Improving Children's Cognitive Modifiability by Dynamic Assessment in 3D Immersive Virtual Reality Environments

David Passig, Bar-Ilan University, Israel
David Tzuriel, Bar-Ilan University, Israel
Ganit Eshel-Kedmi, Bar-Ilan University, Israel

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Abstract
Increasing evidence reveals the efficacy of dynamic assessment procedure (DA) in providing rich and reliable feedback regarding children's cognitive modifiability. Children's cognitive modifiability was examined using DA in two computerized environments: 3D Immersive virtual reality (3D IVR) and 2D. Children in grades 1 and 2 (n =117) were randomly assigned into three experimental groups and one control group. Each of the experimental groups was taught in a different modality: 3D IVR (n = 36), 2D (n = 36), and tangible blocks (n = 24). The control group (n=21) was not given teaching phase. The teaching phase included strategies of solving analogies from the *Analogies* subtest of the *Cognitive Modifiability Battery* (CMB) using the specific modality*,* respectively. Pre- and post-teaching Analogies tests were administered to all groups. The findings indicate that teaching in a 3D IVR contributed to the children's cognitive modifiability more than in the other groups. We found significant differences between the control group and all the other groups as well as a significant difference between pre-and post-teaching in the experimental groups. However, there was a significantly greater improvement in the analogical thinking achievements, in a 3D IVR environment than in the computerized 2D and the non-computerized tangible blocks groups. These findings indicate that children experiencing a DA procedure in a 3D IVR environment demonstrate a significantly higher learning potential than children who experienced the combination of DA procedure with other formats of teaching environments.

Keywords: dynamic assessment, mediated learning strategies, cognitive modifiability, analogical thinking, virtual reality.

Introduction

Cognitive modifiability

Many studies were conducted using a dynamic assessment (DA) procedure with children at early age in order to establish the validity of DA tools, and to prove their efficacy as predictive instruments of learning ability (e.g., Carlson & Wiedl, 1992; Guthke & Wingengeld, 1992; Guthke, 1993; Resing, 1997; Hessels, 2000; Tzuriel, 2001; Sternberg & Grigorenko, 2002; Wiedl, 2003; Haywood & Lidz, 2007). The DA procedure involves a teaching procedure in between a pre- and post-teaching phase. Very few studies however focused on examining the efficacy of the DA procedure in a computerized environment (e,g., Tzuriel & Shamir, 2002). Our main objective was to study the degree to which the learning process in a DA and a 3D immersive virtual reality (3D IVR) framework would contribute differentially to cognitive modifiability of children. We examined the impact of 3D IVR in a DA procedure on the cognitive modifiability while learning analogical problem solving. We hypothesized that cognitive modifiability would be the highest in children who participated in a 3D IVR followed in that order by 2D computerized environment, tangible blocks non-computerized environment, and the control group.

This study was guided by a number of theories regarding factors affecting children's analogical reasoning development. The first is the *Structural Cognitive Modifiability (SCM) and the Mediated Learning Experience (MLE)* theory (Feuerstein, Haywood, Rand & Hoffman, 1979; Feuerstein, Rand, Hoffman & Miler, 1980) from which the DA approach is derived.

According to this theory, the main factors which affect individual differences in children's cognitive development are distal and proximal factors (Feuerstein, et al., 1979, 1980). The distal factors include, among others, hereditary and environmental factors whose effect on the development is indirect. The proximal factors are *mediated learning experiences* (MLE) to which children are exposed to while interacting with parents and teachers. MLE processes describe a special quality of interaction between a mediator and a learner (Feuerstein, et al., 1979; Tzuriel, 2000, 2001, 2013). In this qualitative interactional process, parents or substitute adults or peers interpose themselves between a set of stimuli and the developing child (learner) and modify the stimuli for him/her (Tzuriel, 2000, 2001). MLE processes are considered as the proximal factor that explains cognitive modifiability. *Cognitive modifiability* is defined as the individual’s propensity to learn from new experiences and learning opportunities and to change one’s own cognitive structures.

According to the SCM and MLE theory, intelligence is defined by the individual’s ability to change itself, and to use the principles and behavior models it studied in the past for the sake of adapting to new conditions. Cognitive modifiability, with the help of MLE is considered to lead to change in the expected course of the individual's development. The concept of cognitive modifiability refers to structural change brought about with the help of intervention which guides the individual's absorption of external stimuli (Lidz, 1991; Tzuriel, 2000). Based on this theory, it is impossible to estimate learning potential on the basis of previous learning experiences, or on the basis of the final product of those learning experiences (achievements). The emphasis must be placed on the learning process by itself and on the assessment of the individual's ability to modify intelligence.

Method

Participants

A group of 117 children (61 boys and 56 girls) were randomly drawn from first and second grades from two elementary schools to participate in this study. The children's age range was between 72 to 102 months (M = 90.00, SD = 6.88). Children diagnosed as having learning difficulties were not included in the research. All children were assigned randomly into four groups of the study with somewhat greater number
In recruiting the participants we asked first for parental consent. Out of 167 parents 127 gave their consent. Ten children dropped out of the study at the beginning of the DA procedure, because of lack of interest, despite their parents' consent. The number of boys and girls in each of the study's subgroups is presented in Table 1.
Gender composition in each subgroup did not reveal significant differences $\chi^2 = .75$, df =1, *ns*. The age of children and parents years of education in the four groups is presented in Table 2. Significant group differences were found only in father's years of education.

Table 1. Number of Boys and Girls in the Sample

Group	Boys		Girls	
	N	%	N	%
1. 3D IVR	19	52.6	17	47.4
2. 2D	21	58.3	15	41.7
3. Tangible Blocks	12	50.0	12	50.0
4. Control	9	42.9	12	57.1
Total	61	52.1	56	47.9

Table 2. Parents age and education in the Four Groups of the Study.

		3D-IVR	2D	Tangible Blocks	Control	F(3,113)	Eta²
Age	M	92.30	88.89	88.66	88.23	2.59	.06
	SD	6.08	7.21	6.12	6.79		
Father's years of education	M	16.94	16.91	14.91	15.42	3.26*	.08
	SD	3.38	2.81	3.06	2.83		
Mother's years of education	M	16.56	16.19	15.42	16.19	1.09	.03
	SD	2.26	2.57	2.65	1.99		

- $p < .05$

Scheffe's analysis revealed significant difference only between the Tangible group that used wooden blocks to study analogies and the 3D-IVR group. It should be noted that since the focus of this study was on DA in a computerized environment; the groups assessed through the computer were larger than the other two groups.

Measures

Analogies Subtest from the Cognitive Modifiability Battery (CMB-AN)

For this study we developed two computerized versions of the CMB-AN: a 2D computerized mode (using a mouse and screen interface) and a 3D computerized mode (3D IVR interface). The goal of this test was to assess young children's cognitive modifiability in the analogical reasoning domain. The CMB-AN was designed for children in the age range of kindergarten to fourth grade, but also suitable for children with learning difficulties in the fifth through eighth grades. The diagnostic procedure is based on Feuerstein's theory of mediated learning experience (Feuerstein et. al., 1980).

The CMB-AN subtest includes a preliminary-baseline stage aimed at preparing the child for testing. The preparation is done by acquainting the child with the test dimensions and with the basic rules for solving problems. The test is constructed of a wooden board (18cm x 18cm) which includes 9 windows set in a 3 x 3 format, and 64 wooden blocks in four colors (yellow, blue, red and green). For each color there are blocks in four heights (2cm, 3cm, 4cm and 5cm). The examiner places the blocks in three open windows (top-left, top-right, bottom-left) and the child has to complete the last open window (bottom-right) (see Figure 1). The child is encouraged to solve the problems both horizontally and vertically. The problems are presented to the examiner in a booklet of problems.

The CMB-AN subtest includes two sections: Test problems (14 items) and Transfer problems (9 items). In both, the problems include three parallel items for pre-teaching, teaching, and post-teaching. The goal of the Transfer problems is to assess the degree of internalization of the analogy principles taught in the Test section. All problems in the CMB-AN subtest are based on dimensions of color, height, number and location (See Figures 1 and 2). The Test problems are constructed from three levels of difficulty, derived from the number of dimensions included in the problem and arranged from easy to difficult. The dimension of location is considered to be the most difficult of all.

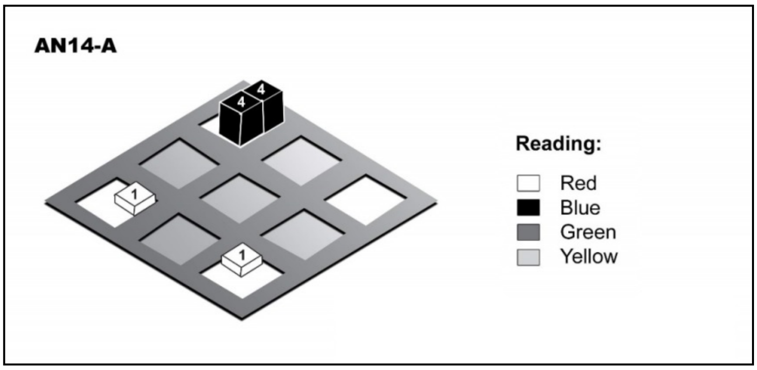


Figure 1. Example of Analogy problem from the CMB-Analogies Subtest (AN14-A) (by permission of David Tzuriel)

The Transfer problems are more complex in terms of the number of dimensions (color, height, number, and location) and the degree of abstraction required. In the present study we administered the Transfer problems according to the static approach. An example of a Transfer problem (TR8-A) is demonstrated in Figure 2.

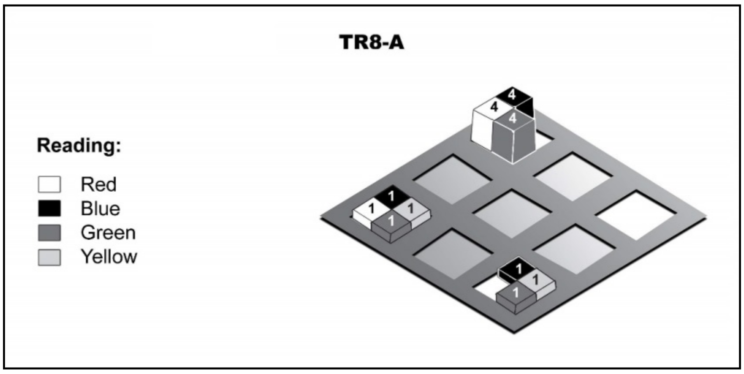


Figure 2. Example of a Transfer problem from the CMB Analogies Subtest (TR8-A). (by permission of David Tzuriel)

The test section is carried out with pre-teaching, teaching and post-teaching stages, thus, enabling assessment of the child's cognitive modifiability. In the original administration each problem is laid out on the board in three open windows and the child has to complete the last open window by choosing the correct blocks from a pile of blocks (see Figure 1). In the pre- and post-teaching phases no mediation is provided, except for giving instructions, as needed, or light probing (e.g., “look in both directions”, “don't rush”, “check your answer one more time"). In the teaching phase the child is taught to look for the relevant dimensions of the problem, develop a systematic exploratory behavior, acquire need for accuracy, understand the transformation rules of analogy, and improve performance efficiency. The mediation strategies include also non-verbal focusing, labeling, verbal anticipation of correct answer, and “rhythmic intonation” of contents.

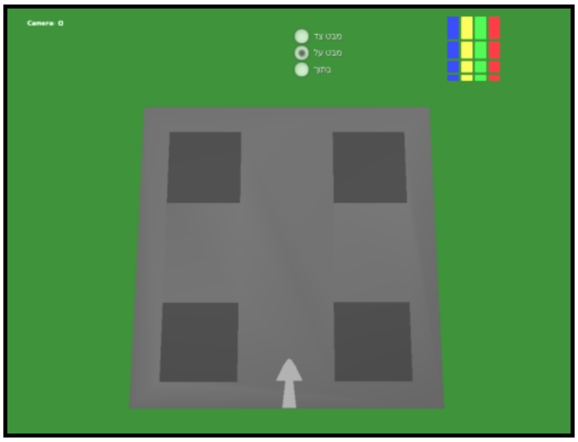
Two main approaches may be used in teaching analogies: analytic and transformative. According to the analytic approach, each dimension is analyzed separately followed by integration of all dimensions. The examiner might sometimes use animation (“the big red block here is a friend of the big yellow block”). According to the transformative approach, the examiner teaches the child the rules of transforming relations between blocks (“on the top side the red block changes from red to green, but the height, number and location remain the same, so also in the bottom side the red block should change from red to green and the rest of the dimensions remain the same”). In the current study, we used both approaches interchangeably. Scoring was carried out only for the pre- and post-teaching phases and the improvement. The pre- and post-teaching scores served for the analysis of the child's cognitive modifiability.
Scoring was carried out by the all or none method and the partial credit method (Tzuriel, 2000). In this method, a score of 1 is given for each correctly solved dimension. The total number of scores was 56 points (14 problems x 4 dimensions). Cronbach's alpha reliability coefficient of the original tangible format is .83 and .78 for pre- and post-teaching stages, respectively (Tzuriel, 2000).

Computerized CMB-Analogies (CMB-AN) test

For this study we developed a computerized version of the CMB-AN test in order to be able to run it as a 2D multimedia computer application using a mouse and screen interface as well as a 3D Immersive Virtual Reality world using a Head Mounted Display interface (HMD) (Figure 3).
We conducted a pilot study in order to test the suitability of the hardware and software for young children use. Following the pilot study we improved the instruments, and added an introductory stage to familiarize the children with the HMD and the 3D environment (e.g., up, down, left, right and rotation). The introductory stage was designed to take 10 minutes, and included the following elements: orientation in the 3D IVR environment, acquaintance with and adjustment to the HMD interface, exercising selection of blocks from a repository and manipulating their location on the digital board, and exercising moves and other features in the virtual environment with a mouse while the HMD is on the subject's head (Figure 3).

Figure 3. A child during a DA procedure wearing an HMD

Virtual worlds



The first screen from which the DA procedure began included a grey, flat, square board with black squares painted on its four sides (hereafter, windows).

Figure 4. The opening screen to the computerized virtual world in the 2D and 3D IVR environments.

In three windows (i.e., top-left, top-right, bottom-right) are representations of the colored wooden blocks, as dictated in each problem. In the front part of the board was a picture of a wooden arrow, which served as a permanent reference point to the front of the problem (the side closest to the child, on the bottom of the screen), and to its opening (Figure 4). Each screen included a storage bin of the represented blocks located on the upper-right side of the screen in four colors (blue, green, red and yellow) that were arranged side by side by height (from highest to lowest; total of 16 blocks). The original storehouse of the original test included 64 blocks. In order not to clutter the virtual reality world with so many blocks we designed a feature that by pressing on the right block in the storehouse, the participant received 4 other blocks of the same color.

The computer application made it possible to observe the problem from three angles: *top*, *side*, and *within* (imagining a situation in which the child being examined is standing in the center of the board and is looking around). The starting point was the top angle. We placed three buttons in the upper center of the screen, and by pressing any one of them one could shift from one to any other angle of observation on the problem. In addition, the computer program was designed so that it would be possible to make the problem turn on a 360º horizontal axis (which enables observation from several points of view) and at an angle of 45º on a vertical (up and down) axis. In Figure 5 there is an example of an analogical problem from different angles: top, front, within and 180º rotation.

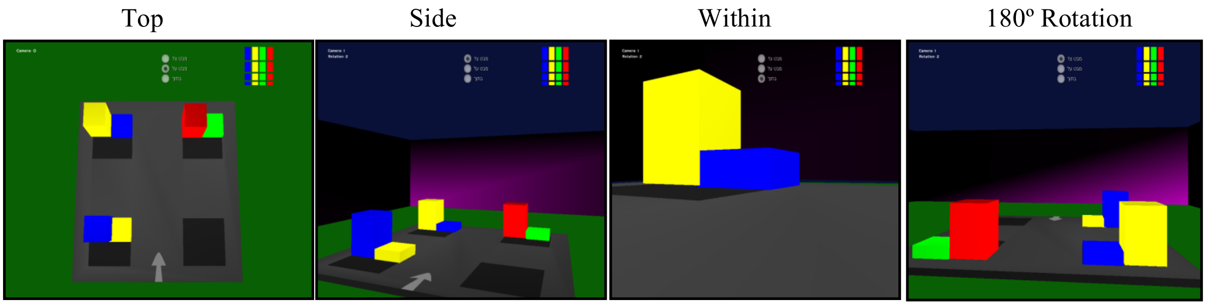


Figure 5. Representation of a problem (TR2-B) in a virtual board as seen from different angles.

Procedure

This study included two measurements that were administered two weeks apart. The first measurement included a DA of analogical thinking (pre-teaching, teaching, and post-teaching) followed by administration of the Intrinsic Motivation Scale. The DA was performed in a small quiet room assigned by the school; only one child was assessed at a time. The DA procedure included pre-teaching (30 minutes), teaching (30 minutes), and post-teaching (30 minutes) stages. A 5-minutes break was given between the stages. Many of the children enjoyed participating in the DA procedure and wanted to stay at the room and continue with the procedure during the break. Before starting the assessment, the examiner introduced himself/herself to the child and led the child through some warm-up exercises to familiarize him/her with the DA tools, concepts (height, number, color, location) and problem solving rules based on to the CMB guidelines (Tzuriel, 1995). In the 2D and 3D computerized environments, the examiner explained the mouse-screen interface, and introduced the child to the buttons which enable movement. The examiner also explained how to use the Head Mounted Display (HMD), how to move and orient oneself in the 3D IVR space. Some more time was given to adjust the HMD to the child, showing her/him how it enables immersion in the virtual space. In the control group, the examiner demonstrated to each child, individually, the solution of a sample problem before administering the pre-teaching test; no teaching stage was given before the post-teaching test. It is important to point out that the teaching stage was similar in all the experimental groups; the mediation strategies that the examiner monitored throughout the procedure with each child in all the experimental groups were similar. An attempt was made that examiners will give more or less equivalent level of mediation, so that the main difference between the groups would remain solely the learning environment (blocks, 2D and 3D IVR).

The second measurement was the Transfer problems of the CMB-AN, which contain more difficult items (see Measures). The Transfer test was conducted with all groups individually using a standardized assessment procedure with a tangible board and blocks. The assessment was conducted in the allocated small room. The administration of the Transfer problems two weeks after the testing phase was carried out to control the memory effects and ensure that performance reflects internalization of the analogical reasoning. Thus, the Transfer phase was different from the Testing problems not only in terms of the nature of problems but also in terms of the time passed from the initial Test phase. The second measurement was administered by a standardized way, i.e., without a teaching stage. Following is a detailed description of the results of these stages.

Results

Cognitive modifiability in the four groups of the study

The DA procedure yielded two main scores: Pre-teaching and post-teaching, each was based on sum score of the dimensions of color, height, number, and location. In addition, each dimension was scored separately. The range of scores in each dimension was 0-14 and the total score was 0-56. Cognitive modifiability is indicated by the level of improvement from pre- to post-teaching.

In order to examine initial differences among groups we carried out a one-way ANOVA of Group where the dependent variable was the CMB-AN pre-teaching score. The analysis revealed no significant Group main effect, $F(3,113) = 1.64$, *ns*.
A repeated measures MANOVA of Group x Time (2 x 2) revealed a significant Time main effect $F(1,113) = 241.77$; $P < .001$, $Eta^2 = .68$, indicating an improvement from pre- to post-teaching. The means and standard deviations of pre- and post-teaching scores as well as the Group x Time interaction are presented in Table 3. The interaction is presented in Figure 6.

Table 3: Means, standard deviations, and F statistics of the four groups in CMB-AN in pre- and post-teaching stages of the DA procedure.

Groups										
	3D-IVR		**2D**		**Tangible Blocks**		**Control**		**Group X Time**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	F(3,113)	Eta^2
M	2.58	10.72	4.02	9.75	4.70	10.45	4.00	4.19	25.18***	.40
SD	3.27	3.89	3.36	2.87	4.49	3.20	4.42	3.57		

***$p < .001$

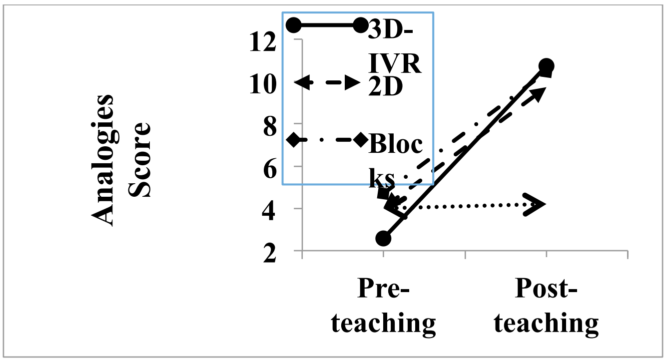


Figure 6: CMB-AN pre- and post-teaching scores in the four study's groups.

As can be seen in Table 3 and Figure 6, the three experimental groups improved their performance from pre- to post- teaching whereas the control group showed no improvement.

Variance analysis (Table 4) was carried out where post-teaching scores were the dependent variable and the pre-teaching scores the variant variable. The findings revealed that the control group, as expected, showed lower scores than each of the three experimental groups. The findings revealed also that the 3D IVR group scored significantly higher than the 2D group and the tangible blocks group. The findings support the research hypothesis, according to which the pre- and post-teaching improvement in analogical thinking are higher in the 3D IVR group than in the other experimental groups (2D and Tangible Blocks), and that all experimental groups will show higher improvement than the control group.

Table 4. Variance analysis for comparison between pairs of the study's groups (Group 1: 3D- IVR; Group 2: 2D; Group 3: Tangible Blocks; Group 4: Non computerized).

Group comparison	df	Mean	F	Eta^2
3>4	1,43	173.08	28.53***	.40
2>4	1,55	202.92	49.11***	.47
1>4	1,55	418.96	117.70***	.68
2=3	1,58	.006	.00	.00
1>3	1,58	41.08	5.88*	.09
1>2	1,70	52.56	9.89**	.12

*$p < .05$, ** $p < .01$, *** $p < .001$

Group Differences on the Transfer Analogies

In order to test the hypothesis on the Transfer test, we performed a one-way analysis of variance (ANOVA) where the independent variable was Group, the dependent variable was the score in the Transfer analogies. The findings showed a significant Group main effect, $F(3,113) = 17.34$, $p < .001$, $\eta^2 = .32$. The highest group was the 3D-IVR (M = 5.32, SD = 2.47) followed by the 2D (M = 3.59, SD = 1.76), Tangible Blocks (M = 3.50, SD = 2.02 and Control (M = 1.47, SD = 1.20). Post-hoc analysis using Scheffe's procedure ($p < .05$) indicated that the control group was the lowest and that the 3D IVR group scored higher than the 2D and Tangible Blocks groups. .

Discussion

The goal of this study was to examine the influences of a teaching process which takes place in a computerized dynamic assessment (DA) procedure and especially in 3D IVR on children's cognitive modifiability in the domain of analogical thinking. We asked whether a DA procedure, conducted in computerized environments, would better reflect the child's learning potential than a standardized tangible blocks situation.

This goal was based on a number of studies addressing the issue of developing thinking skills with computers (Dede, 2005), and on findings of various studies about mediated learning and DA with children (Tzuriel & Shamir, 2002, 2010). The first research objective was to test the impact of learning in a DA procedure on the cognitive modifiability of children's analogical thinking while the procedure is conducted in a 3D IVR environment as compared with computerized 2D and non-computerized tangible blocks environments. The MLE process was presented in a way which was similar in all of the teaching environments. We assumed that cognitive modifiability of children's analogical thinking in a DA in a 3D IVR environment would be higher than with a 2D computerized environment, a non-computerized environment or a control group. The second aim was to test the transfer effect of these three experimental situations on the children's analogical thinking performance of a more complex nature. Our hypothesis was that the transfer scores would be higher after teaching through a DA procedure in a 3D IVR environment.

Our findings supported our hypothesis, as can be seen in the analogies' pre- and post-teaching scores (Tables 3 and 4, and Figure 6). We found significant differences between the control group and all the other groups as well as a significant difference between pre-and post-teaching in the experimental groups. However, there was a significantly greater improvement in the analogical thinking achievements, in a 3D IVR environment than in the computerized 2D and the non-computerized tangible blocks groups.

These findings indicate that children experiencing a DA procedure in a 3D IVR environment demonstrate a significantly higher learning potential than children who experienced the combination of DA procedure with other formats of teaching environments. Similarly, our findings indicate that it is possible to conduct a DA procedure which includes mediated learning experience strategies in a 3D IVR computerized environment. Our findings are supported by findings of other 3D IVR studies (e. g., Passig & Miler, 2014) and add another important layer to the overall accumulation of evidence – it broadens their scope to include the areas of mediated learning and dynamic assessment.

One possible explanation for this lies in the manner in which one uses virtual reality. The improvement of cognitive skills stems from the possibilities embedded within this technology which presents abstract concepts through a concrete, visual, three dimensional experience. It is well established from earlier research, in the field of the development of analogical thinking in early childhood, that when analogies are presented to children by means which they are familiar with and which they deem concretely significant; they deal with them successfully (Goswami, 1992; Halford, 1993). The VR technology by nature expands the diverse ways in which information is presented, as well as assists young children in the course of the DA procedure to strengthen their ability to deduce analogical conclusions.

This study has shown that in the course of the DA procedure in a 3D IVR environment, the children's opportunities for gaining concrete experiences were enriched by means of exposure to new, additional information which is solely virtual. This virtual visual information presumably stimulated a unique perceptual experience which contributed to the creation of new and broadened internal images and of new schemes that enhanced the individual's ability to solve problems. When the children were requested to solve analogies; visual information which was absorbed directly beforehand, transferred, as the Dual Coding Theory suggests (Paivio, 1991) to perceptual information retrieved from the memory while addressing an analogy.

An additional possible explanation is connected to the children's cognitive development stage while solving analogical problems during the DA procedure. It is well established that children have difficulties characteristic of their stage in the development of analogical thinking. One prominent difficulty is their inability to embrace a number of relationships at the same time. It is possible that when assisted in observing a problem from the widest angle and perspective, actions facilitated by 3D IVR, they were better able to grasp the rules of transformation. With this improved tool in hand, they were better situated to make a methodical search for the blocks most appropriate for solving the analogy. Thus they improved their ability to think simultaneously along a number of dimensions which were in a constant state of transformation, to include them in the overall solution to the problem and to perform better in amassing a greater quantity of achievements than those which added up by subjects in the other learning environments.

Yet another explanation for these findings could be associated with the geometric nature of the objects that are included in the virtual worlds simulated in this study. For example, in a study (Passig & Eden, 2002) in which the impact of practicing the rotation of geometric objects (several blocks attached to one another, creating an asymmetrical geometric object) on cognitive performance, there was an advantage among students who practiced rotation of the object in a 3D IVR environment. This was in contrast to the non-computerized environment. In this study, as well, it was found that the simulation of geometric blocks in a 3D IVR environment contributed to the understanding of the problem and to the subject's ability to solve it as opposed to other learning environments. In that sense, it is possible that the use of 3D geometric objects in a 3D IVR environment has a relative advantage over similar contents in other environments. We believe, however, that this aspect should be further examined in future studies in order to deepen our understanding of this advantage.

Summary

The findings of this research may have both theoretical and practical implications. From a theoretical point of view, we learned that integrating a computerized 3D IVR environment as part of a mediated learning and DA procedures creates an "intellectual partnership" between the computer, the subject, and the examiner-mediator. This partnership, it seems, creates a unique perceptual experience that broadens the subject's world of mental images, it strengthens the internalization of the mediated cognitive principles and contributes to her/his achievements. Therefore, one can also say that 3D IVR technology is an important and appropriate environment for assessment. It seems, as well, that the evaluation of a child's ability to express cognitive modifiability is also influenced by the mode of representation in which the assessment is carried out, by the degree of immersion and partnership of the child with the computer and by the examiner. We believe that these two points are an important contribution to the Dynamic Assessment approach.

Our findings show that this study has brought to light a wide range of clinical and educational applications of DA and 3D IVR technology. It seems that it can be used to predict, the subject's degree of cognitive modifiability outside the school or classroom settings. We believe that by that a new additional set of diagnostic instruments has been made available to educational diagnosticians, who will now be able to administer DA procedures that might better reflect the child's learning potential. In the assessment procedures, it will be possible to alter the traditional assessment tools in exchange for rich and versatile 3D virtual worlds that will open up new possibilities for a wide range of cognitive diagnostic procedures and for a wide range of populations. Those tools will open a wide world of opportunities for the examiner that cannot exist in DA procedures without an appropriate technology.

References

Ahissar, M. & Hochstein, S. (2004). The reverse hierarchy theory of visual perceptual learning. *Trends in Cognitive Science*, *8*(10), 457-464.

Bar, M. *et al*. (2006). Top-down facilitation of visual recognition. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*. January 10, 2006, *103*(2), 449–454.

Bransford, J. D., Brown A. N. & Cocking, R. R. (2004). Learning and transfer. In: J. D. Bransford, A. N. Brown & R. R. Cocking (Eds.). *How People Learn, Brain, Mind, Experience and School* (pp. 51-78). Washington D.C.: National Academy Press.

Carlson, J. S. & Wiedl, K. H. (1992). The dynamic assessment of intelligence. In: H.C. Haywood & D. Tzuriel (Eds.). *Interactive Assessment* (pp. 167-186). New York: Springer-Verlag.

Clements, D. & Samara, J. (2002). The role of technology in early childhood learning. *National Council of Teachers Mathematics*, *8*, 340-343.

Cox, B. D. (1997). The rediscovery of the active learner in adaptive contexts: A Developmental–historical analysis of transfer of training. *Educational Psychologist, 32*, 41-55.

Csapó, B. (1997). The development of inductive reasoning: cross-sectional assessments in an educational context. *International Journal of Behavioral Development*, *20*, 609−626.

Dede, C. (2005). Planning for neo-millennial learning styles-shifts in students learning style will prompt a shift to active construction of knowledge through mediated immersion. *Educause Quarterly*, *7*, 7-12.

Eden, S. & Passig, D. (2007). Three-dimensionality as an effective mode of representation for expressing sequential time perception. *Journal of Educational Computing Research*. *36*(1), 51-63.

Feuerstein, R., Haywood, H. C., Rand, Y., Hoffman, M. B. & Jensen, M. R. (1979). *Learning Potential Assessment Device-Manual*. Jerusalem: Hadassah-Canada Research Institute

Feuerstein, R., Rand, Y., Hoffman, M. B. & Miler, R. (1980). *Instrumental Enrichment: An Intervention Program for Cognitive Modifiability*. Baltimore: University Park Press.

Feuerstein, R., Klein, P. S., & Tennenbaum, A. (Eds.) (1991). *Mediated Learning Experience*. London: Freund.

Gentner, D. (1996). More evidence for a relational shift in the development of analogy: Children's performance on a casual-mapping task. *Cognitive Development*, *13*, 453-478.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*, 45-56.

Goswami, U. (1989). Relational complexity and the development of analogical reasoning. *Cognitive Development*, *4*, 251-268.

Goswami, U. (1992). *Analogical Reasoning in Children*. Hillside, NJ: Erlbaum.

Goswami, U. (1991). Analogical reasoning: What develops? A review of research and theory. *Child Development*, *62*, 1-22.

Goswami, U. (1995). Transitive relational mappings in three- and four-year-olds: The analogy of goldilocks and the three bears. *Child Development*, *66*, 877-892.

Goswami, U., & Brown, A. L. (1989). Melting chocolate and melting snowmen: Analogical reasoning and causal relations. *Cognition*, *35*, 69-95.

Guthke, J. (1993). Development in Learning Potential Assessment. In J. H. M. Hamers, K. Sijtsma & A. J. M. Ruijssenaars (Eds.) *Learning Potential Assessment* (pp. 43-67). Amsterdam: Swets & Zeitlinger.

Guthe, J. & Wingenfeld, S. (1992). The learning test concept: Origions, star of the art, and trends. Haywood & D. Tzuriel (Eds.). *Interactive Assessment*. New York: Springer-Verlag.

Haywood, H. C. & Lidz, C. S. (2007). *Dynamic Assessment in Practice: Clinical and Educational Application*. Boston: Cambridge University Press.

Haywood, H. C. & Switzky, H. N. (1986). Intrinsic motivation and behavioral effectiveness in retarded persons. In: N. Ellis & N. Bray (Eds.), *International Review of Research in Mental Retardation*. New York: Academic Press, 1-46.

Halford, G. S. (1993). *Children's Understanding: The Development of Mental Models*. Hillsdale, NJ: Lawrence Erlbaum.

Hessels, M. G. P. (2000). The learning potential test for ethnic minorities: A tool for standardized assessment of children in kindergarten and the first years of primary school. In C. S. Lidz & J. G. Elliott (Eds.), *Dynamic Assessment: Prevailing Models and Applications* (pp. 109–131). New York: Elsevier.

Holyoak, K. J. (2004). Analogy. In K. J. Holayoak & R. J. Forrison (Eds.). *The Cambridge Handbook of Thinking and Reasoning*. New York: Cambridge University Press, 117-142.

Holyoak, K. J., & Thagard, P. (1995). *Mental Leaps: Analogy in Creative Thought*. Cambridge, MA: MIT Press.

Holyoak, K. J., & Thagard, P. (1997). The analogical mind. *American Psychologist*, *52*, 35-44.

Kaniel, S. (2001). Transfer from the learner's point of view. *Journal of Cognitive Education, 1,* 266-293.

Klein, P., Nir-Gal, O. & Darom, E. (2000). The use of computers with or without adult mediation: Effects on children's cognitive performance and behavior. *Computers in Human Behavior*, *16*, 591-608.

Klauer, K. J. & Phye, G. D. (2008). Inductive reasoning: A training approach. *Review of Educational Research*, *78*, 85-123.

Lidz, C. S. (1991). *Practitioner's Guide to Dynamic Assessment*. New York: Guilford.

Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review*, *3*(3), 149-210.

Passig, D. & Eden, S. (2000). Enhancing the induction skill of deaf and hard of hearing children with virtual reality technology. *Journal of Deaf Studies and Deaf Education*, *5*, 277-285.

Passig, D. & Eden, S. (2002). Virtual reality as a tool for improving spatial rotation among deaf and hard-of-hearing children. *CyberPsychology & Behavior*, *4*, 681-686.

Passig, D. & Miler, T. (2014). Solving conceptual and perceptual analogies with Virtual Reality among kindergarten children of emigrant families. *Teachers College Record, 116*(2). Accepted October 2012. Online first February 2014: www.tcrecord.org/library/Abstract.asp?ContentId=17339

Pea, R. D. (1987). Integrating human and computer intelligence. In R. D. Pea & K. Sheingold (Eds.), *Mirrors of Mind: Patterns of Experience in Educational Computing*. Norwood, NJ: Albex, 128-146.

Perkins, D. N. & Salomon, G. (1992). Transfer of learning. *International Encyclopedia of Education* (2nd Ed.). Oxford, UK: Pergamon Press.

Piaget, J. & Inhelder, B. (1969). *The Psychology of the Child*. London: Rutledge & Kegan.

Resing W. C. M. (1997). Learning potential assessment: The alternative for measuring intelligence? *Educational and Child Psychology, 14*(4), 68-82.

Resing W. C. M. & Eliot, J. G. (2011). Dynamic testing with tangible electronics: Measuring children's change in strategy use with a series completion task. *British Journal of Educational Psychology. 81*, 579-605.

Richland, E. A., Morrison, G. R. & Holyoak, J. K. (2006). Children's development of analogical reasoning: Insights from scene analogy problem. *Journal of Experimental Child Psychology*, *94*, 249-273.

Ryan, R. M. & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist*, *55*(1), 68-78.

Salomon, G. & Perkins, D. N. (1989). Rocky roads to transfer: Rethinking mechanism for a neglected phenomenon. *Educational Psychologist*, *24*, 113-142.

Salomon, G., Perkins, D. & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researchers*, *20*(3), 2-9.

Siegler, R. S. & Svetina, M. (2002). A microgenetic/cross-sectional study of matrix completion: comparing short-term and long-term change. *Child Development 73,* 793-809.

Sternberg, R. J. (1977). Component processes in analogical reasoning. *Psychological Review*, *84*, 353-378.

Sternberg, J. & Grigorenko, E. L. (2002). *Dynamic Testing: The Nature and Measurement of Learning Potential*. Boston: Cambridge University Press.

Stevenson, C. E., Touw, K.W.J. & Resing, W. C. M. (2011). Computer of paper analogy puzzles: Does assessment mode influence young children's strategy progression? *Educational and Child Psychology. 28(2)*, 67-84.

Tunteler, E. & Resing, C. M. (2007). Effects of prior assistance in using analogies on young children’s unprompted analogical problem solving over time: A micro genetic study. *British Journal of Educational Psychology*, *77*, 43-68.

Tzuriel, D. (1995). *The Cognitive Modifiability Battery (CMB): Assessment & Intervention. Instruction Manual*. School of Education, Bar-Ilan University: Ramat-Gan, Israel.

Tzuriel, D. (2000). Dynamic Assessment of young children: Educational and intervention perspectives. *Educational Psychology Review*, *12*, 385-435.

Tzuriel, D. (2001). *Dynamic Assessment of Young Children*. New York: Kluwer Academic/Plenum Publishers.

Tzuriel, D. (2007). Transfer effects of teaching conceptual versus a perceptual analogies. *Journal of Cognitive and Education Psychology*, *6*, 194-217.

Tzuriel, D. (2013). Mediated learning experience strategies and cognitive modifiability. *Journal of Cognitive Education and Psychology, 13*, 59-80.

Tzuriel, D., & Galinka, E. (2000). *The Conceptual and Perceptual Analogical Modifiability (CCPAM) Test: Closed Analogies-Instruction Manual*. School of Education, Bar-Ilan University. RamatGan,Israel.

Tzuriel, D. & Kaufman, D. (1999). Mediated learning and cognitive modifiability: The dynamic assessment of young Ethiopian immigrants in Israel. *Journal of Cross-Cultural Psychology*, *13*, 539-552.

Tzuriel, D. & Klein, P. S. (1985). Analogical thinking modifiability in disadvantaged, regular, special needs, and mentally retarded children. *Journal of Abnormal Child Psychology, 13*(4), 539-552.

Tzuriel, D., & Shamir, A. (2002). The effects of mediation on seriational thinking modifiability in computer assisted dynamic assessment. *Journal of Computer Assisted Learning, 18,* 21-32.

Tzuriel, D. & Shamir, A. (2007). The effects of peer mediation with young children (PMYC) on children's cognitive modifiability. *British Journal of Educational Psychology*, *77*, 143-165.

Tzuriel, D. & Shamir, A. (2010). Mediation strategies and cognitive modifiability in young children as a function of peer mediation with young children program and training in analogies versus math tasks. *Journal of Cognitive Education and Psychology*, *9*, 48-72.

Wiedl, K. H. (2003). Dynamic testing: A comprehensive model and current fields of application. *Journal of Cognitive Education and Psychology, 3*, 93-119.

David Passig
Bar Ilan University, Israel
david@passig.com