Virtual Reality as a Tool for Improving Spatial Rotation among Deaf and Hard-of-Hearing Children

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Abstract

The aim of this study was to investigate whether the practice of rotating Virtual Reality (VR) three-dimensional (3D) objects will enhance the spatial rotation thinking of deaf and hard-of-hearing children compared to the practice of rotating 2D objects. Two groups were involved in this study: an experimental group, which included 21 deaf and hard-of-hearing children, who played a VR 3D game, and a control group of 23 deaf and hard-of-hearing children, who played a similar two-dimensional (2D) game (not VR game).

The results clearly indicate that practicing with VR 3D spatial rotations significantly improved the children's performance of spatial rotation that in itself enhanced their ability to perform better in other intellectual skills as well as in their sign language skills.

Key words: Deaf, Hard of Hearing, Children, Virtual Reality, Rotation, Spatial Thinking.

Introduction

Researchers in the past debated the issue of the structure of the human intelligence--is it built as one entity or from many smaller parts? Gardner (1996), Sternberg (1996) and others claimed that intelligence is multi-dimensional, and a single ability cannot reflect the intelligence in its whole range. Nevertheless, our study zoomed on Spatial Intelligence, which Gardner (1996) defines as the ability to grasp the visual world, the ability to make modifications and changes into that world, to recreate, imagine and to operate parts of the visual world even without perceiving them, the ability to understand maps and diagrams, and the ability to appreciate visual esthetics. Some scholars (Emmorey, Kosslyn & Bellugi 1993; Talbot & Haude 1993) named these abilities Visual-Spatial Thinking.

Our research addressed a more precise element of visual-spatial thinking—spatial rotation, which 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 (Piaget 1971).

For example, if we rotate the letter N 90 degrees, what a new letter is created? A person first creates a visual image of the letter N in the imagination, rotates and "looks" at it in order to decide what the new identity of the image is. One examines the new abstract image as if it was real (Atkinson, Smith & Bem 1995). One of the important studies conducted in this area of mental-rotation was the study done by Shepard & Metzler (1971). They presented the subjects with pairs of 2D pictures that represent three-dimensional cubes—part of them were rotated from 0 to 180 degrees. The subjects had to rotate it in their imagination and to identify identical pairs. The results indicate that there is a correlation of 60 degrees per second between the average response time and the rotation angle. Over the years, studies have examined the spatial thinking among deaf and hard-of-hearing children too (Dwyer 1983; Emmorey, Kosslyn & Bellugi 1993; Talbot & Haude 1993). These studies examined the relationship between the knowledge and experience the subjects had in sign language and the skill they performed in the rotation tests.

Rotation is an activity used in sign language—the deliverer of the message marks his/her signs from his/her direction and the scene is therefore fully presented from their point of view. The receiver of the message, on the other hand, standing opposite him/her must make a mental "switch" so that s/he can imagine and understand it. A listener receiving an oral message does not face a similar problem regardless of his spatial position relative to the speaker (Emmorey, Kosslyn & Bellugi 1993).

Based on this, researchers assumed that deaf or hard-of-hearing that communicate using sign language, will do better in rotation tests than others. Talbot & Haude (1993), for example, tested three different groups based on their experience in sign language: a group of normal hearing subjects who do not use sign language, a group of normal hearing subjects that have some experience (x= 0.8 years) in sign language, and a combined group of hearing and non hearing subjects that have an average of 6.1 years of experience. They found that experience in sign language was related to success in the rotation tests. The more experienced the subjects are in sign language the higher the result achieved in the rotation tests. Parasnis, Samar, Bettger & Sathe (1996), Dwyer (1983) and others found similar results. Dwyer (1983) compared between 60 hearing children to 60 deaf children, all 6-10 years old. The researcher reports that deaf signers have a higher rate of success in rotation tasks. Parasnis, Samar, Bettger & Sathe (1996) compared 12 deaf children not exposed to sign language with 12 hearing children as a control group. They found that the groups did not differ in their performance on the visual-spatial-skill's tests. One can conclude, therefore, that the level of success in 3D rotations is a factor of the amount of experience in sign language but not of hearing loss.

Our study aimed at using VR to improve the rotation skills of deaf and hard-of-hearing children. Merickel (1994) conducted a similar study in an effort to study the relationship between spatial rotation and VR technology. Merickel, however, examined normal hearing children. He assumed that children's cognitive abilities could be enhanced by having them develop, displace, transform, and interact with 2D and 3D computer-generated models. He examined the cognitive factors related to the capabilities of 23 children aged 8-11 to solve spatial problems at computerized workstations or VR. The results confirmed that spatially related problem-solving abilities of children are influenced by training in visualization and mental manipulation of 2D figures and displacement (by rotation) and transformation (by mirroring) of mental images of 3D objects. That is to say, a correlation was found between the capability to perform spatial tasks in a VR environment and the cognitive skills of creation, operation and exploitation of mental imaging. Merickel thus concluded, that the technology known as virtual reality is highly promising and deserves extensive development as an instructional and training tool for cognitive skills.

One of the important objectives in educating deaf and hard-of-hearing children is to give them useful thinking tools for a leading better independent life.

Therefore, the hypothesis of this study was that the use of 3D VR technology would improve the mental rotation ability of deaf and hard of hearing children.

Subjects

Forty-four deaf and hard-of-hearing children aged 8-11 (average age 9.3) participated in this study. The hearing loss in the better ear of the children ranged from 50 dB to 120 dB with mean loss of 88.62 dB (see Table 1). They had no additional handicaps. The children came from integrated classes in two schools under the supervision of the Ministry of Education. In these schools the deaf and hard-of-hearing children are taught primarily in small segregated classes, but also participate in general-school-activities. In some cases, some of the classes are taken with normal hearing children of their age. After taking into consideration the children's background, the subjects were placed into one of two groups—the experimental group or control group. The two groups were matched for age, gender, degree of hearing loss, cause of deafness and similar prior-experience with computer work (see Table 1).

The sample comprised of the following 2 groups:

- 21 deaf and hard-of-hearing children who served as the experimental group.
- 23 deaf and hard-of-hearing children who served as the control group.

Table 1: Mean Grade Level, Hearing Loss Level and Gender

Group	N	Grade		Hearing loss (dB)		Gender	
		M	SD	M	SD	Boys	Girls
Experimental	21	3.00	.84	89.29	21.23	9	12
Control	23	3.60	1.35	87.95	18.30	12	11
Total	41					21	23

Procedure

Each participant in the experimental group played unguided with VR 3D Tetris game for about 15 minutes once a week over a period of three months. Children in the control group played with a regular non-virtual 2D Tetris game involving rotation for the same period of time.

The experimental and control groups were evaluated before and after the experiment using Kuhlman-Finch Aptitude Test (1957) with the addition of Feuerstein & Rand (1977) test. The test has two sub-tests—"dolls" (20 items) and "children" (15 items). Each assignment consists of a pattern of a doll or a child figure and four different dolls/figures near it. Just one of them is identical to the pattern except for the rotation. The subject has to choose the appropriate figure. This operation requires the ability to conserve the original pattern and compare it with the other figures in the same line. The possible scores are 30 for the "dolls" test and 40 for the "children" test. Instructions to the test were given orally in conjunction with sign language, to ensure that all children fully understood the requirements.

The VR hardware (Fig.1) used in this study was a Virtual Reality immersive game, with a unique system able to create a dramatic three-dimensional world. The VR program (Fig.2) included three similar games (Tetris, Puzzle, Center-Fill), with the objective, in all three, to fill a large 3D cube with small blocks of different shapes. The participant had to place dropping blocks into the right spaces. In order to accumulate a high score, the subject had to act both accurately and quickly. The optimal solution was reached by a combination of selecting the most appropriate shapes and rotating them as required. The Control Group practiced using a “routine” Tetris style 2D game (not VR game).

Figure 1. Virtual Boy-Nintendo 1995

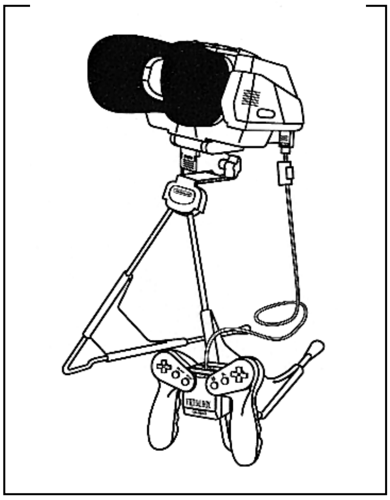
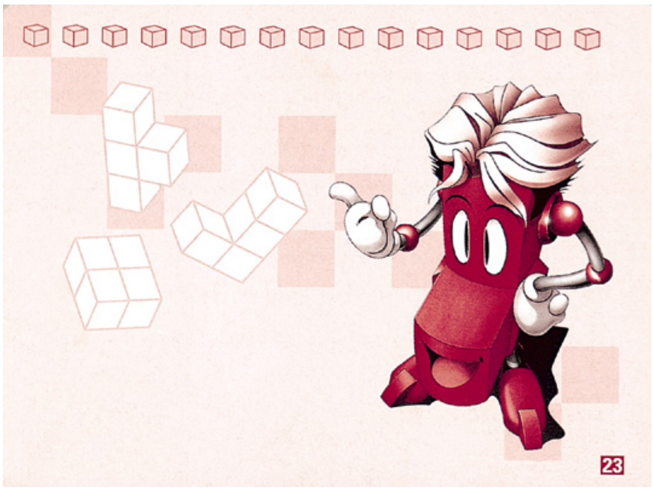


Figure 2. 3D Virtual Reality rotation



Results

We assumed that 3D VR would improve the mental rotation ability of deaf and hard-of-hearing children. In order to test this hypothesis, a repeated measure and analysis of variance was conducted for spatial rotation in a *before* and *after* paradigm.
Table 2-3 exhibits the scores for the two groups—the experimental group and the control group. In addition, the table exhibits the results of the analysis of the variance.

Table 2. Spatial Rotation by Group and Time (“Dolls” sub-test).

Time		experimental HI	control HI	F- scores	Contrasts significance
Before	M	28.62	26.48	F(2,57)=10.83 P<0.001	P(1,2)=n.s.
	SD	4.92	6.58		
	N	21	23		
After	M	32.05	27.70	F(2,57)=7.49 P<0.001	P(1,2)<0.05
	SD	5.34	6.77		
	N	21	23		

- HI= Hearing-Impaired.

Table 3. Spatial Rotation by Group and Time (“Children” sub-test).

Time		experimental HI	control HI	F- scores	Contrasts significance
Before	M	20.76	19.91	F(2,57)=4.99 P<0.05	P(1,2)=n.s.
	SD	5.27	3.74		
	N	21	23		
After	M	23.19	19.82	F(2,57)=6.81 P<0.001	P(1,2)<0.05
	SD	4.71	3.66		
	N	21	23		

- HI= Hearing-Impaired.

The results in Table 2 and 3 indicate that before practicing VR, no significant score difference was found between the two groups of deaf and hard-of-hearing children (experimental and control). After intervention, however, significant difference was found between the experimental and control groups of deaf children.

Discussion

One of the objectives in educating deaf and hard-of-hearing is to nurture their independent thinking. The question always asked is how can educators do so in a manner that will encourage and motivate the young children to be involved in an intervention program designed to improve their cognitive achievements.

This research focused on a specific field of thinking—spatial rotation thinking. The underlying assumption of the research was that this type of thinking could be improved by Virtual Reality technology. The assumption was based on various studies that found that the practice with VR lead to higher spatial thinking among hearing children (McClurg 1992; Merickel 1994; Simmons & Cope 1993).

Although researchers have found that different skills of the deaf improved following adequate training processes (Gruler & Richard 1990; Martin 1991), many of the current intervention programs do not exploit the vast possibilities available with today's leading edge technology. The uniqueness of this study is the use it makes of a virtual game as a method for improving spatial rotation with deaf and hard-of-hearing children. As such, this has become one of the first attempts to use VR technology to improve the cognitive skills of the deaf population.

The results of this study point out to a difference in spatial rotation ability after practicing VR. These findings show a clear priority for the VR 3D intervention over 2D “routine” one.

One may assume that these findings occurred due to the differences between the two types of exercises. While the children in both groups played the Tetris game for similar lengths of time, the only difference between them—the 3D virtual reality game vs. the 2D one—seems to have made all the difference.

A reasonable way to explain these results is through the essence of VR technology. VR technology creates a “pre-symbolic” communication in which the users can communicate with imaginary worlds with no use of words. This creates a world charged with sights, voices and feelings distinct from language and syntax (Passig 1996). The deaf and hard-of-hearing children who used this technology were able to bring out their potential with no language or auditory limitations. VR does not limit the designer in the manner in which the information is presented, or limit his movements so that the user of the technology is able to immerse within the learning environment (Pantelidis 1995). This is the method in which the deaf where immersed in the game. They felt as if they themselves where moving the pieces, searching for the right ones and rotating them. This is to say that the abstract became less vague and more concrete. Different studies in the field of VR found that this immersion upgrades the interface with the senses and improves the understanding of abstract terms by converting them into more concrete ones (Darrow 1995; Osberg 1995).

Another reason to explain the results of this study rely on the key attribute of VR—its interactivity—it allows the users to take a very active role. The increased liveliness and interactivity allows the user to become part of a virtual world. This feature is able to present information in 3D form and in real-time. It is an elaboration of a reality in which a person can hear, look, touch and bond with objects and images. This method allows the user to take an active role in the environment and not remain a passive bystander (Bricken & Byrne 1992; Heim 1992; Osberg 1995, Powers & Darrow 1994). Since deaf and hard-of-hearing children require a more active involvement in learning processes than normal hearing children do (Marzam 1998), it is obvious that VR is a natural tool to enhance their thinking skills.

A different explanation of these results can rely on the fact that VR is just a fun and motivating tool. Various studies have pointed out that children using VR enjoy using it and want to learn more by using it (Bricken & Byrne 1992; Talkmitt 1996). It seems that the high levels of motivation of the participants resulted in their persistence with the program and their eventual success.

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