with ID (12–20 years old).

3. Conception

3.1. Simulator Design

The proposed training simulator is composed of two main elements managed by an application developed with Unity (see Figure 1):

- The main computer launches the application and thus the different scenarios (described below). It permits not only to monitor the content of the headset, but also to add an overlay (see Figure 2) to change the parameters of the scenario as well as to receive visual feedback of the current target of the user's gaze. They could use this type of feedback to check whether the students were looking at the vehicles and not just turning their heads mechanically before crossing, for example. These last points are only visible to the teacher.
- The virtual reality headset (HTC Vive Pro Eye) displays the simulated environment to the learner in which they can interact using a controller (move around, ask for a bus stop, open the train door, etc.). This headset was chosen for its eye-tracking features, permitting to always know what the user is looking at. These data were essential as it could differentiate someone who looks in the right direction but not the intended element from someone who actually looks at this element.

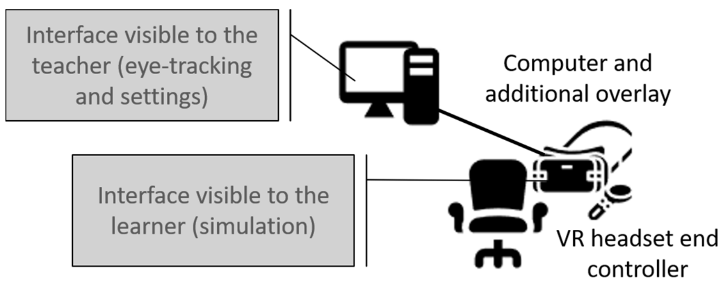


Figure 1. Training simulator architecture.

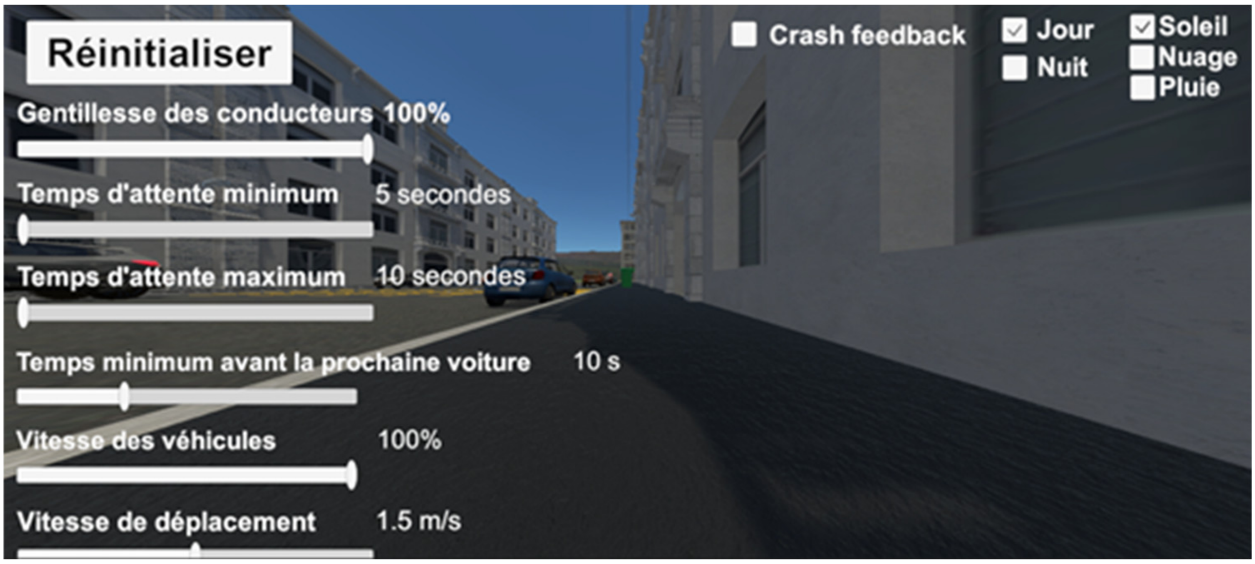


Figure 2. Overlay example for one scenario (with drivers' kindness, minimum waiting time, maximum waiting time, minimum time before next vehicle, vehicle speed, travel speed, day/night, and sunny/cloudy/rainy). The application architecture is composed of a base layer common to all scenarios. This layer includes the following.

The application architecture is composed of a base layer common to all scenarios. This layer contains:

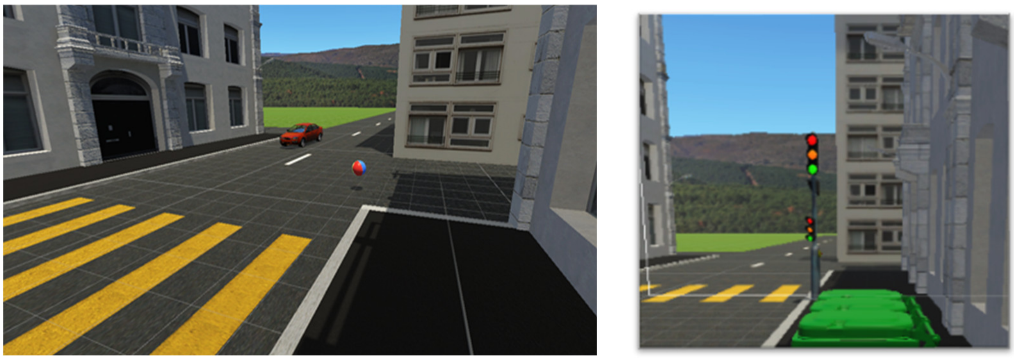
- The system of movement and interaction in VR.
- The logging services that automatically record the experience settings (e.g., difficulty levels and environmental conditions) and the data from the eye-tracking system.
- The system for managing contingencies and the possibility to bring up a virtual smartphone and interact with its simplified interface.

3.2. Training Scenarios

There are three basic scenarios: crosswalk and moving in the street, taking the bus, and taking the train. Except for the common base layer mentioned above, these scenarios are separate: they have their own interface for difficulty settings and customization and each one is divided into subscenarios that allow to work on skills specific to each scenario. We summarize the scenarios below. Each scenario and its variation are further discussed in Appendix A (Tables A1–A3).

3.2.1. Crosswalk and Moving in the Street

The objective is to walk on the sidewalk and cross the street. The basic behaviors of the task are walking near houses, observing relevant features, stopping at the crosswalk, looking left and right then left again, observing the traffic lights, listening, identifying that the cars are stopped, etc. The crosswalk could be protected (traffic light) (Figure 3b) or unprotected (Figure 3a).



(**a**) (**b**)

Figure 3. Crosswalk and moving in the street scenario. (**a**) Unprotected crosswalk with a ball crossing the street (distraction) and (**b**) protected crosswalk with contingencies (trash can in the middle of the pavement).

3.2.2. Taking the Bus

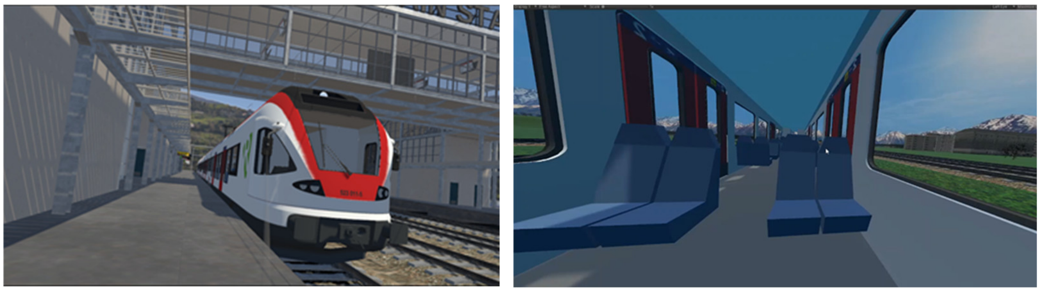
The objective of this scenario is to make a trip taking one or more buses. There can be other buses than the ones the user is supposed to take. The scenario starting point may be far from the bus stop, forcing the user to walk around to reach the stop (Figure 4a). Avatars sometimes wait for the user inside the bus. They approach the users and ask them if they want to go shopping, play video games, etc. (Figure 4b). Various events can occur during the ride, such as a dog starting to bark, people listening to loud music preventing them from hearing the announcements clearly, or the bus breaking down (Figure 4c).

(**a**) (**b**) (**c**)

Figure 4. Bus scenario: (**a**) asking for the bus to stop; (**b**) avatar asking to go with him; and (**c**) use of smartphone because of bus breakdown.

3.2.3. Taking the Train

Taking the train follows the same objectives and options as taking the bus. All situations that were designed for the bus were transcribed for the train, as some users needed to take the train for their daily transportation (Figure 5). In some cases, taking both the bus and the train was required for the child to reach their objective.



(**a**) (**b**)

Figure 5. Train scenario: (**a**) train station and (**b**) inside the train.

4. Materials and Methods

4.1. Material

The material used for this study is a laptop with the simulation software and an HTC VIVE pro eye kit. Both stations are placed on tripods with a fixed room scale configuration. Only one controller is used for the following inputs:

- Navigation (walking): pointing and trigger button;
- Using the environment buttons (bus stop, train door, or traffic light): touch with the controller or pointing and trigger button under certain circumstances;
- Asking for the bus to stop: hand up (gesture);
- Using the smartphone to manage the contingencies: trackpad, pointing, and trigger.

The children sit on a chair in the center of the VR stations. The chair has no casters (it is fixed to the floor) but can turn on itself to change the direction of movement.

4.2. Method: Protocol and Evaluation

The method used for this study was based on the Single-Case Protocol (SCP). It permits to assess the impact of an intervention through the systematic and rigorous study of dependent variables of interest in one or few subjects. This method is based on the observation of target behaviors before and after the intervention [23]. An individualized protocol was developed for each participant. Every protocol was based on 10 learning sequences, each consisting of three exercises, with the complexity of the task increasing with each exercise. These are protocols with changes in criteria (e.g., increasing vehicle speed and introducing a breakdown), which are the type of SCPs most used in learning-centered programs [23]. An example of one sequence is presented in Appendix B (Table A4).

Each learning sequence lasted between half an hour and an hour and took place once every 2 weeks from November to May. This means that during each meeting, which takes place every 2 weeks, the participant performed three exercises. This choice of 2 weeks was made for two reasons. First, from an organizational point of view with the schools. Indeed, the educators who accompanied the students individually could not leave the other students in their class. Each accompanying person had to be able to organize themselves accordingly with the rest of the teaching team. Second, it is necessary to consider the fact that each new sequence of exercises was prepared progressively in order to adapt to the personal learning objectives of each student. Although different basic scenarios were prepared, it was sometimes necessary to combine several of them. The travel time to reach the five schools is also to be considered. A time plan was established for each school, with all teenagers from the same school participating in the sequences on the same day.

The instructions for the exercise were given to the young person by the accompanying professional. For example, at the beginning of the procedure: “You move along the sidewalk without crossing, walking as close to the houses as possible, watching what is going on, listening to what is going on. You don’t have to say what you see and what you hear” or at the end: “You take the usual route home.” One person positioned and adjusted the headset on the student's head and then the student performed the exercise. A member of the research team was present to observe the sequence and complete the observation grids (SCP measurement indicators and regulation scale). At the end of each exercise, the headset was removed so that the student could listen to the instructions for the next exercise and then the headset was put back on. This time without a helmet allowed to limit the risk of motion sickness. At the end of the sequence, the educator completed the sequence self-evaluation scale with the youth.

For each learning sequence, measurement indicators were defined. The first four to six exercises were used to establish the baseline (BL, aimed at describing the behaviors acquired before the beginning of the intervention) [23]. Indicators related to the learning to be achieved were measured during each exercise. In addition, for each sequence, the regulation of behaviors was measured: this involved measuring the young person's self-regulation (how they correct themselves, what help they seek, etc.) and the regulation by the accompanying adult (intensity of instructions given, the help provided, etc.) with the Nader-Grosbois Scale [24]. Usability has been assessed at the end of the study.

The study was conducted with 18 students (11 males and 7 females) in five schools in French-speaking Switzerland. They were between 12 and 16 years old (ages for the last four degrees of mandatory school in Switzerland). The average age was 13.6 years old. Inclusion criteria were (a) abilities in verbal communication and (b) to have to learn mobility during the school year (for ethical reasons, the project had to be included in the individualized plans of the students).

For two young people, the program had to be interrupted prematurely. As they reached the objectives very quickly (after six and eight sequences, respectively) and as the VR program did not allow for the development of more elaborate scenarios, it was decided, by mutual agreement with them and their teachers, to stop the program.

At the end of the study, a group of 11 adult participants (3 men and 8 women) perform a user test to estimate the usability of the developed system from the point of view of the educators. For this, they completed F-SUS and UEQ-S questionnaires. They also gave feedback on the experience and the system.

5. Results

This section provides a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

5.1. Post-Test

A post-test was conducted with each youth approximately 1 month after the end of the project. The instructions for the post-test exercises were the same as those of the last sequence worked on with the youth.

The post-tests were carried out with the youth who were not autonomous at the end of the project (n = 12); one youth was unable to complete the post-test due to health issues. Of these, nine youths achieved a 100% success rate, one youth reached a 93% threshold, and one youth reached a 90% threshold.

5.2. Visual Analysis of SCPs

The visual analyses of 16 cases were performed separately by two judges and then the results were pooled, with an interjudge agreement of 87.5% (14 similar findings out of the 16). Figure 6 shows the graphical data obtained for one youth (Benjamin), namely the behavior index (percentage of successful tasks in each exercise), the mean for each phase, the trend, the score obtained for self-regulation and heteroregulation, and the presence or absence of adult guidance.

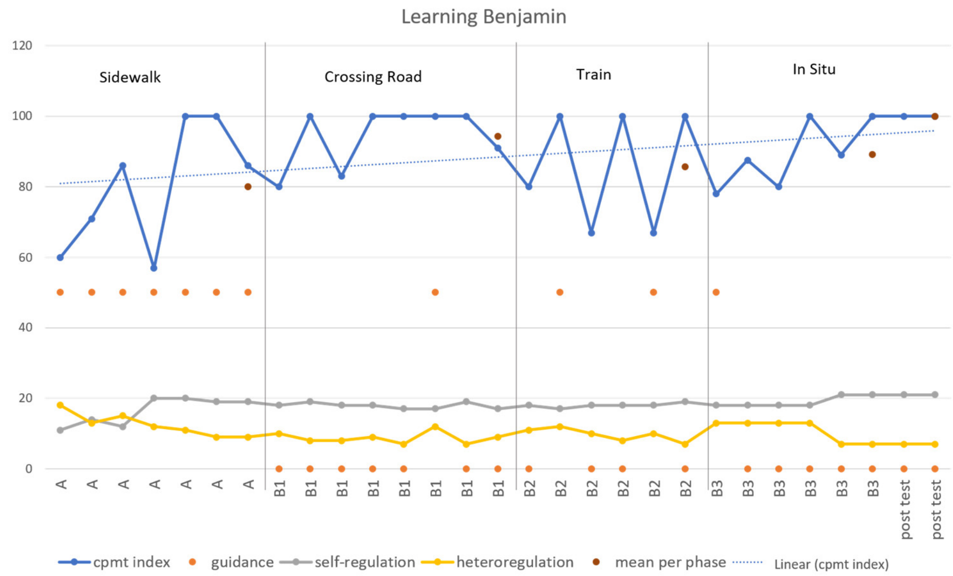


Figure 6. Learning graph—visual analysis of SCP.

The self-regulation is how the learner regulates his or her own learning strategies, e.g., asking for help and trial and error. The heteroregulation is how the adult supports the youth in his or her learning based on what he or she observes in the youth, e.g., questioning the youth about his or her approach and reactivating attention.

If we consider the whole sample, to the question, "Did virtual reality enable learning?" the responses were as follows:

- Yes (Y) in 11 cases
- Partially (P) in 4 cases
- No (N) in 1 case.

Among the 11 teenagers who have achieved learning, four are completely autonomous in their movements. These are two young people who travel on foot and two young people who travel by public transport. For the seven other young people, the implementation of autonomous travel is planned for the next school year, since the intervention ended at the end of the school year. It was not possible to set up these autonomous trips quickly, for logistical reasons (purchase of transport passes and cancellation of the school cabs that usually transport these students). Concerning the student for whom the VR did not allow learning (notably because of health problems), the intervention allowed identifying his needs and difficulties in a precise way.

The average range of self-regulation scores is 47–61, which corresponds to a high level of self-regulation. The range of heteroregulation scores is 25–43, which corresponds to a medium to high level of self-regulation.

5.3. Statistical Analysis of SCPs

The statistical analysis of SCPs was realized with the software SSD for R [25]. Trend, overlap, effect size, and autocorrelation were measured.

5.3.1. Trend Regarding Learning

The learning trend is positive in 11 out of 16 cases, zero in one case and negative in four cases. This means that in 11 cases out of 16, the intervention led to an improvement in the young people's performance. This trend is statistically significant in six cases.

5.3.2. Overlap or Effect Size Regarding Learning

Based on the results for trend and, where applicable, for measures of central tendency and dispersion, effect size could be measured for 13 situations and overlap for 3 situations.

Results for the 11 positive trends showed that the intervention was highly effective in three situations and moderately effective in eight situations.

5.3.3. Autocorrelation

In many cases (75% or 12 of 16 outcomes), the data are not autocorrelated, which gives them good statistical validity. They are autocorrelated in three cases (18.75%); in two cases (12.5%), the autocorrelation cannot be calculated.

The statistical analyses, therefore, corroborate the visual analyses with a result of 11 young people have achieved learning thanks to VR. However, the statistical data put the importance of the intervention's effects into perspective.

Regarding self-regulation, the statistical analysis showed an improvement in 14 cases, a stagnation (no trend) in one case and a decrease in one case. This means that as the intervention progressed over time, most of the young people improved their self-regulation and were therefore more autonomous in carrying out the tasks. These results are statistically significant in eight cases and not significant in eight cases.

5.4. Impact

An analysis of the self-assessment results was conducted to see, for each youth, how the self-assessment changed over the course of the program (measures of central tendency: mean and median). We did not feel it was appropriate to compare self-report scores with each other, given the high degree of subjectivity in the results.

In general, the results are stable over time for self-reported ease, satisfaction, and fatigability. Very few young people, and on rare occasions, mentioned dizziness or nausea at the end of an exercise.

As for the items recorded in the memos, they were considered in the visual analysis of the SCPs in order to weigh the observations. In particular, the transition from VR to in situ movement was carefully evaluated. The analysis software (SSD for R) [25] also allows the introduction of informative elements (e.g., sequence following a prolonged absence) directly into the graphs, especially explaining outliers. Figure 7 illustrates how contextual elements are considered in the analysis of a student's performance (using arrows).

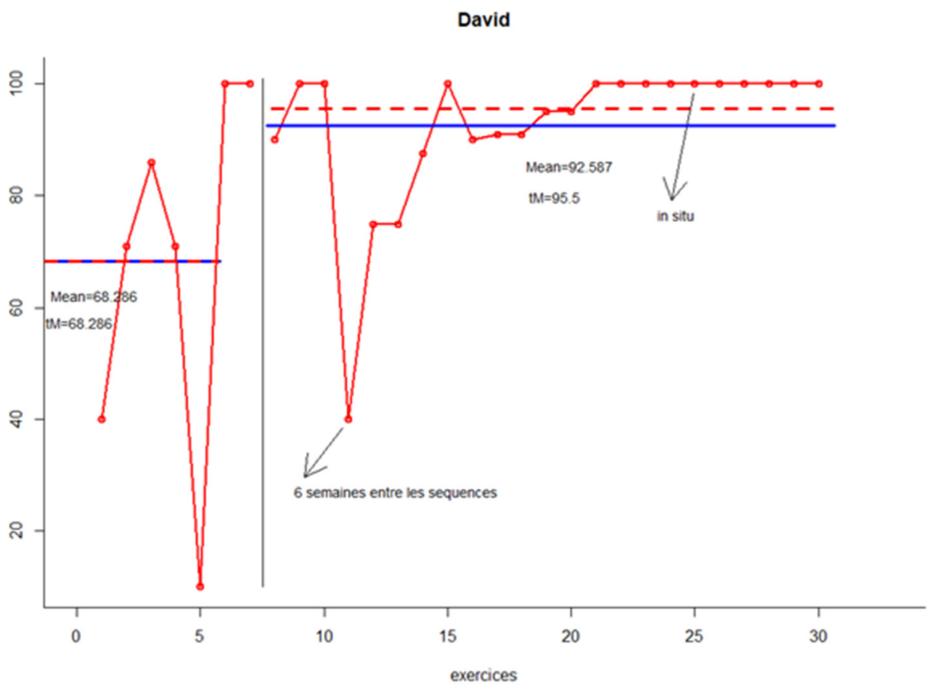


Figure 7. Average of user's performance index (baseline and intervention) with contextual elements considered.

5.5. Usability

The goal of the usability test was to estimate the usability of the developed system from the point of view of the educators. The tests allowed evaluating the usability and the user experience of setting up the material, launching the software, and using it. The test was conducted with 11 adult participants (3 men and 8 women) with an average age of 36.43 years (±11.84). Among the participants, there were six special education teachers, two students, one school principal, and one workshop instructor with an average experience of 10 years* (±10.16) in this occupation. On a scale of 1–7, participants rated their experience with computers as 5*/7 (±0.94) and their experience with new technologies as 2*/7 (±1.35). Of these, six followed the students during the exercises.

Concerning the F-SUS, the median score was 82.5/100 ("good"). The score being between 71.4 and 85.5, we can deduce that the evaluated system has a high probability of acceptability. This score is also confirmed by the general acceptability question that received a score of 5*/5 (±0.5). Finally, regarding the user experience in general, on a score of −3 to 3, the participants evaluated it at 2.16 which corresponds to good results according to the benchmarks provided by the analysis tool. Table 1 summarizes the results obtained.

Table 1. Summary of user experience results.

	Age (Years)	*Work Experience (Years)*	*Computer Experience (1–7)*	*New Technology Experience (1–7)*	*Acceptability (1–5)*	*SUS*	*UEQ-S*
Median	34.00	10	5	2	5	82.5	2.16 (mean)
Standard deviation	11.84	10.16	0.94	1.35	0.5		
Min	20	0.17	3	1	4		
Max	59	34	6	5	5		

Finally, participants could make additional comments if they wished, such as difficulties encountered, advantages or disadvantages, or suggestions for improvement. The comments support the results described above. "Thank you for this experience which will surely be very useful to facilitate learning", "Easy to use and very instinctive for young people, to find their way around in the street and on the bus", "This system is easy to install and to operate with the students [. . .]". However, the main fear concerns potential technical problems that could be encountered: "[. . .] I note, however, that in case of technical problems, I will not be equipped to find a solution." The participants also recognize the need for an installation guide ("it is necessary and useful to have a paper-support in order to be guided for the connections.") that could also be adapted into a video tutorial or even propose a "technical support number to be reached in case of problem".

6. Discussion

Results show that a training program based on VR can help young people with ID to learn new skills for moving in public spaces. The participants learned to identify and avoid dangers, memorize sequences of travel, and resolve problems, as shown in the SCP evaluation. Most of them were autonomous at the end of the project. The regulation measure shows an increase in student autonomy. The VR tool reinforced their motivation to do the exercises. The use of a very structured methodology (the SCPs) could have contributed to these positive results, in comparison with more empirical methods usually used for teaching mobility to young people with ID. This prompts us not to overestimate the role of VR in the intervention's success.

This study confirms the conclusion presented by Courbois et al. [11] on the possibility of using VR as a training tool but also as an assessment tool. Although this study does not use the CAVE technology [16], the children were also successful in learning how to safely engage in a crosswalk. The presented study goes further by proposing two other scenarios (traveling by bus and traveling by train) as well as providing the beginning of social interaction with the use of avatars.

Contrary to the other studies mentioned in the state of the art, the validation experiment could be carried out regularly over several months with a slightly larger number of participants. It is not usual in studies using SCPs, which are traditionally based on a few cases [23,25]. However, it allowed individualized training for the young participants, reflecting the reality of teaching in the ID field. The analysis of the results confirms the benefits of the "learning by doing" strategy with young people with ID using virtual reality. Indeed, the results are positive concerning the learning; the impact validates the feasibility and the benefits of using an immersive headset to learn or improve skills related to urban mobility. A disadvantage of the use of full-VR technology is the level of cognitive skills needed (abstraction and generalization) which exclude young people with severe ID. Yet these young people are not sufficiently considered in learning programs of the ID field [24]. The 360 video VR could be the most appropriate support for them, as it is more concrete. This hypothesis could be explored in another study.

The study also shows positive results regarding the acceptability of using this training tool. Although it was not formally evaluated, the young people accepted the tool and performed the exercises. Regarding the social educators, the user experience validated the acceptability to use this type of training material and application in the learning process although a commercialization phase would be necessary to facilitate maintenance and support.

A limitation of the study is that there is no control group, which could have provided an interesting analysis of the impact of training using virtual reality. May be the students would have achieved their goals without VR. However, the initial goal of this study is not to evaluate whether VR is better for learning, but rather to analyze whether VR allows for learning in the case of travel with youth with ID.

Another limitation to this study was the limit reached regarding the use of social interactions. Indeed, the latter was limited to strangers coming to ask the participant to get off with them. Some participants who had already reached the objective of saying "no" to a stranger could not go further in their learning with this implemented solution. A greater variety of responses would allow them to further develop problem-solving strategies. A continuation of the study could go in this direction in the future by bringing more social interactions, such as the presence of the bus or train conductor (in uniform or in civilian clothes), people who come to sit next to or in front of the child, or people who stare at them.

7. Conclusions

This article presents the development of a Virtual Reality (VR) simulator designed with the help of social educators to train young people with intellectual disabilities (IDs) in several daily tasks. The objective was to use VR to perform learning exercises with adolescents with ID. A study was conducted with 18 students for 7 months. The aim of this study was to evaluate the students' learning (single-case protocols), the impact of the exercises (self-evaluation), as well as the user experience from the point of view of teachers and educators to use this system. At the end of the project, four young people are completely autonomous in their travels: two travel on foot and two travel by public transport. The "learning by doing" approach shows promising results for working on learning objectives in VR and transferring them to the real world. Regarding the impact analysis, the results are stable over time regarding self-reported ease, satisfaction, and fatigability. The system also received valuable feedback from the tutors and teachers.

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Institutional Review Board Statement: The project has been submitted to the Cantonal Commission for Ethics in Human Research and each youth and each legal representative have signed a consent form. This Cantonal Commission adheres to the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects and their legal representative involved in the study.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

This presents all the possible variations for each scenario in three tables.

Table A1. Crosswalk and moving in the street scenario variations.

Type of Scenario	Base	Combination of Scenario	Options	Distractors	Avatars	Break Downs
Moving on the sidewalk	Walk on the sidewalk		crossing without traffic light	obstacles: trash bins	Avatar passing by the student	
			crossing with traffic light	ball rolling onto the road	Avatar walking behind the student	
			crossing with central isle	parked cars		
			at night			
			at daytime, with rain			
			drivers' kindness			
			traffic density			
			30km/h area, without sidewalk			
			path to memorize			

Table A2. Taking the bus scenario variations.

Type of Scenario	Base	Combination of Scenario	Options	Distractors	Avatars	Break Downs
Moving by bus	Asking for stop when getting onto the bus	bus + train	other bus numbers before the right one	path to follow in between bus stops	Avatars getting on the wrong bus	mobile phone
	Pressing on the door button to get on	bus + walking	real bus numbers	music	Avatar addressing the student with various scenarios (mcdonald's, shopping, video games)	break down announces
	Getting on the bus	bus + bus	crossing street to reach the bus stop	barking dog	Avatar staying close to the student	announces stating to stay on the bus
	Seating down	round trip	other stops before the right one	immobile avatars		
	Listening to stop announces		real vocal stop announces	stops display breaking down		
	Pressing on the button to ask for stop		real stops displayed			
	Getting up		crossing street in between bus stops			
	Pression on the door button to get off		path to follow in between bus stops			
	Getting off the bus					

Table A3. Taking the train scenario variations.

Type of Scenario	Base	Combination of Scenario	Options	Distractors	Avatars	Break Downs
Moving by train	Getting to the platform	train + bus	other stops before the right one	increasing background noises	Immobile avatars on platforms	mobile phone
	vocal announces on the platform	round trip	train arriving on another platform	music	Avatars waiting on wrong platforms	break down announces
	displays for announces on the platform		other trains before the right one	Displays on platform breaking down	Avatars getting on the wrong train	announces stating to stay on the train
	Pressing on the door button to get on		Real trains and real stops	Displays on train breaking down	Immobile avatars on the train	
	Getting on the train		real vocal stop announces	Announcing train arriving on another platform	Avatar addressing the student with various scenarios (mcdonald's, shopping, video games)	
	Seating down				Avatar staying close to the student	
	Listening to stop announces					
	Getting up					
	Pressing on the door button to get off					
	Getting off the train					

Appendix B

Table A4. Example of one sequence of SCP.

Exercises	Student Task	Educator	Engineer
1st ex.	1. Raises the arm when the bus arrives 2. Gets on the bus 3. Sits down 4. When the stop is announced, presses the button with the handle to ask for the stop 5. Looks at the relevant elements (bus door, seat, button, and screen) 6. Listens to voice information	Verbal guidance	Basic scenario
2nd ex.	1. Raises the arm when the bus arrives 2. Gets on the bus 3. Sits down 4. When the stop is announced, presses the button with the handle to ask for the stop 5. Looks at the relevant elements (bus door, seat, button, and screen) 6. Listens to voice information	Verbal guidance	Add background noises in the bus
3th ex.	1. Raises the arm when the bus arrives 2. Gets on the bus 3. Sits down 4. When the stop is announced, presses the button with the handle to ask for the stop 5. Looks at the relevant elements (bus door, seat, button, and screen) 6. Listens to voice information	Without	Background noises in the bus

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