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IMPROVING THE SEQUENTIAL TIME PERCEPTION OF TEENAGERS WITH MILD TO MODERATE MENTAL RETARDATION WITH 3D IMMERSIVE VIRTUAL REALITY (IVR)

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ABSTRACT

Children with mental retardation have pronounced difficulties in using cognitive strategies and comprehending abstract concepts—among them, the concept of sequential time (Van-Handel, Swaab, De-Vries, & Jongmans, 2007). The perception of sequential time is generally tested by using scenarios presenting a continuum of actions. The goal of this study was to test whether the perception of sequential time among teenagers with mental retardation would improve, by using an intervention program employing 3D Immersive Virtual Reality (IVR). Eighty-seven teenagers with mild to moderate mental retardation, between the ages of 9 to 21, participated in the study. They were divided into three groups: a) an experimental group, who experienced sequential time scenarios in 3D IVR; b) one control group, who experienced the same scenarios via a series of two-dimensional (2D) pictorial episodes; and c) a second control group, who underwent no program of intervention. Our findings indicate that the participants who used the IVR program improved their time perception more than did the other members of the two control groups. In addition, the results reveal that the achievement required less moderation than executed with the control groups. Similarly, the results

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indicate that teens with mild retardation achieved a higher degree of sequential time perception than did those with moderate retardation.

PREFACE

It is widely accepted in the literature that the process of developing time perception takes place gradually following the child's acquisition of space awareness (Clark, Marschark, & Karchmer, 2001). In the very early childhood period, time is perceived as a group of isolated moments. This is because infants have yet to develop the ability to remember—a faculty which is essential to the creation of an awareness of the past, present, and future. The child acquires a deep understanding of the differences between past, present, and future only at age 5, at which age one begins to absorb the order in which units of time, hours and days, occur. Full time-orientation is acquired at about age 7 and a complete mastery of all time dimensions, including historical time, is achieved only in adolescence (Zakay, 1998).

In this research we studied teenagers with mental retardation, who seem to have difficulties in time perception (Van-Handel, Swaab, De-Vries, & Jongmans, 2007). Our goal was to improve the participants' sequential time abilities by means of an immersive 3D program. Sequential time perception is defined as the ability to comprehend the occurrence of events, one after another, in ranges of days, weeks, months, and years, as well as the ability to arrange sequences of events according to the logical order in which they happen (Piaget, 1969). When a person with a normative perception of sequential time looks at a series of pictures of an event which takes place in time, s/he is supposed to understand the meaning of each point in time, to complete the missing pieces on the basis of her experience, and build a logical sequence of events as they might happen over time.

The present study tested teenagers with mild to moderate mental retardation. People with mild mental retardation are, according to the literature, capable of learning, but have intellectual abilities which are significantly lower than those of the average person their age. They are able to learn to read, to write, and to do arithmetic, but their achievements are usually lower than those expected from normative people of their age group. There are some researchers who maintain that children with mild mental retardation are more similar to children with learning disabilities than to children with moderate or severe mental retardation (MacMillan, Siperstein, & Gresham, 1996).

However, in contrast to the mildly retarded, people with moderate mental retardation have a limited ability to learn. Still, one can help them progress by using special teaching programs. According to the literature (Browder, 2001), their intellectual functioning is significantly lower than the general average. When they are of school age, some are able to acquire very limited functional, academic skills such as reading words which have survival-related context (Stop, Danger, etc.). A very small percentage of the moderately retarded children are able to achieve a first or second grade level of reading and/or arithmetic. Schools tend to teach the teenagers with moderate mental retardation mostly adaptive behavior, such as social and language skills, personal hygiene, and so forth. Approximately up to age 14, they develop the skills of basic personal care, short and simple conversations, certain social patterns of interactions, and functional language.

People with mental retardation have a variety of difficulties. Most have weak language abilities, and attain different stages of language development over much more time than do children with normal mental ability. They tend to have difficulties with using abstract concepts because they possess small vocabularies with limited syntax (Borkowski & Buchel, 1983). They tend to have difficulties in focusing and paying attention to the different elements of a task or a stimulus they are presented with (Polloway, Patton, Payne, & Payne, 1989). They also have trouble focusing on the information needed for solving a particular problem (Scharnhorst & Buchel, 1995). People with mental retardation often are unable to solve problems involving the generalization of relationships (Dermitzaki, Stavroussi, Bandi, & Nisiotou, 2008), and therefore have difficulty transferring what they have learned regarding one situation to another.

Various studies have found that time perception of children with mental retardation, if it develops at all, does so later than that of the general population (Dykens & Leckman, 1990). Other studies found that children with mental retardation have great difficulty in carrying out assignments which demand continuity over a span of time (Van-Handel et al., 2007). On account of these difficulties, the aim of this study was to develop a program of intervention using 3D Immersive Virtual Reality (IVR), in order to test whether it would improve the sequential time perception of teens with mental retardation, in comparison with a 2D pictorial program of intervention.

Immersive Virtual Reality and Children with Mental Retardation

One of the unique qualities of IVR is its ability to immerse the user in a synthetic world (Cliburn, 2004). A number of studies in the field of virtual reality demonstrated that immersion improves the ability to understand abstract concepts by making them more concrete, and by presenting a special point of view of processes which the real world can't provide (Eden & Passig, 2007).

Reflecting this common knowledge, different researchers in recent years studied IVR and its impact on populations with special needs (Standen, Brown, & Cromby, 2001). For example, Eden and Passig (2007) found that children with hearing impairment perceive sequential time better via 3D immersive virtual worlds than via other presentation methods: pictorial, verbal, written, and signed modes. Other studies investigated the influence of IVR among populations with special intellectual disabilities. These studies were designed to see whether it is possible to improve independence and various functioning skills, and also to determine whether it is possible to strengthen and increase their self-confidence (Weiss, Bialik, & Kizoni, 2003).

Practical Rational

Indeed, during the years many practical programs were developed to enhance a variety of physical and cognitive skills of children and teenagers with mental retardation. Most of the programs used conventional techniques and technologies and some even used cutting edge technologies such as VR (Standen & Brown, 2005; Tam, Man, Chan, Sze, & Wong, 2005). However, to the best of our knowledge, no IVR program tailored for participants with mental retardation was developed to enhance time perception.

Time perception is a very important skill for teens with mental retardation. Without a good comprehension of time it is hard to manage and follow many daily tasks. However, it is also a very difficult skill to teach. Thus, our goal in this study was to test whether IVR is a better way to improve sequential time comprehension and test its effectiveness as compared with conventional pictorial mode of representation. Accordingly, the research question was, whether there are any differences in improving sequential time perception among three research groups: one experimental group and two control groups.

a. the experimental group, whose members exercised full 3D immersive VR sequential time worlds;
b. one control group, whose members exercised the same worlds via a series of 2D pictorial scenarios; and a
c. second control group, whose members were not involved in any program but were tested nonetheless at the same time the other groups were evaluated in the pre and after tests.

We assumed that this study could open a variety of options to better teach and enhance some difficult mental skills and cognitive capabilities characterizing mental retardation.

PARTICIPANTS

Eighty-seven teens with mental retardation participated in this study. Forty-eight were teenagers with mild retardation (57%) and 39 with moderate retardation (44%). A x^2 analysis was performed to determine whether the degree of mental retardation was distributed equally, and a significant difference was not found x^2 (1) = .931, $p > .05$. In other words, the number of participants with mild mental retardation was not significantly different from the number of participants with moderate mental retardation.

The participants' degree of mental retardation was determined by psycho-didactic diagnostic testing and by earlier reports documented in the participants' personal files. This data was handled to the researcher by the schools where the study was carried out. All the participants had an inborn type of mental retardation. The participants' ages ranged from 9 to 21, and the average chronological age was 14 years and 9 months.

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The average age of the participants with mild mental retardation was 14 years and 7 months ($M = 14.96$; $SD = 3.38$), and the average age of the participants with moderate mental retardation was 14 years and 11 months ($M = 14.96$; $SD = 2.84$). A t-test for comparing the two groups by age indicated that there was no significant difference in the ages of the two groups $t(85) = -.502$, $p > .05$. In the group with mild mental retardation there were 22 males (45.8%) and 26 females (54.2%). In the group with moderate mental retardation there were 24 males (61.5%) and 15 females (38.5%).

In order to see if there were differences of gender distribution between the two groups, a χ^2 analysis was performed. No significant difference was found $\chi^2(1) = 2.13$, $p > .05$. Table 1 presents the distribution of the participants according to family characteristics: parents' years of schooling, number of siblings, and participants' place in birth order.

Two members (4.2%) of the group of mildly retarded participants received assistance in communicating and expressing themselves and 46 (95.8%) did not have that assistance. Seventeen (43.6%) members of the group of moderately retarded participants were as well assisted, while 22 (56.4%) did not have that assistance.

The assistance was as follows: in the group of participants with mild retardation, the assistance for two of them (4.2%) was in the form of gestures. In the group of participants with moderate retardation, the assistance for four of them (10.3%) was

Table 1. Participants' Characteristics

	Mild mental retardation ($N = 48$)		Moderate mental retardation ($N = 39$)		
Measures	M	SD	M	SD	t
Years of schooling—father	11.50	2.47	13.12	2.01	$t(54) = -2.656$**
Years of schooling—mother	12.09	2.44	12.6	1.77	$t(61) = -.939$
Number of siblings	2.43	1.79	2.28	2.15	$t(83) = .358$
Place in birth order	2.6087	1.57	2.13	1.36	$t(82) = 1.492$

Note: *$p < .01$.

as well in the form of gestures, nine (23.1%) received picture communication symbols' support (PCS) developed by Mayer-Johnson (1985), three (7.7%) received assistance in the form of gestures and PCS, and one (2.6%) received assistance via sign language and PCS.

All the participants were active in the special education system in a metropolitan area. Eleven (22.9%) of the teens with mild retardation had been students in the general education system at some time, while 37 (77.1%) had always been in the special education system. Two (5.1%) of the participants with moderate retardation had been students in the general education system, while 37 (94.9%) had never been connected to the general educational system.

The range of years of schooling was between 1 and 13 years; the average number of years of schooling in the group of the participants with mild retardation was 5 years and 5 months ($M = 5.04$; $SD = 3.06$) and the average number of school years in the group of the participants with moderate retardation was 5 years and 8 months ($M = 5.72$; $SD = 2.71$). The *t*-analysis for comparing the two groups by years of schooling indicated that there was no significant difference between the two groups: $t(85) = -1.078$, $p > .05$.

RESEARCH INSTRUMENTS

2D Pictorial Scenarios

Three 2D animated pictorial scenarios were developed for this study. Each scenario consisted of four to five animated color pictures which formed a story with a time sequence. The three scenarios were taken from the daily life of a child who is baking a cake, planting a tree, and making a chocolate milk drink. Arranging the scenarios required the skills of sequencing, ordering, and understanding time relationships.

3D Immersive VR Scenarios

The same 2D animated scenarios were generated as 3D immersive virtual worlds. The participants used VR immersive technology (head mounted display with a head tracking sensor) to interact with them. Each of the IVR episodes had its own opening screen, which was represented by a picture stretched all over the screen (Figure 1). This picture was the cue for the scenario and for the name of the story. Four small, separate pictures in random order appeared in a column on the right side of the screen. They represented different episodes of the VR scenario.

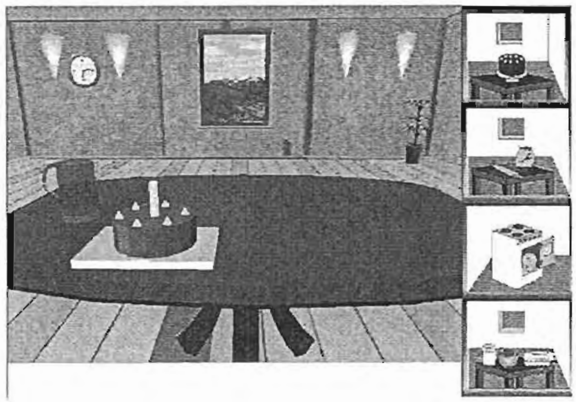

Figure 1. One of the screens from the virtual world in which a cake is baked.

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The pictures appeared in random order. When any of the pictures was pressed, the participant was brought into a specific IVR episode on which s/he could work (Figure 1). In the IVR version, the participants were able to manipulate the objects, interact with them and move around as they see fit. For example, in the scenario in which a cake is baked, the participant could break eggs, mix milk, and perform other cake-baking activities. The experience included 3D visual and auditory stimuli, which generated the immersion sense in the episode.

After experiencing the IVR world, the participants were brought to a multimedia program in order to assess their ability to place the episodes in the correct order. For that matter, we constructed a multimedia program designed to arrange the sequence of the scenario for each of the episodes (Figure 2). The main screen was made up of four or five squares. A number appeared on each episode, as did small circles for the visual identification of the number, since some of the participants had yet to learn to identify the numbers themselves. Four pictures pointing to the episodes belonging to the scenario appeared on the lower part of the screen. The pictures could have been dragged from one spot to another on the screen by using a mouse. The participants were asked to drag the pictures and arrange them according to the logical time sequence estimated, in the appropriate place on the squares. After the participants finished arranging the pictures on the squares they pressed a red button which allowed them to generate and watch a video clip (consisting of the four episodes) reflecting the time sequence that they had created.

After the participants watched the video clip, whose time sequence they had generated, they received feedback from the flash based multimedia program

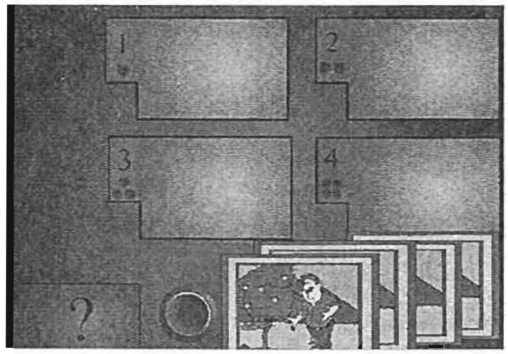

Figure 2. Sample of the animated episodes arrangement screen.

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informing them the number of errors on each attempt to create a logical sequence and the number of attempts.

Validation

The scenarios were validated by experts to have a similar level of difficulty. The experts' validation involved 10 experts with the help of 20 normative teens (12-14 y/o) without cognitive or language difficulties: we have brought together a group of five academics working on special education and five teachers working with teens with mental retardation. The group developed in collaboration the scenario's stories and divided them into episodes. The episodes were developed into a series of pictorial cards. The experts then asked a group of 20 teens to organize the episodes in a logical sequence and validated the difficulty of the sequences.

In order to certify that the episodes forming a scenario brought in front of the teens were not put initially in a logical sequence, an additional blank episode with a question mark was put at the end of each scenario. The teens were asked to organize the episodes as to form a logical sequence in order to better predict the episode marked with the question mark. We later used in the study the only scenarios that generated full agreement among all the normative teens that participated in this validation process.

The Picture Series Subtest

All the participants were tested before and after the intervention on the picture series subtest of Kaufman's test for children (1983), so as to determine whether there was improvement after the intervention. We used the second edition of the Kaufman Assessment Battery for Children (KABC-II, n.d.). This test measures the ability to organize a series of randomly arranged pictures in a way which fits the time sequence of an event presented in those pictures. The test examines visual-motor-channel thinking, and measures specific abilities such as arranging items in a logical order, sequencing, planning, results' expectation, comprehension of time relations, the concept of time itself, and the comprehension of causal relations. The test was designed for children and teens between the ages of 6 and 12.

One of its sub-tests was designed to examine achievements of sequential time before and after an intervention. Our study tested this ability only, and didn't aim to test general understanding of time-relatedness. The instrument's reliability was found to be .76, and its validity .65. The test includes 17 series of cards on which there are photos. Each series has from four to ten pictures. The pictures were presented to each participant in an illogical order. The participants were asked to arrange the pictures according to the correct sequence of actions. Every item in the test is dichotomous. In other words, a correct answer gives a score of 1 point, while an incorrect answer gives 0 points. The raw score was calculated with the number of the correct answers. The conversion of the raw score to a standard score was generated by a special key.

PROCEDURE

Before engaging in the study, we ran a usability pilot involving 10 teens with mild and moderate mental retardation (ages10-15) in which we tested their ability to use the IVR platforms without requiring extensive mediation, including the use of a Head Mounted Display (HMD). The aim was also to test the usability of the 3D and 2D scenarios as well as the multimedia program with which we tested their ability to organize the correct sequences. No special difficulties were observed in using the VR environments. We found that with some guidance they all managed to use the technology and follow the instructions.

After completing the pilot study successfully, we divided the participants into three random research groups: one experiment group and two control groups. The experimental group and the first control group have exercised the same scenarios. The only difference between the groups was the mode of presentation—a 3D immersive VR, as opposed to a 2D pictorial mode. Each participant in the experiment and first control groups practiced the scenarios during seven sessions, two each week spread across one month. Each session was devoted to a different scenario. If they didn't finish one in one session they would return to it in the following session. The duration of each session was 20 minutes at most.

In each of the sessions involving each participant of the experimental and control groups, four to five episodes (forming just one logical story) belonging to the same scenario were introduced to the participants. The researcher verbally requested that the participants arrange the episodes so that they would tell a story. The researcher explained each episode, and pointed to it.

If the participants arranged the episodes to a correct scenario in the multimedia program, and without the assistance of the researcher, they moved on to the next scenario during the same session. If the participant erred in arranging the scenario after practicing a while in the 3D IVR or with the pictures, the researcher began the process of mediation, which included a request for an explanation of what was going on in each episode. If the participants didn't know how to explain one of the episodes, the researcher assisted them, by explaining in detail what was happening in the episode they had difficulties in understanding. Following this, the participants were asked to arrange the same scenario again in the multimedia program, and if they did so correctly, the session was ended. If they arranged the scenario incorrectly, the researcher helped them understand the episodes until they successfully rearranged the scenario in its proper order.

RESULTS

In order to measure subtle changes in the sequential time perception of the participants, we have performed two kinds of measures:

1. a pre- and post-measure of the sequential time perception of the three groups participating in this study using the Kaufman's pictures series subtest; and

Table 2. Averages and Standard Deviation of Sequential Time (Kaufman's Subtest) in Different Times of Measurement (Pre- and Post) by Research Groups (3D, 2D, and No Intervention)

	Perception of sequential time—pre ($N = 29$)		Perception of sequential time—post ($N = 29$)		
Research groups	*M*	*SD*	*M*	*SD*	$F(1,28)T$
Immersive 3D	5.078	.128	5.767	.183	20.784***
2D	5.010	.128	5.376	.183	4.787*
No intervention	5.038	.128	5.179	.183	3.136

Note: $^{***}p < .0001$, $^{*}p < .05$.

2. another measure during the intervention program using a multimedia program designed to measure success and failure rates in organizing logical episodes into correct scenarios.

Pre- and Post Measures

In order to test whether there are differences in sequential time perception before and after the intervention program, we performed a two way ANOVA with repeated measures on the participants' standard score calculated by the Kaufman's pictures series subtest.

We found a significant difference between the different experimental groups and the different time measurements in perceiving sequential time, $F(2,84) = 3.988$, $p < .05$, $\eta^2 = .087$. We found that the perception of sequential time after the intervention in the groups exposed to immersive 3D mode of presentation and 2D mode of presentation was significantly higher than the perception of sequential time before the intervention (Table 2 and Figure 3). However, as can be seen from F, the differences with the participants exposed to the 3D intervention were greater than those with the participants exposed to the 2D intervention. In contrast, no significant difference was found in the perception of sequential time in the test after the intervention in the second control group, whose members underwent no intervention after their first test.

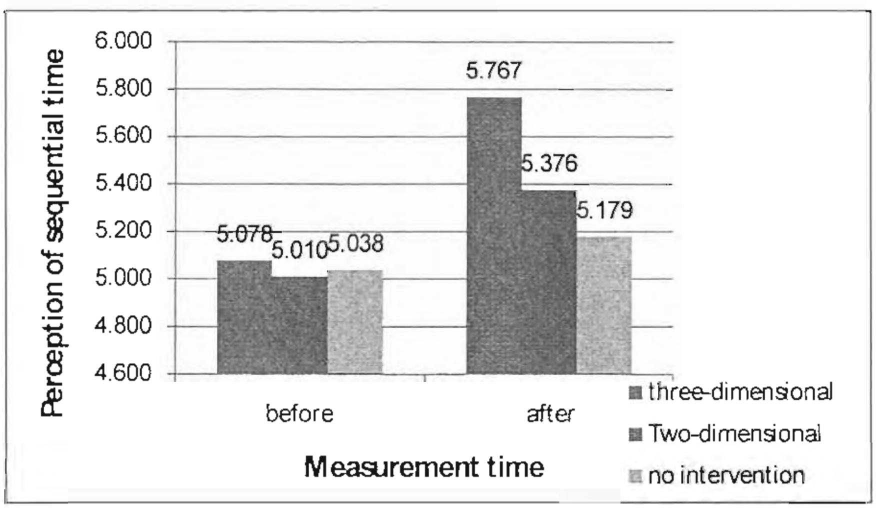

Figure 3. Sequential time perception (Kaufman's subtest) in pre- and post-intervention measurement times by the different research groups (3D, 2D, and no intervention).

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During the Intervention Measures

In addition to the comparison between the groups before and after the intervention with the Kaufman's subtest, we have also tested whether there are differences in sequential time perception between the experimental group (3D IVR) and the first control group (2D) during the intervention program itself. For that matter, we performed a χ^2 independence analysis for the differences' analysis between success and failure in arranging the various scenarios. Success was noted if the participant achieved the average number (and above) of the group's successful attempts as recorded by the multimedia program. Failure was noted as below the group's average number of successful attempts. We found a significant dependency $\chi^2(1) = 3.783$, $p < .05$. Meaning, the level of success among the experimental group (3D IVR) was significantly higher than among the first control group (2D) (Table 3).

Levels of Mental Retardation Measures

In this study we have also examined whether there are any differences between participants with different levels of mental retardation (mild and moderate) in their perception of sequential time, before and after the intervention with 3D IVR. We performed a two way ANOVA analysis with repeated measures on the participants' perception of sequential time. The analysis indicate that there are significant differences between the different levels of retardation in perception of sequential time $F(1,85) = 28.094$, $p < .0001$, $\eta^2 = .248$. It seems that the perception of sequential time on the part of participants with moderate mental retardation was

Table 3. Success During the Intervention in Arranging All the Scenarios by Modes of Representation (3D and 2D)

	Success in arranging scenarios			
	Success	Failure	Total	$\chi^2(1)$
3D IVR	26	3	29	
Percent	44.8%	5.2%	50.0%	
2D	20	9	29	
Percent	34.5%	15.5%	50.0%	3.783*
Total	46	12	58	
Percent	79.3%	20.7%	100.0%	

Note: $^*p < .05$.

significantly lower than that of participants with mild mental retardation after the same intervention (Table 4).

In order to test whether there are any differences in sequential time perception among the two levels of mental retardation (mild and moderate) during the intervention, we performed a χ^2 independence analysis for the differences' analysis between success and failure in arranging the various scenarios. We found a significant dependency $\chi^2(1) = 7.548, p < .01$. Meaning, the level of success among the participants with mild mental retardation was higher than among the participants with moderate mental retardation (Table 5).

DISCUSSION

In reviewing the research literature we found that teens with mental retardation demonstrate marked difficulty in the perception of sequential time (Dykens &

Table 4. Averages and Standard Deviations of Sequential Time Perception in Groups with Different Levels of Mental Retardation (Mild and Moderate)

Mild mental retardation (N = 48)		Moderate mental retardation (N = 39)		
M	SD	M	SD	$F(1,85)$
5.584	.097	4.820	.107	28.094***

Note: ***$p < .0001$.

Table 5. Success During the Intervention in Arranging All the Scenarios by Level of Mental Retardation (Mild and Moderate)

	Success in arranging scenarios			
	Success	Failure	Total	$\chi^2(1)$
Mild mental retardation	37	11	48	
Percent	42.5%	12.6%	55.2%	
Moderate mental retardation	19	20	39	
Percent	21.8%	23.0%	44.8%	7.548**
Total	56	31	87	
Percent	64.4%	35.6%	100.0%	

Note: **$p < .05$.

Leckman, 1990; Van-Handel et al., 2007). This is expressed in frequent inability in carrying out tasks requiring continuity over a range of time. Beyond that, children with mental retardation develop a perception of time later, if at all, than do normative children.

Our research question was whether exercising sequential time episodes in an immersive 3D VR environment would lead to greater success in demonstrating sequential time perception than exercising it in a 2D environment or no exercising at all. The results indicated that participants with mental retardation who were exposed to an immersive 3D VR program achieved a greater degree of sequential time perception than did those exposed to a 2D program, or those who were not exposed to any program. These results could be explained in three ways.

The advantage achieved by using a 3D VR program is well reflected in the literature. It is well documented that the ability of the 3D immersive experience can provide a sensation of real presence (Cliburn, 2004) that motivates the user to become much more engaged and active in the tasks delivered in a 3D environment. It has been argued in a variety of studies that immersion is a feature unique to VR, one which have an impact on a variety of cognitive abilities (Passig & Eden, 2000a, 2000b; Rose, Brooks, & Rizzo, 2005). Reflecting this literature, we have developed in our study a number of episodes that formed clear short scenarios where the participants became immersed in the virtual worlds in ways that were not reported in the literature as yet due probably to the unique research population of this study. For example, some of the participants, while wearing the virtual reality HMD, stretched out their hands, and asked why they couldn't see their hands in the simulation. One of the participants said that he felt like a pilot, and that he "saw everything from his brain."

As far as we know this is the first time a population with mental retardation is being involved in a study with VR. The immersive aspect, thus, had an impact not yet reported with teens with mental retardation which probably contributed to the results.

Another possible explanation to the positive results draws from virtual reality's ability to make what is abstract more concrete (Ellis, 2001). Recent studies reconfirm that immersion improves the ability to understand abstract concepts, by making them more concrete, thereby making it probably easier to perceive time. For example, in a recent study we found (Eden, 2008; Eden & Passig, 2007) that children with hearing impairment and hearing children who have been exercising time perception in immersive 3D virtual worlds perceived and expressed sequential time better than those exposed exclusively to visual-pictorial representations, verbal representations, and other modes of representation. Osberg (1995), as well, maintained that abstract concepts can be presented in a creative way, since virtual reality does not limit the designer insofar as the form of presenting information is concerned, and does not limit the movements of the user. As a result, it is possible to improve the ability to understand abstract concepts through the use of virtual reality. In that respect the concept of time is an abstract concept based on representative thinking (Eden & Passig, 2007). The person who looks at a series of pictures of an event which takes place over time is meant to understand the meaning of each point in time, to cover the gaps on the basis of her experience, and to construct a sequence of events which take place over time. This demands the ability to think abstractly (Bornens, 1990). Children with mental retardation have greater difficulty in grasping abstract and symbolic concepts than understanding concrete ones, and therefore demonstrate pronounced difficulty in the perception of sequential time (Dykens & Leckman, 1990; Van-Handel et al., 2007). Thus, immersive VR could have played a significant role in enhancing its perception.

Some studies in the early times of personal computer simulations (Hasselbring & Goin, 1989) have already attributed importance to the inclusion of simulations in the education of the mentally retarded population, as simulations provide repeated examples of situations from real life which can be presented on a computer screen. This form of presentation allows the educator to change the situations, to emphasize them, or to simplify their complexity, according to the students' needs and the educator's goals. This concretization and process of matching needs and goals was found to make learning easier for the student with mental retardation, who can be expected to have difficulties in dealing with the abstract.

A third possible explanation is related to the interactivity characteristic of virtual reality—a feature which makes its users especially active. The nature of VR is that the user is not passive, but active in an "expanded" or "enhanced" reality, in which the participant uses all his senses. The user can react to situations of the real world through graphic images presented to him. One can converse with the images, move and activate virtual objects, and perform different behaviors (Franchi, 1995; Pan, Cheok, Yang, Zhu, & Shi, 2005). Manrique (1997) points out that simulation via immersive virtual reality expands the limits of the presentation to the level of personal interface interaction as it makes the icon and symbol coding of content possible.

An important principle in the teaching of teens with mental retardation is learning through doing and active experience. Because of their difficulties with abstraction, it is important to use lots of concrete examples (Hasselbring & Goin, 1989). Involving the students in a learning program supported by a wide variety of aids and multi-sensory stimuli is likely to focus the learning process, to empower it, and, by doing so, to give another opportunity to children with special needs (Mike, 1995).

Another finding of this study was noticed in the differences between the groups of participants with mental retardation (mild and moderate) in their perception of sequential time. We found that participants with mild mental retardation demonstrated a greater perception of sequential time than did the participants with moderate mental retardation. MacMillan et al. (1996) support this finding, and maintain that children with mild mental retardation are more like children with learning difficulties than children with lower degrees of mental retardation, whereas children with mild retardation achieve basic, functional levels in reading and arithmetic—up to the level of third to fifth graders. Only a very small percentage of moderately retarded school age children are able to acquire functional scholastic skills, and then only to a very limited extent. The main emphasis in their education is in the area of adaptive behavior, such as social skills, language skills, personal hygiene, and so forth. Only a very small fraction of the population with moderate mental retardation is able to attain the first or second grade level of reading and arithmetic (Browder, 2001).

In summary, the findings of this study show a clear advantage for a program of intervention which includes immersive 3D presentation based on virtual reality technology, which contributes to an improvement in the perception of sequential time in participants who have mild to moderate mental retardation. Beyond that, we demonstrated that participants with mild mental retardation obtained with VR better results in perceiving sequential time than did participants with moderate mental retardation.

This research added new theoretical knowledge to the cognitive facet of sequential time perception of the population with mental retardation, and contributed a new body of knowledge in the area of the use of virtual reality technology with this population.

To the best of our knowledge, the results of this study could have immediate implications for the education of teens with mental retardation. The type of program we developed enables educators and treatment staff to advance teens in this important cognitive domain, which could assist them better understand reality and take their place in society.

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