Intelligent Virtual Reality
and its Impact on Spatial Skills and Academic Achievements

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ABSTRACT

It is known that the training of intelligent virtual reality, through the use of computer games, can improve spatial skills especially visualization and enhances academic achievements. Through an experiment of using Tetris software, two objectives were achieved: developing spatial as well as intelligence skills and enhancing academic achievements, focusing on mathematics. This study followed studies dealing with the impact on putting the learner into action in 3d space software. During teaching a transition from 2d to 3d spatial perception and operation occurred. A positive transfer from 3d virtual reality rotation training to structural induction skills, by means of mental imaging, was also achieved. At the same time the motivation for learning was enhanced, without using extrinsic reinforcements. The duration of concentration while using the intelligent software increased gradually up to 60 minutes.

Keywords: Abstract Thinking, Academic Achievements, Artificial Intelligence, Virtual Reality and Visualization.

1. THEORETICAL REVIEW

Definitions

According to the summary of McGee (1), there are two different sets of spatial skills: Orientation in space and Spatial Visualization. Mastery of these skills enables the pupil to locate the position of objects in space and the relations between them from a changing viewpoint (see also: (2) (3) (4)). The application of spatial visualization enables him/her to predict and imagine potential spatial changes in the observer's position, or those of any other object in his/her vicinity for a long term (2). The spatial concepts have metaphoric implications. Thus we must distinguish between the meaning of the concrete spatial concepts, such as above-under, in front of-behind etc. and **metaphorical expressions** based on such concepts (verbal translations of spatial concepts, which do not always make sense when taken from one language to another). For example: "fields" of interest, "levels" of thought (5). These metaphoric meanings extend the benefit of improving spatial skills to language comprehension and application. Greenfield & Schneider (6) and Greenfield & Westerman (7) found parallelism between the ability to organize the syntactic structures in sentences and the manipulation of objects in space in children, three years old.

Lohman (8) stated that the visualization is the main factor regarding spatial ability (See also: (5) (9) (10) (11). Lohman (12) argued that the ability to think and orient in innovative situations is amenable to learning. Spatial orientation can be programmed and is also carried out by Artificial Intelligence. Such as in the "Sharadlu Robot" who is able to elaborate spatial structures according to instructions, for example: "Put the blue ball on the red cube" (13). The same procedure is used in the exercises to manipulate space in "referential communication" with human subjects (14) (7).

The Relationships between Spatial Orientation and the Basic Skills of Arithmetic and Reading, Ability to Design and Mapping Skills

Many studies show the relationships that exist between the level of spatial skills and mathematical achievements in all ages. Battista (15) testified the relations between space visualization and success in mathematics at the university. He further showed that the ability to imagine changes in 3-D designed structures affected significantly the scores of students in Algebra and Geometry courses in the middle classes of Junior Schools.

Some studies found relationships between reading achievements and the level of spatial abilities. Stockdale and Possin (16) focused on specific features such as the shapes' position and the order of the letters presented in words. Meanings of words are depended on the position of the letters in a sequence. Changing the order of letters changes the meaning of the words. For example: "on" – "no", "saw"-"was", "angel"-"angle". The positions of words, sentences and paragraphs in the text, are defined by spatial concepts such as: right, left, above, below and beside. As mentioned above, another spatial feature related to meaning is shape. The shape of each symbol in written language is meaningful. Each letter and number has a specific shape and often a specific direction in space (Examples: "b"-"d", "g"-"p","2"-"s","3"-"e"). Text comprehension also requires spatial skill since the reader must extract meaning by analyzing the complex syntactic structure of sentences. For example, the reader must link a subject to a certain verb even though the two words may be separated by a dozen of words. Flexible and meaningful reading requires the ability to produce questions and reach the meaning. The successful reader wonders and asks questions about the text while reading it. The reader uses spatial skills to track the direction of an argument.

Similarly, paraphrasing, an essential reading skill, requires combining, sorting and rearranging the printed text to restate points in a different way. Finally, the expert reader can understand different viewpoints, that is, the reader can understand how an event or an argument would appear to another person (see also: (6)). Sharing viewpoints requires seeing something from other perspectives or positions, which is essentially a spatial ability.

Livni and Bar (17) suggested four spatial starting abilities that are needed for pupils in order to see a map as a 2-D vertical projection of the 3-D landscape, and to encode and decode topographic heights represented by contour lines and colored strata. These abilities are also related to Piaget's stages of spatial development (17). Their research found that Spatial skills are the basis of mapping skills such as other academic skills like designing, reading, writing and arithmetic, as described here.

Training Spatial Skills by Computers

New method to train spatial skills is based on the use of the computer (18) (19). The uniqueness of the method consists of a dynamic putting objects into action over the screen by the child himself, as occurs in many computer games (20). Generally, all computer games train spatial orientation and visualization, as the player has to orient himself/herself within a rapidly changing environment. These exercises should be complemented by verbal interaction aimed to teach spatial concepts and practice them eventually. Such Computer games can also be used by pairs of pupils (21).

Pantelidis (22) defines virtual reality (VR) as a multimedia interactive environment that is computer based and enables the user to assimilate and to become an active partner in the virtual world. This technology enables presenting information in three dimensional formats in real time. It allows the user to become an active part of the environment and to benefit from interactive communication without using words. Thus virtual reality enables converting the abstract into concrete by giving perspectives on processes that are impossible to perform in the real world (23) (24).

Passig & Eden (25) investigated whether the practice of rotating three-dimensional (3D) objects in Virtual Reality (VR) will positively affect the ability of 44 deaf and hard-of-hearing children aged 8-11 (average age 9.3) to use inductive processes (such as extending sequences) when dealing with shapes. The findings indicated that training with VR 3D spatial rotations significantly improved the inductive thinking for shapes used by the experimental group, as compared with control group (I), coming from similar population, who did not significantly improve its performance. Before the training the deaf and hard-of-hearing pupils attained lower scores in inductive abilities than pupils with normal hearing (control group II). The findings showed that the achievements of the experimental group, after the VR 3D training, improved to the extent that there was no noticeable difference between its pupils and the pupils with normal hearing. This investigation testified the impact of practicing Tetris game on spatial skills and thereby on the achievements in arithmetic and in intelligence tests.

Tetris Game

The Tetris game was invented by Pazhitnov in 1985 (26). Since then, this computer game was considered as a hard task exemplifying problem solving. During practicing Tetris task, block-shaped pieces appear at the top of the screen and fall down, while players manipulate them, so that they fit into point-scoring rows. While using this game, the users race to fit falling blocks together within a short time span. Building an algorithm to play Tetris quickly and efficiently is very hard (27). In spite of the hardness in playing this software, the game exploded in popularity , mainly after Nintendo Co. put it on their popular gaming machines.

Implications of Using Tetris Game on VR in General

Passig & Eden (25) showed that training spatial rotations with 3d virtual reality games, such as the Tetris 3d games, improve the induction of structure by deaf and hard-of-hearing pupils. It was thus shown that putting virtual reality into action through the use of Tetris software enabled the user to become an active part of the environment. Using this virtual reality in 3d, provided the user with perspectives on processes that are impossible in the 2d space (22), which offered an advantage for inducing the series' sequence of shapes according to a structural paradigm.

Through the use of this software, the users can experience movements in space without the need to learn an operating system or a programming language, and also without needing the skills of reading or calculation. But the trick of creating these new experiences requires basic academic skills, thinking skills and a clear mental model of the system. Virtual worlds can be linked to the physical world through telepresence, where distant learning systems could be expanded to allow students and teachers to share worldwide learning environments. Real-time access to a multitude of people and information sources opens the virtual world – and the classroom – to the world.

Virtual reality learning environments allow entirely new capabilities and experiences. The users can control time, scale and physical laws. The users have unique capabilities, such as the ability to fly through the virtual world, to occupy any object as a virtual body. Observing the environment from many perspectives is both a conceptual and a social skill: enabling pupils to practice this skill in ways we cannot achieve in the physical world may be an especially valuable attribute of virtual reality.

Dynamic programming software enables to add viewpoint control, command structures, manipulations of objects, movement constrains, animations and object behaviors. One instance of the virtual reality is the "Tetris game" that was investigated also in our country. The treatment was done on a group of students coming from Attention Deficit Hyperactivity Disorder (ADHD) population by Roza-Zada (28). Roza-Zada's (28) research group was composed of 22 ADHD pupils with 11 in Experimental group and in 11 Control group, aged 15-17. All the pupils were tested in spatial skills, mathematics and intelligence tests before and after manipulation. The findings showed a significant development in the Experimental group relative to the Control group, in spatial and arithmetic skills and also in intelligence tests. The level of attention and concentration in the experimental group increased after they used the "Tetris computer game". In this study it was demonstrated that students could be motivated to use computer software, which integrates motion in two and three- dimensional space, which affected an improvement in the spatial skills as well as the level of arithmetic.

Other researchers focused on describing the advantages of the Tetris game which presents a problem and tries to manage it before it happens. The player sees the objects graphically and tries to organize them before they fall (29). Computer game Tetris allows students to replay the same game. Computer manipulators link the concrete and the symbolic by means of feedback. The computer connects manipulations that students make, with numbers and words. The manipulations of the shapes over the computer screen (rotating them to the right and/or to the left side) through the use of the symbolic commands link them to a sensory-concrete turning action. By receiving their explorations over several tasks, they develop awareness of quantities, angles and rotation of the geometric shapes (30).

2. METHOD

Qualitative longitude research based on observations, measuring outputs of subjects during game sessions and using tests, was conducted.

Research Group

The group is composed of 8 pupils aged 16-17 years, learning in high grades of special education school from which two cases were chosen for detailed description.
Case 1: This pupil is hearing impaired with mental retardation. At the beginning he behaved like an autistic. He has difficulties in all learning domains, in thinking skills, basic skills and academic skills. This pupil does not communicate with other pupils, His concentration span is limited to only several minutes and afterwards he shuts himself. He has a very low self-image, and becomes frustrated of every failure and then stops performing the task. He is anxious when he fails.
Case 2: This pupil is hearing impaired with learning disabilities and he is very passive. He does not promote any task that he is supposed to perform, works very slowly and he is also unmotivated for learning. The pupil has very low self image. His concentration span lasts for a short time, and he does not continue to perform the task especially after he fails.
These two students were observed during practicing the Tetris software and their achievements were scored. For comparison one regular student was also observed during the same performance, and his achievements were scored. Accept of the follow up of these three cases the whole group was evaluated by the following testing tools.

Research Tools:

Observations were made of the three students' performances during sessions and scoring their achievements in each session.
Raven matrices test (31)
The analytic skills of the participants are tested according to their ability to complete a matrix according to logical rules.
Cubes' Organization test (32).
Mathematical achievements (33)
This test is composed of basic skills in mathematics as ordering, sequencing, basic exercises in addition, subtraction, multiplication and division, based on the "reversal law".
Reading Comprehension test (34)

Media

The Computer software "Tetris Game" was used in order to examine its impact on the achievements in spatial skills and mathematics. The player aims at filling 2D shapes into rows and a large 3D cube with small blocks of different shapes. The user had to place the dropping blocks into the fitting spaces. In order to attain a high score, the user needs to act both precisely and rapidly. The user had to complete the blank locations on the board according to an induced rule which he had inferred and to fit the appropriate shape in the blank locations.
The "Tetris" computer game has four levels. At the first level, the game is based upon two dimensions basic forms. The number of forms is determined by the user (maximum 5). The task is easier and less complex when it includes fewer shapes. In the second and third levels, the forms are still two dimensional, but they are smaller and demand more careful manipulation in order to be located. At the highest level (the fourth one), three dimensional forms should be treated and arranged into a template of a cube. The common characteristics of all the levels of this software are the following:

1. Each form appears in the upper part of the game board and is going down in a constant speed.
2. The degrees of difficulty are determined by the speed in which the forms move down.
3. At any time when the line or the surface in the 3-D Tetris game is filled, it is erased and the participant collects his points.
4. The keys for performing all the "Tetris" software are the same: The user can move the form to the right or move it to the left or take it down. These movements are done by using the arrow keys. The form can also be rotated to fit the empty space needed to be filled. This is done by the use of the space bar, and rotating it by 90^0 to the right or to the left.

The use of the "Tetris" game trains both Orientation and Visualization, motor skills, hand to eye coordination, and time orientation.
This research aimed at following the gradual development of the ability to manipulate the Tetris game by hearing impaired as well as mentally retarded pupils, to compare their achievements with those of normal pupils, and also to evaluate the effect of the game on spatial and arithmetic skills, and the intelligence level.

3. FINDINGS

Table 1: Comparison between the achievements of normal and abnormal adolescent pupils in using the Tetris software

Normal Adolescent		Mentally retarded hearing impaired pupil Curve of development				Learning disabled hearing impaired pupil Curve of development		
Start Training	End training	Start Training	Training1	Training 2	End training	Start Training	Training	End training
2640	3360	60	215	285	385	255	280	551
2750	3010	112	305	295	286*	355	295	436
		122	305	295	226*	410	360	606
		141	397	325	250	510	406	266*
				345	266			616
				365	157*			607
				380	267			147*
					380			562

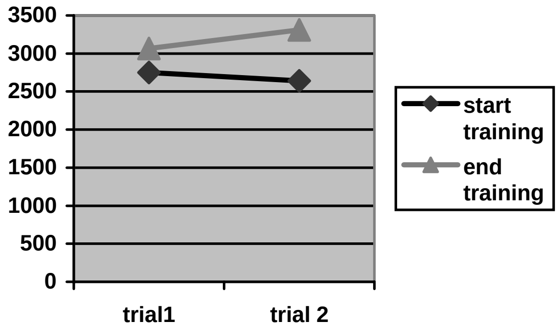
Gains acquired by normal adolescent and by special education adolescents. Comparison is made of the starting points and the curves of development in Tetris software.
* These low achievements points that occur during the sessions reflect stages of dropping of coordination typical to the population.

Time Table of the Training:

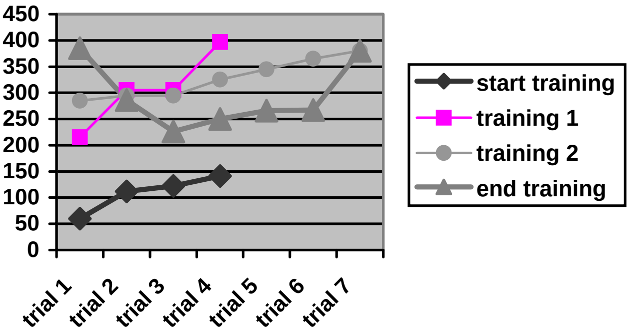
The training lasted for a month, twice a week, each meeting lasted for 45 minutes. The training was conducted in the computers' laboratory. During each training session, the participant tried to process the game in several trials. The starting level of each participant, achievements in one or two of these trials are shown in table 1 together with the end achievements of the session (more details are given in graphs 1, 2, 3).

In each graph the development of a pupil is drawn. The Black line depicts the achievement of the first trial. The upper lines show the situation during the trials and of further trainings at their end. The graphs show the gradual development in the achievements at the end training. Sudden decreases observed in the achievements of the special education pupils are typical to the population. Thick gray curved show how the pupils did at the end training and their significant achievements.

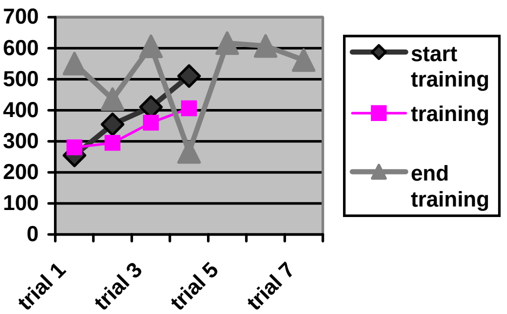
Graph No. 1
Regular adolescent
Points of gain



Graph No. 2
Mentally Retarded Hearing Impaired Pupil
Points of gain



Graph No. 3
Learning Disabled Hearing Impaired Pupil
Points of gain



The gains of the normal adolescent were of the order of ~3000 points, these gains increased gradually, but relatively less than those of the abnormal pupils. Abnormal pupils started with the very low gain of about 60 or 225 (See table 1) but their gains significantly increased, the gains more than doubled during the trainings. The increase of the gains was recorded in spite of the eventual "falls" of the achievements of the pupils, typical to their population. The learning disabled student scored better than the retarded participant, but both participants developed significantly during the training.

Table 2: Achievements of hearing and hearing-impaired pupils in spatial visualization observed through intelligence tests, reading and mathematical tests, before and after training the Tetris software

Test	Standard Progressive Matrices of Raven Case 1 Case 2	Cubes' Organization Case 1 Case 2	Reading Case 1 Case 2	Mathematics Case 1 Case 2
Before training	38% 41%	8 9*	0% 0%	9% 12%
After training	61% 63%	19 21	~20% ~18%	19% 22%

* This score is given in points (Max. score 54).

As these pupils did not read before the treatment we could not measure by quantity methods, how manipulating the Tetris game affected their reading. Other achievements increased significantly, the concentration span of the subjects also increased gradually. Their final concentration span was over the expected average level typical to their population. Even though we did not measure the reading skill formally, we have a hint that both of the special education participants improved in reading. In this stage, we can attribute this finding to the improvement in the concentration span during the training period.

Case 1: The pupil is concentrated on the task for a long time (up to 60 minutes consecutively). He is able to complete rows according to the rules of the game. He is ready to try again and again without being frustrated even if he fails. The student learned to plan his various acts over the computer screen and on a worksheet of paper. He became very relax even when he performs complex and complicated tasks.

Case 2: The pupil makes all the efforts to fulfill rows as much as possible. He became an initiator in his activities, while trying to communicate with other pupils in the class and compare his gains with theirs, his self image improved, he is satisfied about his challenge of the Tetris game and his gains while playing it. The pupil is motivated to try again and again, he prefers doing this activity instead of going to trips or other special activities. His concentration span increased even up to 60 minutes and over. He performs various tasks much more quickly, planning his acts reasonably and precisely.

Regarding both Cases 1 and 2: After “training” they are able to perform other intelligent activities which require high level of reasoning, accuracy and speed.

4. DISCUSSION

The question raised in this article as well as in former ones is weather intervention in the method of teaching and training could enhance special education pupils' perception and, thereby, some other cognitive skills. In spite of the varying population, a significant improvement of the spatial skills and academic achievements were recorded, as a result of different modes of training.

Zaretsky (11) (35) showed progress in language skills and in the readiness for arithmetic learning of hearing-impaired students that accompanied the improvement of their spatial skills. A raise in intelligence level and motivation in this population was also recorded (See also: (36) (37)). The enhancement recorded by Zaretsky (9) (10) (11) and Roza-Zada (28) of the intelligence level is explained partially as a result of the improvement in the spatial skills, and partially by the improved academic achievements in reading and arithmetic, that contributed to a better performance in the intelligence tests (38) (39). Similar results appeared here as a result of the use of the Tetris game by ADHD pupils, and hearing impaired mentally retarded or learning disabled pupils.

Tetris Game Effect on Improved Skills and Concentration

Traditional computer training is focused on, and stresses the exact concepts chosen, whereas computer games environment is unique in its dynamic representation. Success in the game, that is “gaining the points”, has its motivating effect on the participants and thus enhances the effect of the training. In this research the effect of the “Tetris game” on the improvement of spatial and other skills were checked.

The game research exemplifies the effects of the manipulation of forms moving rapidly over the computer’s screen. The participants were asked to follow instructions given over the computer’s screen, while observing the movement of objects. The participants should manipulate the fast changing environment on the computer screen. This study succeeded by showing the improvement of spatial skills, which were accompanied by improving significantly the mathematical achievements. Tetris game can also effect an improvement in reading. While making meaningful reading, the reader’s eyes dart ahead in some places, barely skimming the words. S/he might stop focusing on one word, or a part of a word. Suddenly, s/he double back to the beginning of a sentence, and then jump ahead again. These eye movements reflect cognitive activity (40). The reader searches for the information s/he wants in the right places, allocating attention to the elements that help her/him to grasp words, sentences and texts. He checks the text he is reading against what he already knows, makes predictions about future coming, and continuously construct and revises a sense of the whole out of the parts (41). These activities are also utilized while planning the acts during the use of Tetris software since users of the computer game Tetris may prefer to preview each upcoming shape manipulating, while using the same skill needed for meaningful reading. Indeed some improvement in reading was observed as a consequence of training in spatial skills. The natural sequence of this research is combining our trial to teach retarded adolescent to read and improve their reading achievements by Tetris manipulation.

Summary

The significance of virtual reality to education is expressed by comparing the implications of Objectivism to those of Constructivism: Objectivism and Constructivism represent alternative conceptions of learning and thinking (42). Objectivism assumes that the role of mental activities is to represent the real world and that the role of education should focus on helping students to learn about the world and to replicate its content and structure in their thinking. Whereas Constructivism claims that to a certain extent we construct our own reality through interpreting perceptual experiences, that reality is both in the mind of the knower and in the object of their knowing. Constructivists, rather than prescribing learning outcomes, focus on tools and environments to help learners to interpret the multiple perspectives of the world in creating their own view of it (43). Through making and using virtual reality tools and environments, which are now available to educators, we may discover more about the process of learning. By participating in the development of virtual reality, educators can guide the growth using this technology, and perhaps influencing the course of educational change.

Among those innovative trials we mention the uniqueness of Passig & Eden’ (25) research concerning the innovative and attractive technology of the virtual reality for improving structural inductive processes of deaf and hard-of-hearing children. Our research used a virtual game that exercises, among other things, the improvement of the ability to make three-dimensional spatial rotations. Spatial rotation is defined as a cognitive activity, applied when imaging a situation as seen through the eyes of another person viewing it from a different location (44). Success in this performance is equivalent to a success in the classical Piaget (44) tests and points at improved level of spatial ability. Post versus Pre test showed that this was actually the case in this research, when the achievements in Mathematics were also improved.

Students must reflect on their manipulating objects, such as Tetris forms and those of other computer games, for gaining a better understanding of the issue of place value in mathematics (45). Different manipulations can also be used to assess whether students understand the studied idea or just have learned to use material in a rote manner. Computer manipulations allow students and teachers to pose and solve their own problems and to develop increasing control of a flexible and extensible mathematical tool. The computer manipulations can also be used for many other purposes and help to form connections between mathematical ideas (46). Certain computer manipulations encourage easy alterations of scale and arrangement. Such manipulations also encourage, way beyond what can be done with physical manipulations, in situations that demand increasingly complex and precise specifications. Students learn to use such manipulations as tools for thinking about mathematics. Manipulating forms through playing Tetris game develops improvising the organization of the forms and fitting the new organized form into the fitting place. This similarity between mathematical needed skills and the skills needed for the Tetris game is in the basis of the effect of manipulating the Tetris game on the achievements in mathematics. This effect became clear in this investigation.

Computer assisted manipulations guide students to alter and reflect upon their actions, always predicting and explaining. These manipulations leaded the students to recognize that a lot of information can be presented even before using computers. Such information includes defining the objective of the software, knowing the ways how to operate hardware and software, and finding strategies to solve mathematical problems (47). In addition to the mentioned skills, we can add here reading comprehension skills, while the student needs to understand the meaning of certain words according to the context of the sentences and being able to translate them into the formal language of mathematics (19). S/he needs to comprehend the required actions in order to fit the falling Tetris forms into their right places.

A major advantage of the computer is the ability to link active experience with objects to symbolic representations. The computer connects objects that we create and move, and change them to numbers and words. Students can draw rectangles by hand, but never go to further thinking about them in a mathematical way. However, in "Logo", students must analyze the form in order to construct a sequence of commands (a procedure) to draw a rectangle or any other form. Studies confirm that students' ideas about shapes are more mathematical and precise after using Logo. Lohman (48) emphasized that the precision use of Tetris may also lead the way towards achieving the same aim, as was indicated here.

Mainstreaming

The enhancement of the intelligence level and the level of operating the skills can help some pupils of the target population to be integrated into the mainstream. This conclusion is also supported by the fact that the recorded improvement in the mathematical skills, and a higher score in the intelligence tests, which were observed, can lead to higher achievements in reading and academic achievements in general and help pupils to proceed towards Mainstreaming.

5. CONCLUSIONS

Since manipulating Tetris does not need reading and mathematics as necessary entrance skills, it is obvious that hearing impaired and even mentally retarded pupils can manipulate Tetris, and be highly motivated to use its software. Significant improvement was observed in mastering the game and it affected the achievements in intelligence tests positively. Thus we hope that combining reading through self-creation of texts (18) with manipulating Tetris shapes will induce an improvement also in reading.

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