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The impact of virtual reality on parents' awareness of cognitive perceptions of a dyslectic child

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Abstract Parents of dyslexic children encounter many difficulties in understanding and accepting their children's disability. This affects the child's self-image and the way s/he copes (Hallahan and Kauffman 1991; Einat 2003). The goal of this study was to develop VR immersive simulated states. The simulation was designed to help the parents of dyslexic children experience the kind of errors their children make when reading. Two groups of parents of dyslexic children participated in this experiment, an experimental group (N=37), which experienced ten 3D worlds simulating different kinds of reading errors, and a control group (N=30), that watched a movie describing and explaining similar errors. All the subjects were administered a cognitive questionnaire (Shavit 2005) before and after the intervention. In addition, the participants in the experimental group were interviewed before and after the intervention. The results indicate that experiencing a variety of simulated types of dyslexia with virtual reality can bring about improvement in parents' awareness of the dyslexic child's cognitive experiences, and that this improvement is significantly greater than that achieved by watching a film about dyslexia.

Keywords Virtual Reality · Reading impairment · Awareness of dyslexia · Parents of dyslexic children

One can find in the literature that some point to phonological coding deficits as the more likely source of dyslexia. Vellutino and Fletcher (2005) claim that too much dyslexia research has mistaken the results of poor/misguided initial teaching for some biological/neurological etiology. We did not want to touch this issue in our

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study since our scope was only to test the effectiveness of VR technology to transfer abstract knowledge about a very difficult cognitive situation. Our study focused at only enhancing the knowledge and awareness to this cognitive experience as suggested by one of the many typologies of the phenomenon in the literature.

However, one can find also in the literature that some define dyslexia as a unique learning disability whose etiology is neurological (Lyon et al. 2003). According to this definition, dyslexia is characterized by difficulties in reading accuracy and/or in fluent identification of a variety of words, and by weakness in the ability to spell words and to decipher them. These difficulties generally, according to this body of literature, stem from a deficiency in the phonological component of language. This is a phenomenon which often is unexpected, relative to the person's other cognitive abilities. Secondary difficulties may include problems in reading comprehension, and a proclivity to an avoidance of reading, which is all too likely to result in a limited vocabulary and a low level of general knowledge.

Researchers, in this school of thought, have identified to date two types of errors stemming from mishaps in different stages in the reading process (Gvion and Friedmann 2004). These types of errors are divided into two main groups (Shallice and Warrington 1977): peripheral dyslexia and fundamental dyslexia. Peripheral dyslexia is a disability in the visual process in which stimuli are identified. It prevents a person from reliably matching a familiar word with its visual form (the ability to identify letters, to encode the order of letters in a word, and to attribute the letters to words). Nonetheless, the professional literature is replete with definitions and descriptions of various kinds of dyslexia (Murphy 2004).

In this study, we used an available taxonomy of dyslexia, carried out by Friedmann and Gvion (2001), to construct virtual worlds and to test their relative merits in increasing the parent's awareness of dyslexia in general, and of the reading-impaired in particular. The purpose of the study was to test the effectiveness of virtual technology in enhancing parent knowledge and awareness of this complex phenomenon known as dyslexia. The study did not seek to verify the distinct patterns of dyslexia included in the Friedmann–Gvion taxonomy independent of particular instructional histories. Rather, this taxonomy served us to validate the virtual worlds we built. The Friedmann–Gvion taxonomy (see Gvion and Friedmann 2004) consists of ten distinct categories of dyslexia:

1. Visual letter agnosia: A dyslexia that causes difficulties in identifying individual letters, making it impossible for the child to identify letters visually. Children who suffer from visual letter agnosia can identify letters via sensory stimulus. For example, dyslexics can distinguish between letters which have been cut out of woolen cloth. In addition, they can identify letters via kinesthetic stimulus by tracing the letters' shapes with their fingers (Lott and Friedman 1999; Friedmann and Gvion 2001).
2. Neglect dyslexia: In this kind of dyslexia, attention is directed to letters located on one side of a word and text (usually the right side). As a result, as the person reads, he or she removes or exchanges letters on the neglected side of the word. For example, 'river' is read as 'liver,' 'cabin' as 'robin,' or 'liquid' as 'squid.' In addition, the person with neglect dyslexia will find it hard to report on the first sound of nonsense words. For example, there would be difficulty in

identifying the letters 'ti' of the nonsense word 'tiggle.' As reading is influenced by word structure, it seems most likely that this dyslexia cannot be attributed to the result of processing letters or information, but to attention impairment on a higher level of representation (Behrman et al. 1990; Ladavas et al. 1997; Gvion and Friedmann 2004).

3. Visual dyslexia: This is a type of dyslexia where one word is read as another, which is visually similar to it. There is not necessarily visual similarity to the letters that have been exchanged. For example, the word 'pod' could be read as 'pad,' 'colonel' as 'color,' or 'read' as 'road.' (Friedmann and Gvion 2001; Shallice and Rosazza 2006).
4. Letter position dyslexia: In this form of dyslexia, the letters of the word are identified correctly, but their position within the word is incorrect. As a result, many errors are made by transposing the letters within the word. This dyslexia was first identified in Hebrew. Hebrew is written without vowels, and has a unique morphology, which allows for the existence of many words which share the same letters, but in different order. The native Hebrew speaker would be more liable to be affected by letter position dyslexia than a speaker of a different language (Friedmann and Gvion 2001; Shallice and Rosazza 2006).
5. Attentional dyslexia: In this form of dyslexia, letters are properly identified, as are their position in the word, but letters wander between words, while maintaining their relative position in a word. The identity of the letter is maintained at the time of reading, but there is a deflection of its position in the word. The difficulty in focusing attention increases with the number of words on a page. Warrington and Shallice (1979) hypothesized that these dyslexics derive meaning while reading since they depend more on the concept than on the semantic process (Warrington and Shallice 1979; Price and Humphreys 1993). The movement of the letters may be between adjacent words in a line (horizontal wandering), for example: The pair of words 'win fed' might be read as 'fin fed' (Mayall and Humphreys 2002).
6. Letter by letter dyslexia: This is a form of dyslexia where the most striking characteristic is the reading of words letter after letter, and, only after reaching the end of the word, reading the whole word. The process of reading is very slow, and the pace of reading is dependent on the length of the word being read. The child suffering from letter by letter dyslexia can read all types of words, including abstract words, such as 'destiny,' or concrete words, such as 'table,' or when the word is recorded according to the rules of neat writing, such as 'hand.' The ability to write a word remains intact, but after writing a word, the person with this type of dyslexia has difficulty in reading what has been written, because of his difficulty in identifying letters written down not always in a clear hand (Lott and Friedman 1999; Montant and Behrmann 2000; Rayner and Johnson 2005).
7. Surface dyslexia: A difficulty in reading words written in other than standard ways, or when there is an unusual connection between the written word and its accompanying sound, as in 'yacht,' or 'borough.' People with this type of dyslexia can read words well only if they are written according to the rules. Examples are words like 'mosquito,' 'hand,' 'state,' and nonsense words, such as 'blape' (Marshall and Newcombe 1980; Plaut 1999; Branch-Coslett 2000).

8. Phonological dyslexia: A difficulty in reading new words, although the dyslexic person can read words whose writing he has mastered (this dyslexia is a complementary syndrome to surface dyslexia). In phonological dyslexia, which is acquired after the acquisition of reading, there is a problem only with new words or with nonsense words, as the dyslexic person cannot rely on the connection between letters and sounds. Subjects who were able to read approximately 90% of real words were able to read only 10% of nonsense words (Glosser and Friedman 1990; Plaut 1999; Branch-Coslett 2000). Dyslexics people who possess a mental reserve of written words (an orthographic absorption lexicon) may not have their dyslexia diagnosed, so long as they read words that are familiar to them, but will encounter difficulty in reading new words, the written forms whereof they have yet to see. This is not the case with the developmental phonological dyslexic who has just begun to read. This child will have great difficulty acquiring reading skills. However, gradually, the child will fill his absorption lexicon with words to which he or she has been exposed, and will succeed in reading familiar words in this way. The child will continue to experience difficulty when encountering a new word. In reading nonsense words, the same process takes place as in reading new words of any kind. Nonsense words are not included in the child's orthographic lexicon, and they cannot be read according to the usual rules of attaching sounds to letters, so that the child searches for a familiar word which is similar to the nonsense word presented. The most common error pattern is in exchanging the nonsense word for a familiar one, as when 'phope' is read as 'phone.' The response for nonsense words that are not similar to anything in the orthographic lexicon is "I don't know." (Coltheart 1980; Temple 1997; Gvion and Friedmann 2004).
9. Semantic access dyslexia: This form of dyslexia is sometimes called hyperalexia. People with semantic access dyslexia usually do well in reading familiar and new words, words which are written in a standard and a non-standard way, and also rare words. Despite this, they do not understand the words they read. One must draw a distinction between cases where the problem of understanding stems only from semantic access to the written word, or from a problem in understanding, which becomes apparent in spoken words, as well (Warrington and Shallice 1979; Gvion and Friedmann 2004).
10. Deep dyslexia: A person with this kind of dyslexia can read only via semantics (a storehouse of meanings of words). He or she can grasp the meaning of written words, but will have difficulty in selecting the word from his storehouse, which fits exactly the word seen on the page. For the most part, these children can read words with similar semantics to those placed before them; for example, reading 'knight' instead of 'castle,' and 'canary' instead of 'bird.' Children with this diagnosis may also make visual errors, such as 'scale' instead of 'skate.' A group of words that are difficult are called functors. These include nicknames, prepositions, compound words, and words of reference, or conjunctions such as 'which,' 'that,' and 'because.' Abstract nouns, such as 'wish,' 'fate,' and 'destiny' are harder to read. It is also difficult for children with this type of dyslexia to read nonsense words, such as 'flig,' which might be read as 'flag' (Marshall and Newcombe 1980; Plaut 1999; Branch-Coslett 2000).

Indeed, the professional literature is replete with definitions and descriptions of various kinds of dyslexia. In order to simplify this research we had to choose a typology according to which we would be able to construct virtual worlds and to test their relative merits in increasing the parent's awareness of dyslexia in general and of the reading-impaired in particular. We chose to base our study on this typology, solely since Friedmann and Gvion were available to help us validate the virtual worlds we constructed on the basis of their taxonomy and since their typology was clear enough for reproduction in a synthetic simulated world.

1 Parenting a child with a reading disability

A great deal of research has been conducted over the years on many aspects of the subject of dyslexia. Studies which focused on the parents of a dyslexic child dealt mainly with emotional and family issues, with diagnosing the disability, and with treating it (Dyson 1996). However, in making an exhaustive search of the literature, we have been unable to find any study on the subject of developing the parental awareness of a child's disability. Parents generally see their children as an improved model of themselves, and expect their dreams to be realized in their children's lives (Powell et al. 1985). When a child is diagnosed as having a developmental disability, the parents are faced with a new reality, one in which their dream has been shattered. The parents' functioning is made appreciably more difficult when a broad gap stands between reality and the dream (Galinsky 1987). Einat (2003) adds that children with learning disabilities are not diagnosed as such early in their development, as is the case with mentally retarded or physically handicapped children. The diagnosis of learning disability is usually made during the first years of elementary school (Pihko et al. 1999). Until the children's disability is discovered, their handicap accompanies them, silently and invisibly, through infancy and kindergarten (Dyson 1996). Despite the inevitable pain suffered by parents, no studies have been made to date, of efforts to increase awareness of the cognitive aspects of the child with learning disability. While Shavit (2005) looked into the influence of virtual reality on the teacher's understanding of the cognitive, emotional, and social experiences of the dyslexic child, her focus was primarily on the teachers, who were meant to treat the child's disability, as well as to function as classroom teachers. In the present study our goal was to expand on Shavit's research, and to test the advantages of virtual reality technology as a means of improving parents' awareness regarding their child's reading disability.

2 Method

Sixty-seven parents of dyslexic children participated in this study, all of them parents of elementary or junior high school children, who had been diagnosed as having learning disabilities; specifically, reading impairment. The parents were divided into two groups: the experimental-VR group (N=37), who made up 55.2% of the population, and a control-movie group (N=30), or 44.8% of the population. The experimental group experienced the virtual worlds, which simulated the kind of reading errors made by children with reading impairment. These experiments were

conducted in the parents' homes on an individual basis. Each experiment lasted about 25 min. The control group watched a movie of about 25 min. The movie was a documentary of a workshop for teachers, parents, social workers, psychologists, and occupational therapists, in which the participants learned about the various kinds of difficulties coped with by children with learning disorders. The control group, just as the experimental-VR group, filled out a questionnaire before and after the intervention. Most of the children whose parents participated in the study were enrolled in a school for children with learning disabilities, while some were integrated into regular classes in their local schools. Table 1 presents the distribution of the characteristics of the parents who participated in the study, comparing the experimental (VR) group to the control (movie) group.

3 Research tools

3.1 Movie

The title of the movie was "Understanding Learning Disabilities: How Difficult Can This Be?" (Lavoie 1989). We used 25 min of excerpts from the original 70-min film

Table 1 Distribution of the subjects' characteristics

Characteristics	Values	Groups of subjects					
		VR		Movie		Total	
		N	Percentage	*N*	Percentage	*N*	Percentage
Gender	Males	7	18.9	8	22.4	15	22.4
	Females	30	81.1	22	73.3	52	77.6
Age	Up to 40	8	21.6	4	13.3	12	17.9
	41–45	18	48.6	8	26.7	26	38.8
	46–50	11	29.7	13	43.3	24	35.8
	51+	0	0	5	16.7	5	7.5
Reading Impairment	Difficulty acquiring reading	4	10.8	10	33.3	14	20.9
	No difficulties	33	89.2	20	66.7	53	79.1
	Thinks he/she is reading impaired	4	10.8	10	33.3	14	20.9
	Doesn't think he/she is reading impaired	33	89.2	20	66.7	53	79.1
	Diagnosed as reading impaired	1	2.7	0	0	1	1.5
	Not diagnosed as reading impaired	36	97.3	30	100	66	98.5
Learning disability in family	No	13	35.1	17	26.7	30	44.8
	Yes	24	64.9	13	43.3	37	55.2
Relation	Parent	2	8.3	0	0	2	5.4
	Uncle/aunt/cousin	2	8.3	1	7.7	3	8.1
	Niece/nephew	7	29.2	5	38.5	12	32.4
	Brother/sister	6	25.0	7	53.8	13	35.1
	Spouse	5	20.8	0	0	5	13.5
	Brother-in-law	2	8.3	0	0	2	5.4

so as not to tire out the parents and yet to provide an experience for them lasting the same amount of time as the intervention in the experimental group. The audio-visual clips from the film demonstrated how children with learning disabilities perceive different letters and words. This program allows viewers to experience the same frustration, anxiety, and tension that children with learning disabilities face in their daily lives. Also in the film, teachers, social workers, psychologists, parents, and friends who have participated in Richard Lavoie's workshop reflect on their experience and the manner in which it altered their approach to children with dyslexia.

3.2 Cognitive questionnaire

The questionnaire used for testing the level of parents' awareness of their dyslexic child's difficulties was developed by Shavit (2005), and is called "The Text as Seen by the Dyslexic Child." The goal of the questionnaire was to test the parents' knowledge of the dyslexic child's way of perceiving the world. The items on the questionnaire were composed, based on the taxonomy of Gvion and Friedmann (2004). The cognitive questionnaire included ten sections (Table 2), each one relating to a different type of dyslexia. The questionnaire was validated by a group of researchers and teachers who specialize in learning disabilities. The questionnaire was found by Shavit to have a Cronbach's α value of 0.71.

3.3 Interview

The participants in the experimental VR group underwent a semi-structured personal interview before and after the intervention. The subjects were quite free to express themselves as they wished. Each interview was personal, mostly in the home of the interviewee. The goal of the pre-intervention interview was to complement the information provided by the Cognitive Questionnaire. In addition, the goal was to

Table 2 A sample of questions from the Awareness Questionnaire

d	c	b	a	Cognitive Questionnaire		
s/he can not read the word		cab	slack	A dyslexic student, who fails to recognize letters, will read the word 'black' as:	Visual letter agnosia	1
page	pong	pay	lay	A dyslexic student, who fails to read and report letters on a specific side of the word, will read the word 'play' as:	Neglect dyslexia	2
red	door	dab	baby	A dyslexic student, who makes visual paralexias, will read 'bad' as:	Visual dyslexia	3
dare	beard	reading	breakfast	A dyslexic student, who makes errors of letter migration within a word, will read 'bread' as:	Letter position dyslexia	4
hot–put	pity–big	hat–pat	hit–pit	A dyslexic student, who 'migrates' letters from one word to another word in the same position, will read hut-pot as:	Attentional dyslexia	5

allow the parents to speak about their feelings, emotions, experiences, and not to leave with the feeling that perhaps there was a point which was not raised, but which they would have liked to discuss. The goal of the post intervention interview was to test the effect of the virtual experience on the parent, from the cognitive point of view. The method used for analyzing the interviews was to extract categories from the parents' responses. While examining the responses, we read all of the parents' responses to the first question, identified categories of responses, and then moved on to the next question, and so forth. After the categories were sorted out, we coded the responses, counted the number of times each category appeared in the parents' response, recorded them, and summed them up in table form.

3.4 Virtual worlds

The virtual worlds that were the focus of our intervention with parents were constructed specially for this study. We simulated ten cognitive processes of various types of dyslexia based on the Freidmann–Gvion taxonomy described above. The virtual worlds took place within a building divided into many rooms. In each room a task was presented based on one of the types of dyslexia. Each room was placed in a floating corridor, so that if a user left the room before finishing the task, he would enter an infinite space. This was designed to simulate for the teacher a feeling of desperation and of "I'm alone in the world…like in the middle of a desert" such as is experienced by a reading-impaired child.

The parents received instructions on how to use the virtual equipment and were given a password which they had to type in as a first assignment. In addition, it was explained to parents that at the beginning of each experience a sign would appear, and that a click on it would operate the experience's audio instructions. During the entire experience in the virtual worlds no additional explanations or instructions were provided as to how to proceed. The participant had to cope on his or her own, or reach the conclusion to ask for help. This feature was intended to bring home the feeling of helplessness experienced by the reading-impaired child, as well as the child's dependence on the parent.

Each parent participating in the study began his virtual experience in an experimental world. This world was designed to enable the parent to gain some practice and experience in working with a three-dimensional virtual world, the head mounted display (HMD) and joystick. In such a world, parents were able to move around and act as they wished. When parents felt comfortable they moved on to world no. 1, and the beginning of the research. Following are shorts description of two examples of the worlds that parents experienced.

3.4.1 Visual letter agnosia

The subjects find themselves at the entrance to a maze (see Fig. 1). Ahead of them is a sign on which is written "Identify the letter you are walking through." The subjects can also hear that command by clicking on the $. The subjects enter the maze, wander around inside the letter, and at the end of the path through the maze they must identify and mark the letter in which they are located on a chart which displays four letters. When they complete the task, a door opens, allowing them access to the

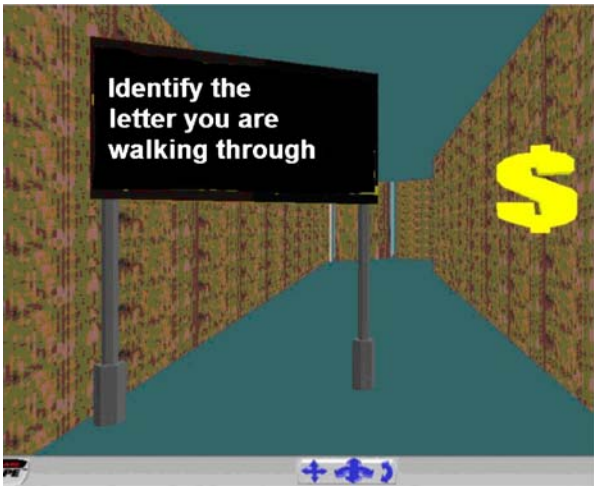

Fig. 1 Simulation of visual letter agnosia

next room. This activity brings home the difficulty the child has in making visual identification of a letter, the best way possible for them to identify a letter is through movement within its structure. A child with this disability is suffering from visual letter agnosia, sometimes called pure alexia (Friedmann and Gvion 2001; Seki et al. 1995; Gvion and Friedmann 2004).

3.4.2 Phonological dyslexia

An example of another task which makes the dyslexic children's reading more concrete for their parents was the three-dimensional world we constructed around phonological dyslexia (see Fig. 2). In this virtual world the subjects enters a living room in which there is a piano, clock, sofa, bookshelf, television, table, and some other items. A stamped envelope is on the table, written on the envelope are the words "To Nobomidi." Four letters are on the table, a different word is written on

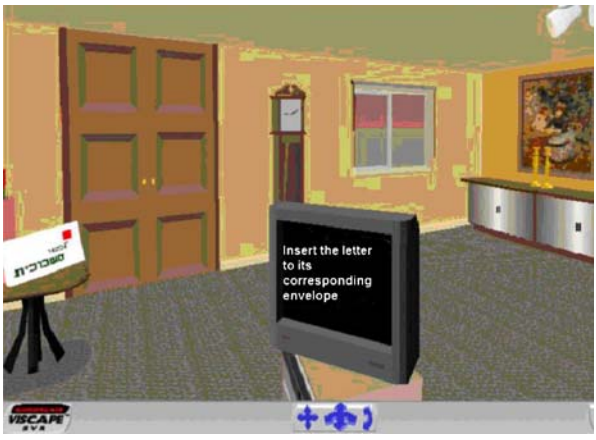

Fig. 2 Simulation of phonological dyslexia

each letter: (1) Phopedi; (2) Longrishi; (3) Eredolimy; (4) Aristoc. The instruction to the parent is "Insert the letter in its corresponding envelope." The instruction may be read on a television screen in the virtual living room, and/or it may be heard after clicking on the $ sign. When the subject makes a number of attempts and fails to find the right combination of letter and envelope, the word on one of the envelopes changes to Nobomidi, and a sound is heard in the background. When the word changes, the parent is able to complete the task. This activity was designed to provide a concrete simulation of phonological dyslexia. This disability makes the reading of new words a difficult task, but does allow for the correct reading of words which appearance has already been acquired. In phonological dyslexia, which is developed after the skill of reading has been acquired, the child has problems only with new words and nonsense words, as he/she cannot depend on the conversion of letters to sounds (Branch-Coslett 2000; Glosser and Friedman 1990; Plaut 1999; Gvion and Friedmann 2004).

4 Results

The cognitive aspect was tested by means of a questionnaire: "Parents' Awareness of Cognitive Aspects of the Dyslexic Child," which was developed by Shavit (2005). We used 17 questions from the test which were relevant to the parents' level of awareness of the way in which the disability appears in children with reading impairment. Each question had only one correct answer.

At the end of the process we constructed a summary variable which tested the number of correct answers scored by each of the parents who participated in the study, from both the experimental and control groups, before and after the intervention (minimum grade=0), or no correct answers, while the maximum score was 17, for a parent who answered all the questions correctly.

In the first stage we calculated a *t* test for independent samples of the score before the intervention, between both research groups. The goal of this test was to make certain that there was no significant difference in the beginning level of knowledge between the two groups. In Table 3 one can see the level of parents' knowledge on the cognitive dimension in the experimental (VR) group and the control (movie) group, before and after the intervention.

The results indicate that there was a significant difference between the two research groups regarding their knowledge about reading disabilities prior to the study: $t(65)=1.14$; $p<0.05$. We investigated whether there was a significant difference in the number of correct answers in the pre-intervention Awareness Questionnaire, compared to the number of correct answers in the post intervention. We also examined whether there was a significant difference in the degree of change

Table 3 Level of parents' knowledge of the cognitive dimension pre-intervention

	Group	*N*	*M*	SD
Summary of cognitive dimension Pre-intervention	Experimental	37	8.97	3.40
	Control	30	7.93	4.05

Table 4 Parents' level of awareness before and after the intervention

	Research groups					
	Experimental (N=37)		Control (N=30)		Total (N=67)	
Time	M	SD	M	SD	M	SD
Pre	8.97	3.40	7.93	4.05	8.51	3.71
Post	14.51	1.39	9.27	3.76	12.16	3.76

post intervention between the experimental and the control groups. In order to obtain that information we performed a general linear model, repeated measures test, which compares the average score before and after the intervention, interacting with the kind of intervention. The findings are displayed in Table 4.

Generally, a significant difference was found between the average number of correct answers before and after the intervention (Fig. 3): $F(1,65)=107.8$; $p<0.01$, $\acute{\eta}^2=0.62$. Before the intervention the parents answered an average of 8.51 correctly (out of 17), while after the intervention the average went up to 12.16.

Similarly, we found a significant interaction according to the kind of intervention: $F(1,65)=40.4$; $p<0.01$, $\acute{\eta}^2=0.38$. The degree of improvement in the number of correct answers was significantly higher in the experimental group (the average score went from 8.97 to 14.51). In the control group, by comparison, there was only a slight improvement in the average number of correct answers (from an average of 7.93 to 9.27).

In summary, the research hypothesis maintained that experience in a virtual simulation would improve parental awareness of the cognitive aspect of a child's reading impairment, and would do so better than exposure to a movie. The research hypothesis was affirmed by the results of the research.

In interviews carried out with the experimental group we received further evidence of a positive change in the cognitive measure. Table 5 presents the categories which featured most prominently in the interviews with the parents of the

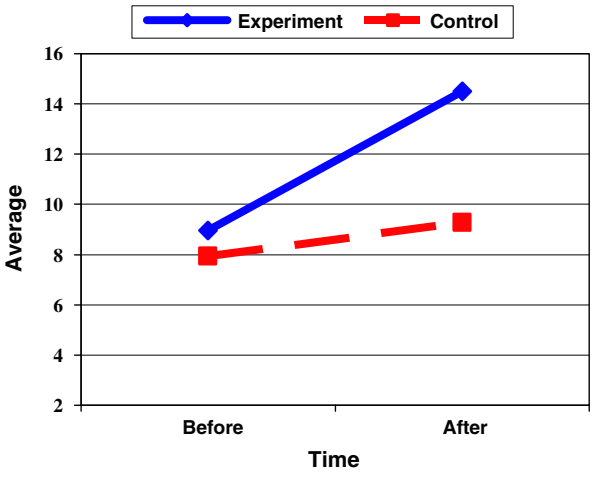

Fig. 3 Average scores on the measure of cognitive awareness in the control and experimental groups before and after the intervention

Table 5 Findings from the analysis of pre-intervention interviews

Question	Categories	*N*=37	Percentage
The parent thinks s/he succeeds in understanding his/her child's way of thinking while reading	1. Understands	15	40.5
	2. Doesn't understand	22	59.4
Filling out the questionnaire	1. It was hard	27	72.9
	2. Via logic	32	86.4
	3. On the basis of personal knowledge and experience	21	56.7

experimental group on this measure, as found in the analysis of the pre-intervention interviews.

Table 5 indicates that 40.5% of the parents thought that they understood the way their children were perceiving reading, while 59.5% thought that they did not understand their children's thinking pattern: "I think I know what's going on in his head when he's reading, but to say that I'm 100% sure, I haven't got a clue." "I think he's helped by hints, if there's a drawing it can be very helpful for him sometimes, you know, it depends on the drawing." "It's something his teacher does with him, as a helpful comment, she helps him to think the right way. I see how he tries to understand by looking at the title, or by looking for a picture, or by reading short sentences."

On the other hand, 72.9% of the parents reported that it was hard for them to respond to the Awareness Questionnaire, 86.4% said they were helped by mere logic in giving their answers and 56.7% of the parents mentioned knowledge and personal experience as the basis for their responses: "To tell the truth, I combined logic and personal knowledge. Where I didn't know, I used logic."

Table 6 indicated that 83.7% of the parents reported that the VR experience contributed to their understanding of their children's way of reading. Examples of their comments were: "Now I understand how hard he works….I knew beforehand how much effort he puts into reading, but now I understand how hard it really is."

However, 16.2% reported that the intervention did not contribute anything to their knowledge, 92.7% of the parents said that they completed the questionnaire on the basis of knowledge and personal experience. One of the mothers said: "Now I can say that I had more knowledge with which to respond to the questions than I had prior to this experience…," as opposed to 2.7% who said they answered the questions by using their logic.

Table 6 Findings from the analysis of the post-intervention interviews

Question	Categories	N=37	%
Experiment's contribution to understanding	1. Understands	31	83.7
	2. Doesn't understand	6	16.2
Responding to the Questionnaire	1. Via logic	1	2.7
	2. On the basis of personal knowledge and experience	36	97.2

5 Discussion

Vellutino and Fletcher (2005) summarized the research on dyslexia, debunking visual perceptual theories as well as visual tracking theories as origins of dyslexia. Their review points to phonological coding deficits as the more likely source of the origins of dyslexia. They contended that excessive dyslexia research has mistaken the results of poor/misguided initial teaching for some biological/neurological etiology. It is important to note that our study focused only on improving the knowledge and awareness of the dyslexic experience as suggested by one of the many typologies of the phenomenon in the literature. It was beyond our ability to engage in the debate Vellutino and Fletcher (2005) have stirred to suggest a cohesive typology or even to hint that the typology we used is a candidate to evolve into such a typology.

Nonetheless, the literature addressing disabilities is multi-faceted, and has yet to be organized into a complete, comprehensive theory, as we realized when we were designing the different phases of this study. We discovered many definitions of dyslexia, and were not always able to say that all those who carried out research in the field were in agreement on its parameters. This is the reason we had to make an arbitrary decision, and developed the virtual worlds according to a taxonomy which seemed sufficiently simple for translation into a virtual environment. We are certain that many researchers will not agree with this choice. However, we believe that within the scope of this study it is acceptable.

Thus, the aim of this study was to test whether virtual reality is having a greater impact on the awareness of parents to the phenomena termed in many places worldwide as “dyslexia” or in other places just as “reading difficulties/disabilities.” We did not aim at testing in this specific study whether virtual reality is having an impact on behavior that might lead to improved reading outcomes for dyslexic students. In order to test whether virtual reality is having such an impact there is a need to design a very different study, which we believe is indeed needed in the future but could not be the scope of the current study. This study reflects the need to use the most efficient technologies and was just assuming that the use of virtual reality can achieve a higher level of awareness to the phenomena compared to watching a movie.

Indeed, as assumed, the findings of the awareness measure match the results of Shavit’s (2005) study, which examined a population of teachers who went through a virtual reality experiment in order to improve their awareness of the dyslexic student’s cognitive experiences. Shavit found that the teachers who experienced the simulation in a virtual reality setting markedly improved their awareness of what the dyslexic child goes through while reading.

A possible explanation for these results can be traced to the sensory stimuli produced by VR technology, which involves the person to the point of immersion into the environment (Smedley and Higgins 2005). Psotka et al. (1993) maintain that the phenomenon of immersion is a cognitive phenomenon. They point out that every visual creation reflects the creator’s point of view, while the viewer looks on from a point of view different from that of the one who created it. In contrast, the immersion into the environment seen in VR creates a unity between the points of view of the creator and the viewer. The process of immersion, therefore, can help the adult better

comprehend cognitive processes of visual perception (Psotka 1995). It follows, therefore, that experiencing cognitive processes with VR helps parents understand the cognitive skills that make fluent reading possible, which are based on accuracy and speed in reading letters and words, and which improve reading comprehension. Support for this explanation can be found in the personal interviews we conducted. For example, one of the parents said "… it's like always living in a kind of riddle…is what I read correct? Is what I'm doing correct? Did I understand the instruction at all? To be looking for hints all the time…maybe the connections, that is really tiring."

Another possible explanation lies in the interaction between VR and its ability to be a tool which causes participants to be especially active and totally present in the simulated situation. The high level of presence causes the user to become part of the virtual world. This tool has the ability to present information in three dimensions, and in real time. A kind of broadening of reality which exists in VR allows a person to hear, look, touch, and communicate with objects and figures. This approach enables the user to be an active part of the environment, rather than observing it passively (Barab et al. 2001; Cromby et al. 1996; Lannen et al. 2002). This high level of interactivity might explain the significant results the VR can achieve while raising the level of knowledge and awareness to skills and disabilities which are hard to imagine (Winn et al. 2006).

In summary, to the best of our knowledge, the current study represents a unique attempt in concretizing for parents a problem they are too often expected to "cope with," and a situation they are expected to "understand." The functioning of the child's brain has always been veiled in layers of mystery. Much professional research has been devoted to understanding the way children think at different stages of their emotional and cognitive development. Parents as well as teachers have been expected to become familiar with the results of this academic effort. The parents of the children subject to the disabilities are in need of emotional resources in order to experience for themselves the difficulties encountered by the child having the disability, and to familiarize themselves with its behavioral expressions. This has not been easy, as the professional literature dealing with disabilities is multi-faceted, and has yet to be organized into a complete, comprehensive theory. We realized this when designing the different phases of this study. If we encountered difficulties in arranging the different reading disabilities in one clear, simple list, we assume that parents who care for their children with this disability act from within the context of a haze of conflicting elements of information. As noted above, participants in our research expressed this unreservedly. Thus, this study could open a venue for parents to familiarize themselves with other cognitive difficulties of their children that are hard to cope with and hard to understand.

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