

Improving children's Cognitive Modifiability through Mediated Learning and Dynamic Assessment within 3D Immersive Virtual Reality Environment

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Abstract: The objectives of this study were to examine (a) the effect of dynamic assessment (DA) in a 3D Immersive Virtual Reality (IVR) environment as compared with computerized 2D and non-computerized (NC) situations on cognitive modifiability, and (b) the transfer effects of these conditions on more difficult problem solving administered two weeks later in a non-computerized environment. A sample of 117 children aged 6:6-9:0 years were randomly assigned into three experimental groups of DA conditions: 3D, 2D, and NC, and one control group (C). All groups received the pre- and post-teaching Analogies subtest of the Cognitive Modifiability Battery (CMB-AN). The experimental groups received a teaching phase in conditions similar to the pre-and post-teaching phases. The findings showed that cognitive modifiability, in a 3D IVR, was distinctively higher than in the two other experimental groups (2D computer group and NC group). It was also found that the 3D group showed significantly higher performance in transfer problems than the 2D and NC groups.

Keywords: Dynamic assessment, mediated learning experience, cognitive modifiability, analogical thinking, virtual reality

1 Introduction

1.1 Dynamic Assessment

A growing number of research evidences in the literature of cognitive evaluation shows significant contribution of the dynamic assessment (DA) approach in obtaining a richer and more reliable feedback with respect to (a) children's cognitive capacity (b) construction of intervention programs and (c) effective programs for the development of the abstract thinking (Tzuriel, Klein, 1985; Tzuriel, 2001; Tzuriel, 2000; Tzuriel, Caspi, 1992; Tzuriel, Kaufman, 1999; Tzuriel, Shamir, 2002; Tzuriel, Shamir, 2007; Tzuriel, Shamir, 2010).

The DA approach is based on the Structural Cognitive Modifiability (SCM) and the Mediated Learning Experience (MLE) theory and forms a key working assumption in the current research (Tzuriel, 2001, 2002; Feuerstein, et al., 1980, 1991; Feuerstein, Klein, Tennenbaum, 1991). The DA approach to the measurement of the learning process represents a relatively new trend in evaluating learning potential (cognitive modifiability) and is offered as an alternative with an advantage over the static assessment (SA) in evaluating the child's cognitive ability. While the conventional static procedure measures only the level of the subject's achievements, without any attempts at intervention, the focus of DA is on the observing and measuring of the learner's cognitive modifiability with the assistance of adequate MLE (Tzuriel, 2001).

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). The measurement process of the cognitive modifiability in a dynamic assessment consists of a pre-test which provides a preliminary evaluation of an initial performance, a learning phase which includes mediation by an adult and a post-test to examine post-learning performance.

1.2 Dynamic assessment in computerized environments

Numerous studies indicate, alongside the developments in the DA, that the use of computerized environments, including virtual reality environment, contributes to the development and empowerment of children's thinking ability (Klein, Nirgal, Darom, 2000; Tzuriel, Shamir, 2007; Clements, Samara, 2002; Passig, Neuman, Eden, 2002, Passig, Miler, 2014; Passig, 2013; Passig, Eden, Rosenbaum, 2008; Passig, Eden, 2002).

In light of the findings attesting to the significant contribution of a computerized environment to the learner's thinking development, well as the findings indicating that the DA process provides a clearer picture of the child's learning potential, we have decided to integrate the two domains. In the current research we focus on examining the learner's cognitive modifiability, through experiencing various environments, including computer environments, using a DA approach. The diverse learning environments in which we conducted the DA process were: (1) a three-dimensional immersive environment (3D Immersive) via virtual reality technology with three-dimensional immersive Head Mounted Display-HMD (enabling the subject to feel as if he or she were immersed within the virtual world) (2) two-dimensional computerized environment with a mouse-screen interface (where the virtual world is in front of the subjects) (3) board and blocks (with no technological aids). DA in a virtual reality environment (three-dimensional immersive environment – 3D IVR) is the first known study.

In the process of the DA we have examined the following questions: (a) in which learning environment will children show higher cognitive modifiability? (b) Does DA provide a more accurate measurement of the learning potential than static assessment? Likewise, we examined the degree of the learning potential over time under various learning conditions.

1.3 Transfer test

An important aspect of the present study was the transfer test of the principles learned in the DA procedure regarding problem solving of a higher order. Transfer is the effective and reasoned use of principles, relationships, and strategies at the time of carrying out a task perceived by the examiner as clearly more difficult than the tasks whose frameworks were taught (Salomon, Perkins, 1989).

An additional aspect, in which the concept of transfer was examined, touched on the correlation between the use of computerized technology and the improvement of cognitive skills over time, as opposed to the improvement in cognitive skills over time without technology. A few studies (Pea, 1987; Salomon, Perkins, Globerson, 1991) posited a distinction between two processes in which technologies impact cognition over time. One included a process called the "Effect with Technology," while the other is called the "Effect off Technology."

The first process addresses the changes in achievements, which happen in the course of interaction with technology, and therefore, is called the “Effect with Technology”. The second process addresses the effect on the cognitive ability of the user over time. The intellectual partnership with the computerized tool leaves a cognitive imprint transfer on different cognitive abilities, such as the ability to generalize and self-regulate.

In the present study we assumed that the subject’s experience in DA in a variety of environments, via the computer and through the use of wooden cubes, would not only affect the learner’s achievements at the time of the assessment, but would also be preserved and consequently manifested even at a later stage.

1.4 Analogical thinking and dynamic assessment

The cognitive domain was selected from a major field in children’s cognitive development – analogical reasoning. It constitutes one of the important fields in evaluating cognitive capacities and considered central to the measurement of learning processes and mathematical thinking (Holyoak, 2004; Halford, 1993; Sternberg, 1977; Goswami, 1992). Analogical thinking is strategic thinking, which enables children to reach conclusions about phenomena, which are presented to them for the first time (Holyoak, 2004). In a number of studies it was shown that infants demonstrated an ability to solve analogical problems at the age of 18 months, but failed to reach a high level of ability by the time they have reached puberty (Richland, Morrison, Holyoak, 2006). Although the overall consensus is that analogical capability is important to a child’s cognitive development, there is a lack of agreement regarding the mechanism involved in developing analogical conclusions.

One of the interesting findings, which surfaced from the research based on the Dynamic Assessment approach over the last decade, is that children succeed in solving analogical problems on a much higher level after a short, intensive phase of learning (Tzuriel, 2000, 2001, 2007; Tuntler, Resing, 2007). In those studies, which examined children’s analogical ability, researchers found that mediation in analogical thinking relevant to children based on familiar relationships with visual and concrete imaging or gaming, helped young children in analogies solving (Richland, Morrison, Holyoak, 2006).

To sum, the main hypothesis was that children’s cognitive modifiability in analogical thinking, in a DA process, within a three-dimensional immersive computer environment would be higher than in a two-dimensional computerized environment, in a non-computerized environment and in a control group.

Furthermore, it was hypothesized that children’s cognitive performance scores in transfer analogies (i.e., more complex than those tested at the DA stage) given two weeks later in a non-computerized environment, would be higher in the three-dimensional immersive computerized environment group as compared with the other experiential groups and the control group.

2 Method

2.1 Subjects

The sample was composed of 117 children at the age of 6:6 to 9:0 years, 61 boys and 56 girls. All children attended schools in the central region of Israel and were randomly selected from 4 schools. The children were randomly assigned into four groups: three experimental and one control group. The experimental groups participated in three different DA environments (i.e., three-dimensional immersive computer environment (3D IVR), two-dimensional computerized environment (2D), and non-computerized environment (NC)); whereas the control group participated in a NC environment, in which cognitive performance measurement was held with no learning phase. Following in table 1 is the breakdown of the groups by gender.

Table 1: Breakdown of the research groups by gender

Groups	Gender			
	Boys		Girls	
	N	%	N	%
1-3D-IVR	19	52,6	17	47,4
2- 2D	21	58,3	15	41,7
3-Blocks	12	50,0	12	50,0
4- Control	9	42,9	12	57,1
Total	61	52,1	56	47,9

In general, the number of boys was somewhat larger than the number of girls, 52.1 % vs. 47.9 %. χ^2 analysis did not indicate a statistically significant difference between the groups $\chi^2 = .75$, $df=1$, ns.

It is worth noting that since the focus of this study was about DA in a computerized environment, we decided, already at the planning stage, that the groups assessed through the computer would be bigger than the other two groups.

In the course of the research we also examined the age of the children and the education level of the parents. According to the findings, there were no statistically significant differences among the four groups studied in our research, except significant difference in the NC group in which the fathers' education level was relatively lower than in that of 3D IVR Group.

2.2 Research instruments

Analogies sub-test from the CMB test (Tzuriel, 1995) was used for the purpose of examining cognitive modifiability in analogical reasoning. The test was designed for children in kindergarten and those attending first through fourth grades. The test is built of a board, 18 cm x 18 cm which includes 9 windows set in a format of 3 x 3, with 64 wooden cubes in four colours (yellow, blue, red and green). Each coloured brick has four lengths (2 cm, 3 cm, 4 cm, and 5 cm). Four windows are open at the top of the board. The examiner places the bricks in three of the four open windows, and asks the child to complete the placing of the bricks in the fourth window. The problems are based on dimensions of colour, height, number, and location (for example, figure 1 – problem #14 from post-learning stage). The test has problems of three levels of difficulty, derived from the number of dimensions included in the problem. The problems are organized from easy to difficult.

The test also produced a measure of transfer scores. The goal of the transfer problems was to assess the degree of internalization of the principles of problem-solving through the use of analogical thinking, which were taught in the first stage.

The test on transfer was administered according to the static assessment approach, which included problems with no a learning stage. An example of the problem of transfer (TR8-A) can be seen in figure 1.

This test was also converted to a computerized version. The computer program made it possible to observe the problem from three angles: from above, from the side, and from within. We placed three buttons in the upper centre of the screen, and while pressing any one of them made it possible to move from one to any other angle of observation on the problem. In figure 2 there is a sample of an analogical problem from side angle.

In addition, the computerized program was written to enable the problem to rotate on a 360° horizontal axis (and thus made it possible to observe it from several perspectives) and at a 45° angle on a vertical (up and down) axis.

The grading system, in the DA and transfer stages, in both versions (original CMB test and computerized CMB test) was carried out according to the

measure-research approach, which included two methods of grading: 1. all or nothing, and 2. partial scores. In the all or nothing approach, a score was registered when all of the problem's dimensions have been identified correctly.

The total number of points for each stage in all or nothing method (pre or post-learning) was 14 points. Based on this scoring method graded the level of analogical performance of the pre-learning and the post-learning stages. In the partial scores method, the scores were given for each correct identification of one of the dimensions (colour-(c), number-(n), height-(h), location-(l)). For each correct answer the child was scored with one point. Based on this scoring method we produced the grade representing the level of analogical performance of each of the analogy's dimensions. The total number of points was 56 points. The advantage of assessing each child with two methods lies with the recorded gap between the two results. This indicated a difficulty in the integration of the dimensions in solving the problem (Tzuriel, 2001). In total, from the CMB-AN test we obtained three measures: pre-learning score, post-learning score and transfer score. The Cronbach's alpha reliability coefficient of the wooden bricks' format of the CMB-AN test was found to be $\alpha = .83$ for pre-learning and $\alpha = .78$ for post-learning (Tzuriel, 2000).

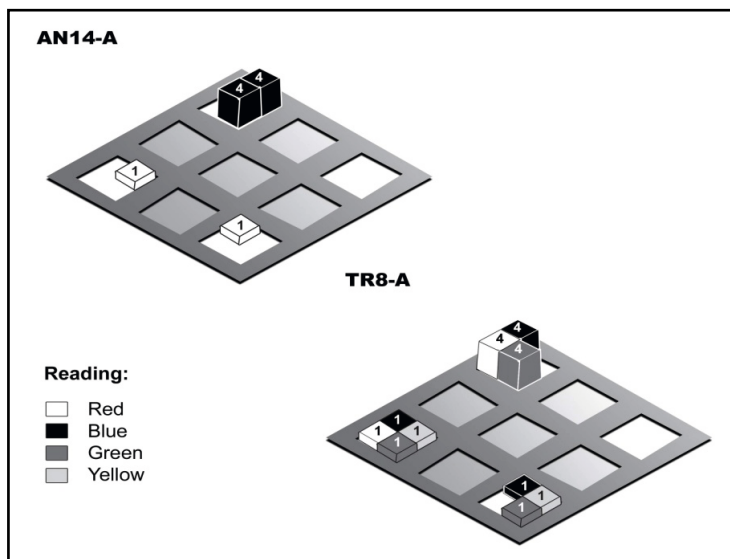


Figure 1: Analogical problem #14 from post-learning stage (AN14-A) and Transfer problem (TR8-A)

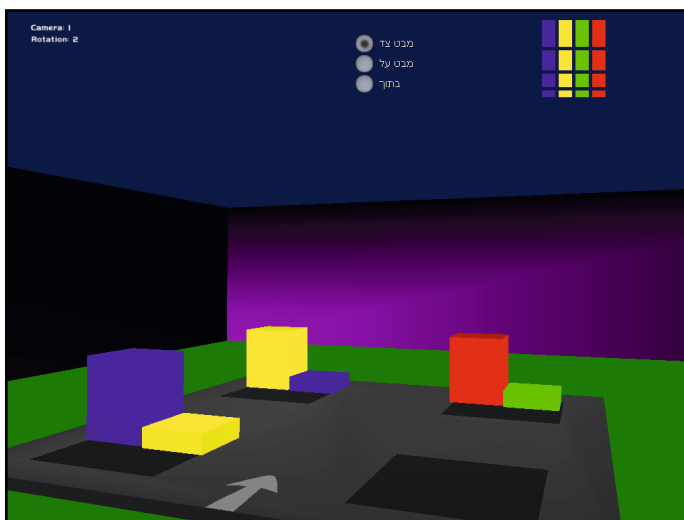


Figure 2: Presentation of problem TR2-B on the multimedia board as seen from the side

2.3 Procedure

The research consisted of two measuring stages, conducted two weeks apart from one another. The first consisted of DA in analogical thinking in the various diagnostic environments; the second consisted of transfer problem solving (more complex problem) in a non-computerized environment.

The assessments were performed in a small room assigned for that purpose by the school. Individual DA procedures were carried out in the first phase in all experimental groups.

All groups received the pre- and post-teaching Analogies subtest of the Cognitive Modifiability Battery (CMB). The experimental groups received a teaching phase in conditions similar to the pre- and post-teaching phases. In this way we assessed the level of the subjects' cognitive modifiability. The amount of time allotted for the DA procedure in the three groups was identical: 90 minutes divided equally for each stage (30 minutes each).

The assessment included all the items of the CMB-AN test. Each part of the assessment included 14 items. In the control group we measured cognitive achievements with problems of pre- and post-learning phase without the learning stage.

3 Results

3.1 Differences among the groups in cognitive modifiability

Table 2: Averages, standard deviations, and F analyses of analogy scores pre- and post-learning among all four groups

Research Groups											
		3D-IVR		2D		Blocks		Control		Group X Time	
Scores		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***
	SD	3.27	3.89	3.36	2.87	4.49	3.20	4.42	3.57		

Table 3: Covariance analysis of the comparison between couples of four experimental groups in the pre- and post-learning (DA)

Group comparison	df	F	Eta ²
3-4	1,43	28.53***	.40
2-4	1,55	49.11***	.47
1-4	1,55	117.70***	.68
2-3	1,58	.00	.00
1-3	1,58	5.88*	.09
1-2	1,70	9.89**	.12

3.2 Differences between the groups in the dimensions of analogical thinking

Table 4: Averages, standard deviations, and F analyses of the four dimensions in the various groups and the MANOVA results for each dimension separately.

Dimensions		3D-IVR		2D		Blocks		Control		Time X Gr.	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	F(3,113)	Eta ²
H	M	9.47	12.02	9.36	11.58	10.0	13.16	9.95	10.14	*2.82	07.
	SD	3.56	43.	3.81	43.	3.16	52.	3.90	5.64		
L	M	9.55	12.25	9.13	12.05	9.33	11.58	9.71	10.76	1.85	04.
	SD	2.71	38.	3.04	38.	2.69	46.	4.31	50.		
C	M	10.52	13.50	11.13	13.00	9.16	13.08	10.52	10.42	3.83*	09.
	SD	4.84	34.	3.79	34.	4.44	42.	3.41	45.		
N	M	11.69	13.33	11.11	12.72	9.16	12.70	9.57	9.66	3.56*	05.
	SD	2.85	36.	3.38	36.	4.74	44.	4.08	48.		

3.3 Differences between the groups in the transfer test of analogical thinking

Table 5: Averages, standard deviations, F analysis of cognitive performance in the transfer test in all four research groups.

Groups							
Transfer Analogies Scores		3D-IVR	2D	Blocks	Control	F(3,113)	² Eta
	M	5.32	3.59	3.50	1.47	17.34***	.32
	SD	2.47	1.76	2.02	1.20		

*** $P < .001$

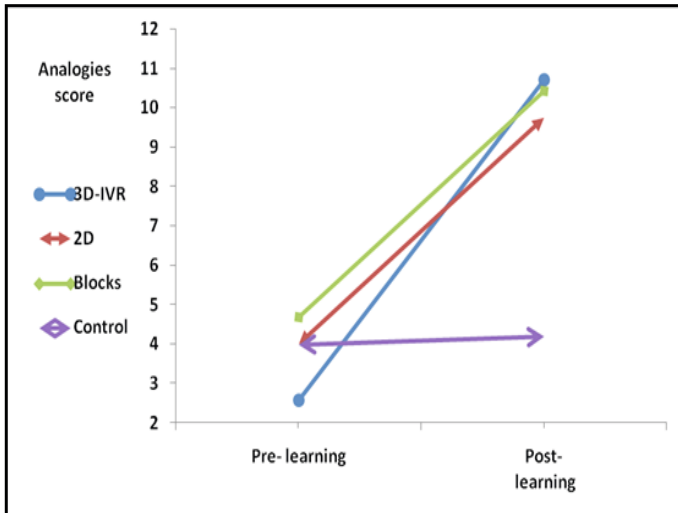


Figure 3: Average analogies scores of the pre- and post-learning among the four experimental groups

3.4 Differences between groups in the dimensions of the transfer test

Table 6: Averages, standard deviations, and the F analysis of different dimensions in the transfer test by the four research groups

Dimen- sions		Groups					
		3D-IVR	2D	Blocks	Control	F(3,113)	Eta ²
H	M	10.75	10.36	9.95	8.66	3.91*	.09
	SD	1.72	1.95	2.47	3.24		
L	M	9.75	9.75	9.04	8.61	1.28	.03
	SD	2.40	1.82	2.09	3.91		
C	M	12.41	12.13	11.87	9.90	8.18**	.18
	SD	1.18	1.29	2.55	2.93		
N	M	10.61	9.75	10.08	9.47	1.47	.04
	SD	1.98	2.37	1.93	2.56		

*P < .05, **P < .01

4 Discussion

4.1 Differences among the groups in cognitive modifiability

The research findings indicate distinct improvement in the analogies scores from pre- to post-teaching phases in the experimental groups. As hypothesized, cognitive modifiability in a 3D IVR was distinctively higher than in the two other experimental groups (2D computer group and NC group).

These results support findings of other VR studies, and add another important layer. From our findings we learn that the experience in solving problems with the assistance of virtual reality can improve cognitive abilities. Our study, in this regard, supports Passig's (2014) claims and broadens his scope to include the areas of mediated learning and Dynamic Assessment. But different from Steinwandel and Ludwig's (2011) results where recognition and processing of spatial structures within the working environment "model" was superior to the other two forms of representation – like illustration or interactive animation.

As opposed to earlier research in the fields of mediated learning and DA, this study adds an additional layer by integrating a DA procedure of analogical thinking with 3D IVR. Indeed, it seems that a DA procedure in a 3D IVR setting can better reflect the subject's potential for learning than other settings. One possible explanation for this lies in the manner in which we use virtual reality. The improvement of cognitive skills derives from the possibilities embedded within this technology to present abstract concepts in concrete, visual, three dimensional, and game oriented ways. 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 are both familiar to them and which in their view have concrete significance; they do well at solving them (Goswami, 1992; Halford, 1993). These characteristics, embedded in the nature of the VR technology, seem to have expanded the ways in which information is presented, as well as having assisted the young children's ability in the course of the DA procedure to reach an analogical conclusion.

It seems that in the course of learning and assessment, the children's opportunities for gaining concrete experiences are empowered by means of exposure to additional information – both visual and new which are solely virtual. It seems that this visual information stimulates a unique perceptual experience which contributes to the understanding of the transformations in the dimensions of the problem and creation of new and more broadened representations as

well as schemes which empower the children, and present them with the ability to solve problems.

On the basis of these findings, one may conclude that the use of the virtual reality environment contributes to the empowerment of the children's cognitive capacity. We may further conclude that integrating the DA into a three-dimensional immersive environment reflects to a greater extent the learning potential of the subject's in comparison to the DA in the other research diagnostic environments.

4.2 Dynamic assessment in the context of the four dimensions of the test

The performances requiring analogical thinking was also tested with four additional dimensions: location, height, number and colour. In testing the impact of mediation on the performance in the different dimensions, we found a statistically significant difference between the first and the second measurements, though not find a significant difference in cognitive performances on the various dimensions between the 3D IVR group and the rest of the experimental groups.

We may explain the difference between the results of the first to the second by means of the differing approaches with which we scored the achievements. In measuring the score for the analogical from pre- to post-learning, we adopted the approach of 'all or nothing'. In this approach the emphasis was on the complete solution of the problem. In this scoring method, the subject must weigh a number of transformations together and provide one answer. Only a correct answer in all four dimensions would give him or her one credit. However, in measuring the score with each of the test dimensions, we applied the partial scoring approach, according to which the score given to the correct solution of each of the dimensions was calculated separately, with no interdependence between them. According to this approach, it was possible the subject to solve three out of four dimensions correctly and to receive for this a partial grade of three points (one point for each correct answer). It may be that for each scoring method, different thinking abilities are required, and thus the 'all or nothing' method required integration of all the dimensions. That way, the advantage we found in the 3D IVR environment overall score was not preserved in each of the dimensions of the analogy.

We may summarize by saying that the DA experience with 3D IVR had an impact on the cognitive performance of the child in a way that it improved his other ability to generally observe the problem, simultaneously address the transformations which occurred in the dimensions of the analogy, and generate

a valid integration between them towards its full solution. Accordingly, when dealing with a solution involving each dimension separately, the DA experience with 3D IVR had a similar impact as a DA experience with a computerized 2D or a wooden board and bricks settings.

4.3 Differences between the groups in the transfer Test of analogical thinking

Moreover, it was found that in the transfer test, held two weeks later in an NC environment and consisted of more complex problems, the cognitive performance, among the subjects who experienced an assessment in a 3D IVR, was maintained and distinctively higher as opposed to the subjects' achievements in the other groups. The DA in the 3D IVR was more effective in internalizing the mediated cognitive principles, namely in the ability to apply them in solving more complex problems. These findings point both to the credibility of the results, obtained at the DA stage, and to the possibility of maintaining and 'transferring' the level of achievements, measured in assessment in a three-dimensional environment to an environment with no technological aids.

Integrating the use of a 3D IVR in a DA procedure generates "an intellectual collaboration" (Pea, 1987; Salomon, Perkins, Globerson, 1991) among the computer, the subject and the examiner. This collaboration apparently creates a unique perceptual experience, which broadens the subject's mental imagery world, heightens the internalization of the mediated cognitive principles and contributes to its performance. The virtual reality technology, therefore, is an appropriate and important diagnostic environment.

As in the first phase no differences were found between the 3D IVR to the other groups in terms of the scores of the test's dimensions.

5 Conclusion

This research has increased our understanding regarding the contribution of integrating the use of computerized environments in DA processes. The current research is added to a limited number of earlier studies, which had examined thinking development in a virtual reality environment as well as to a line of research in the DA domain. It may be inferred from the current research findings as a whole that integrating the virtual reality technology in a DA procedure is one of the effective means of a computer use in this procedure. Thus, a DA of an analogical reasoning capacity in such environment reflected the child's

learning potential to a greater extent in comparison with a 2D computerized environment and a NC environment.

Consequently, we suggest that the evaluation of the child's cognitive modifiability capacity is affected by the environment where the assessment is conducted through the collaboration between the child, the computer and the examiner.

In practice, the research has clinical and educational applications. Based on the current research findings, we may conclude that diagnosticians and educators can relate to the DA results in a 3D-IVR as predictive of cognitive modifiability capacity in reality. A possibility is opened for diagnosticians to consider and select out of a number of diagnostic environments the one, which would best reflect the child's learning potential. Conducting the DA in the virtual reality is an additional layer in the development and integration of dynamic assessment processes in computerized worlds and advanced technologies.

References

- Clements, D., Samara, J. (2002). The role of technology in early childhood learning. *National Council of Teachers Mathematics*, 8, 340–343.
- 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., 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.
- Goswami, U. (1992). *Analogical Reasoning in Children*. Hillsdale, NJ: Lawrence Erlbaum.
- Halford, G. S. (1993). *Children's Understanding: The Development of Mental Models*. Hillsdale, NJ: Lawrence Erlbaum.
- Holyoak, K. J. (2004). Analogy. In Holyoak, K. J., Forrison, R. J. (Eds.). *The Cambridge Handbook of Thinking and Reasoning*. New York: Cambridge University Press, 117–142.
- Klein, P., Nir-Gal, O., Darom, E. (2000). The use of computers with or without adult mediation: Effects on children's cognitive performance and behaviour. *Computers in Human Behavior*, 16, 591–608.
- Lidz, C. S. (1991). *Practitioner's Guide to Dynamic Assessment*. New York: Guilford.
- Passig, D., Neuman, T., Eden, S. (2002). Improving the awareness to toddlers' initial emotional experiences in kindergarten with virtual reality. *Educational Media International*, 39(2), 185–193.
- 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., Eden, S., Rosebaum, V. (2008). The impact of virtual reality on parents' awareness of cognitive perceptions of a dyslectic child. *Education and Information Technologies*, 13(4), 329–344.
- Passig, D. (2013). *Forcognito – The Future Mind*. Tel-Aviv: Yediot Press.
- Passig, D., Miler, T. (2014). Solving conceptual and perceptual analogies with virtual reality among kindergarten children of emigrant families. *Teacher College Record*, in print on 116(2).
- Pea, R. D. (1987). Integrating human and computer intelligence. In Pea, R. D., Sheingold, K. (Eds.), *Mirrors of Mind: Patterns of Experience in Educational Computing*. Norwood, NJ: Albex, 128–146.

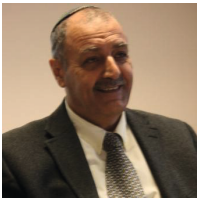
- Richland, E. A., Morrison, G. R., Holyoak, J. K. (2006). Children's development of analogical reasoning: Insights from scene analogy problem. *Journal of Experimental Child Psychology*, 94, 249–273.
- Salomon, G., Perkins, D. N. (1989). Rocky roads to transfer: Rethinking mechanism for a neglected 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.
- Steinwandel, J., Ludwig, M. (2011). Identifying the structure of regular and semi regular solids – a comparative study between different forms of representation. In *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education*, 670–680. Rzeszów, Poland: European Society for Research in Mathematics Education.
- Sternberg, R. J. (1977). Component processes in analogical reasoning. *Psychological Review*, 84, 353–378.
- 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(2), 194–217.
- 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., Caspi, N. (1992). Dynamic assessment of cognitive modifiability in deaf and hearing preschool children. *Journal of Special Education*, 26, 235–252.
- 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., 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

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Biographies



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David Tzuriel is a Professor Emeritus at the school of Education at Bar-Ilan University, Ramat-Gan, Israel 52900. He is a clinical and educational psychologist and an expert on dynamic assessment of learning potential. He served as President-Elect of the International Association for Cognitive Education and Psychology (IACEP) during the years of 1997–1999 and President during the years of 1999–2001.



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