

Cognitive intervention through virtual environments among deaf and hard-of-hearing children

D Passig and S Eden

Bar-Ilan University, Israel

passig@mail.biu.ac.il, ueden@trendline.co.il

<http://faculty.biu.ac.il/~passig>

ABSTRACT

The deficiencies of the auditory sense in the hearing-impaired raises the question as to the extent to which this deficiency affects their cognitive and intellectual skills. Researchers have found, that in regard with reasoning, particularly when the process of induction is required, hearing-impaired children usually have difficulties (Hilleyeist & Epstein, 1991). Another cognitive process, which hearing-impaired children have difficulties in, is the ability to think in a flexible way. Studies have proven that hearing-impaired children tend to be more concrete and rigid in their thought processes. They usually choose one familiar means of solving problems and use it to deal with most of the problems that they encounter (King & Quigley, 1985; Laughton, 1988; Saraev & Koslov, 1993).

In recent years, one can identify a trend for active intervention in the cognitive capabilities of deaf children in a growing effort to improve their intellectual functioning (Gruler & Richard, 1990; Huberty & Koller, 1984; Martin, 1991). The uniqueness of this study is the use it makes of Virtual Reality, as a tool for improving structural inductive processes and the flexible thinking with hearing-impaired children. The results clearly indicate that practicing with VR 3D spatial rotations significantly improved inductive thinking and flexible thinking.

1. INTRODUCTION

Intelligent performance has two main expressions: a) thinking, which means making different activities over memory knowledge, and b) learning, which is the extension of this knowledge (Tzelgov & Nevo, 1996). "Thinking", as a concept, has many definitions and models. One of them defines thinking as a mental undermining process, which is directed to forming data system according to conscious goal, and right or wrong criterion (Glanz, 1989). "Thinking" is a broad field, and include many processes. This study dealt with *inductive processes* among hearing-impaired children. Trochim (1996) defined the inductive method as "bottom up"—i.e., a process which goes through the stages of making specific observations, creating testable hypotheses that lead to generalization and create generalized conclusions. Glanz (1989) reports on "induction of laws"—a process in which induces leads to the inference of common rules that dictate the order of components within a given system. It is possible to identify the rule by formulating it verbally by adding components to the system continuously or both—formulating and adding components.

Researchers (Hilleyeist & Epstein, 1991) have found that reaching a reasoned conclusion is a process in which hearing-impaired children have some difficulties. Although it may seem that hearing-impaired people are similar to normal hearing people in the structure of their thoughts and in their cognitive capabilities, auditory and language deficiencies may lead to lower verbal functioning and an overall lack of appropriate experience. The consequences, it is suggested, can be lower results in Conclusive Thinking and in reaching reasoned conclusions using inductive processing (Friedman, 1985; Hilleyeist & Epstein, 1991).

The goal of this study was to examine the influence of an intervention program, practicing spatial rotation in a Virtual Environment (VE), on the structure-inductive thinking among hearing-impaired children.

Another aspect, which the study focused on, was *Flexible Thinking*. Sternberg & Powell (1983) define flexible thinking as the ability to look at things from different angles. They point out that during adolescence the ability of the child to think flexibly is more prominent. This flexibility is expressed in two opposite directions. On the one hand, children exhibit better ability to think consistently and adhere to methods that proved effective in solving problems. On the other hand, when necessary, they are capable of changing their

work methods and exchanging them for more successful methods. Flexible thinking is one of the most important characteristics of intelligent behavior.

Guilford (1967, 1970) claims that flexible thinking is the ability to create a flow of ideas while changing direction or correcting information. In his opinion, there are two types of flexibility

1. spontaneous flexibility—spontaneous change in the thinking process and the transition to another, and
2. adaptive flexibility—the ability to adapt to changing instructions. The component of flexibility appears to Guilford to be related to the ability to generalize and abstract.

Researchers studied the ability of hearing-impaired children to think flexibly both verbally and in terms of shapes. This study relates solely to non-verbal ability. Saraev & Koslov (1993) examined 100 deaf children and 164 hearing children between the ages of 7–12. One of their findings shows lesser ability in creative imagination among the deaf, and rigidity in their way of thinking. Also, King & Quigley (1985) claim that hearing children surpass deaf and hard-of-hearing children in creative ability. Laughton (1988) compared the traditional approach of teaching art to teaching programs geared to developing creative ability. He studied 28 deaf children between the ages of 8-10, who took part in one of the two programs for twelve weeks. The children were tested in the Torrance formal test before and after the intervention. It was found that there was a significant improvement in flexibility and originality among the children who studied according to the new program. Laughton (1988) also claims that by means of the appropriate teaching strategy it is possible to develop creative aptitudes with deaf children and to help them to become less concrete and rigid in their thinking.

In recent years, however, there have been growing efforts for intervening in the cognitive capabilities of the deaf children to improve their intellectual functioning. This trend is backed by the new assumption that deaf children have the same intellectual potential as normal hearing children. Researchers believe that they may fulfill this potential if the environment, the instructions and the available materials are adequate and motivate learning. Moreover, some researchers tend to emphasize the importance of intervention programs as a mean to improve the cognitive achievement of hearing-impaired children (Gruher & Richard, 1990; Huberty & Koller, 1984; Martin, 1991). The goal of such cognitive intervention programs is to assist the deaf child and promote certain thinking capabilities. Some of the intervention programs are using technology. Researchers report on the correlation between computerized activity and enhancing cognitive skills. They believe the computer has a hidden potential that can enhance the intellectual skill of the learner, develop self study strategies, enhance the ability to solve problems and develop thinking skills at all ages (Samaras, 1996). One can perceive the computer as a tool, which provides thinking and learning strategies. For example, Volterra, Pace, Pennacchi & Corazza (1995) examined the interaction of hearing-impaired children (aged 6-16) with the computer. They found that if deaf children were given learning context that allowed information with or without language through visual modeling, the children's motivation for learning would increase.

The purpose of this study was to examine whether it is possible to improve the induction process and the flexibility of thinking in hearing-impaired children with the help of a leading edge technology – *Virtual Reality (VR)*.

Pantelidis (1995) defines Virtual Reality as an interactive multimedia environment, based on the computer, in which the user is assimilated into, and becomes an active participant in the virtual world. This technology can present information in a three-dimensional format in real time so that the user becomes an active participant in the environment that communicates interactively without the use of words. Virtual Reality makes it possible to convert abstract symbols to more concrete ones by providing a perspective on processes which is not possible in the real world (Darrow, 1995; Durlach & Mavor, 1995; Osberg, 1995; Pantelidis, 1995).

This study is unique since, as far as we are aware of, it is the first attempts to join the need of a cognitive intervention program for hearing-impaired children with Virtual Environment.

2. SUBJECTS

The participants in this study were 44 hearing-impaired children aged 8-11. 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. In these schools the hearing-impaired 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 data, the subjects were placed into one of two groups—the

experimental group and the control group. The two groups were matched for age, gender, degree of hearing loss, cause of deafness and equivalent prior experience with computer (see table 1).

An additional group of 16 normal hearing children were selected in order to establish whether in general, hearing-impaired children achieve lower results than normal hearing children in inductive skills. The ages of the hearing children ranged between 8-10 (average age 8:8).

The sample of 60 children, therefore, comprised the following 3 groups:

- 21 hearing-impaired children who served as the experimental group.
- 23 hearing-impaired children who served as the control group.
- 16 hearing children who served as a second 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 1 | 23 | 3.60 | 1.35 | 87.95 | 18.30 | 12 | 11 |
| Control 2 | 16 | 3.83 | .83 | ---- | ---- | 8 | 8 |
| Total | 60 | 3.42 | | 88.62 | | 29 | 31 |

3. PROCEDURE

Each subject in the experimental group was given 15 minutes once a week over a period of three months to play unguided a VR 3D Tetris game, involving the rotation of objects in space. Children in the hearing-impaired control group played with a regular non-virtual 2D Tetris game involving rotation for the same period of time. The subjects of the normal hearing control group were given no rotation tasks.

The experimental and control groups were evaluated before and after the experiment using two tests: Cattell and Cattell's (1965) sub-test of "Structural Sequences", and Torrance (1966) sub-test "Circles". This was done in order to establish whether practicing rotation exercises with VR has an effect on the structural inductive processing and on the flexible thinking of the subjects. Cattell and Cattell's (1965) sub-test of "Structural Sequences" has twelve items, each contains a series of three shapes that differ from each other according to a discernable pattern. The subject has to infer the pattern by induction and choose the missing fourth shape out of five possible choices. For each correct answer the subject receives 1 point. The range of possible scores is from 0 to 12. Cattell and Cattell (1965) report a reliability score of over 0.80 with groups of students. Torrance (1966) sub-test "Circles" was used in order to study whether practice in the rotation of three dimensional objects, which requires the ability to view objects from different angles, will have an impact on the flexibility of thinking with the subjects. The test includes verbal and non-verbal tasks. We used the non-verbal tasks owing to the verbal insufficiency of the subjects. The test includes 36 identical circles. The subject has to produce as many associations as s/he can to each stimulation. The subject accumulates points only if the circle is an integral part from the painting. The number of the different categories is equal to the amount of points that the subject receives. This test has been carried out many times over the years and has received the high score of 90 in reliability (Torrance, 1966).

Instructions to the tests were given orally in conjunction with sign language, to ensure that all children fully understood the requirements. The normal hearing subjects took the test once only.

4. VIRTUAL ENVIRONMENT

The VR hardware (fig.1) used in this research was a virtual reality interactive game, with software that is able to create a three-dimensional environment. The software (fig 2) included three games (Tetris, Puzzle and Center-Fill), in all of which the objective was to carry out certain demands via control over three-dimensional blocks. The subject had to fill a three dimensional block with various shapes made up of smaller blocks. The subject had to put the dropping blocks in the right place, and accordingly, accumulate points. In order to accumulate more points, the user had to act accurately and rapidly. The optimal solution was reached by a combination of selecting the most appropriate shapes and rotating them as required. The subject had to complete the blank locations on the "board" according to an induced rule which s/he had inferred, and fit the appropriate shape in the blank locations. Similarly, the control group # I practiced a similar routine using a Tetris style 2D game (not VR game).



Figure 1. *Virtual Boy- Nintendo.*

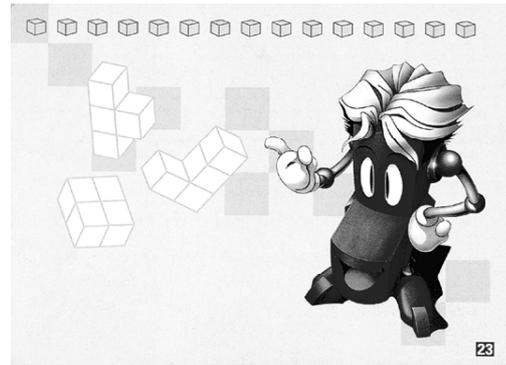


Figure 2. *Three-Dimension Rotation.*

5. RESULTS

The primary assumption of this study was that before practicing with spatial rotations, a distinct difference would be found between hearing impaired children and normal hearing children in their inductive thinking of spatial structure. After practicing in the VR mode, it was expected that the experimental group would improve to the point where no distinct difference would exist between them and the group of normal hearing children. That is to say, the scores of the hearing-impaired children in the experimental group will be similar to the grades of the normal hearing children. In order to test this hypothesis, a one-way analysis of variance was conducted for the Index of Structural Induction (ISI) in a before and after paradigm.

Table 2 exhibits the ISI scores for the three groups—the experimental group, the control group of the hearing-impaired, and finally, the control group of the normal hearing. In addition, table 2 exhibits the results of the variance’s analysis. Figure 3 presents graphically the results before the intervention, and Figure 4 presents the results after the intervention.

Table 2: *ISI by Group and Time.*

| Time | | (1) experimental HI | (2) control HI | (3) control hearing* | F- scores | Contrasts significance |
|---------------|----|------------------------|-------------------|-------------------------|---------------------------|---|
| Before | M | 5.23 | 5.13 | 10.93 | F(2,57)=62.48 P<0.001 | P(1,2)=n.s. P(1,3)<0.001 P(2,3)<0.001 |
| | SD | 2.04 | 2.00 | 0.57 | | |
| | N | 21 | 23 | 16 | | |
| After | M | 11.00 | 5.65 | 10.93 | F(2,57)=102.04 P<0.001 | P(1,2)<0.001 P(1,3)=n.s. P(2,3)<0.001 |
| | SD | 0.77 | 2.08 | 0.57 | | |
| | T | -16.1 | -2.02 | ----- | | |
| | N | 21 | 23 | 16 | | |

HI= Hearing-Impaired.

The normal control-hearing group was tested only once. The results were entered for comparison with the “before” and “after” experimental results.

In observing the data in table 2 and figures 3 & 4, we can see that before practicing VR, no significant difference was found between the two groups of hearing impaired children (experimental and control). However, a significant difference in ISI was found between the hearing children and both the experimental and control groups of hearing impaired children. After intervention, however, there was no difference between the experimental group and the hearing children. Significant differences were found in structural inductive thinking between the two control groups (deaf and hearing) and between the experimental group and the two control groups (see table 2). After the intervention, the scores achieved by the experimental group of hearing-impaired children reached the same level as those of normally hearing children while the scores of the hearing-impaired control group remained low.

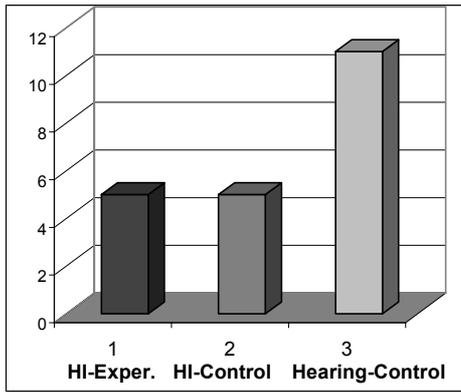


Figure 3. ISI averages before intervention.

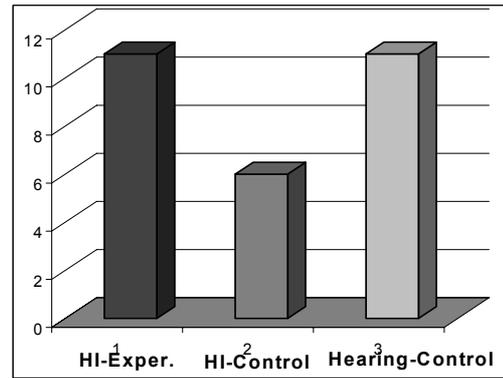


Figure 4. ISI averages after intervention.

The second hypothesis of this study was that a clear difference would be found between the experimental group of hearing-impaired children and the control group of hearing children in their ability to think flexibly before practicing spatial rotation, by means of the VR game. After the practice, in contrast, the ability to think flexibly improved in the experimental group to such an extent that no clear difference was found between this group and the control group of hearing children. That is to say, the scores of the deaf and hard of hearing children in the experimental group were similar to those of the hearing children in this examination. In order to verify this, we conducted a one-way analysis of variance.

Table 3 presents the averages in the measurement of the Index of Flexible Thinking (IFT) in the three research groups.

Table 3: IFT by groups and by time

| Time | | HI experimental | HI control | Hearing control* | Model P,F | Group P |
|--------|---------|-----------------|------------|------------------|---------------------------|--|
| Before | Average | 7.05 | 5.91 | 23.00 | F(2,57)=177.92 P<0.001 | P(1,2)=n.s. P(1,3)<0.001 P(2,3)<0.001 |
| | SD | 2.85 | 3.50 | 2.37 | | |
| | N | 21 | 23 | 16 | | |
| After | Average | 18.10 | 5.96 | 23.00 | F(2,57)=102.04 P<0.001 | P(1,2)<0.001 P(1,3)<0.001 P(2,3)<0.001 |
| | SD | 5.76 | 3.47 | 2.37 | | |
| | N | 21 | 23 | 16 | | |

HI= Hearing-Impaired.

Comment: the control group of hearing children took the tests once only; that is to say, the data in the table was copied from “before” to “after”.

Figure 5 presents the average scores in IFT of the three research groups – experimental, control hearing impaired and control hearing, before intervention. Figure 6 presents the average scores in IFT after intervention.

A look at table 3 and figures 5 and 6 indicate that prior to the practice there was a considerable gap in flexibility of thinking between the research group of hearing-impaired children (both experimental and control groups) and the control group of hearing children. The difference favored the hearing children. No considerable difference was found between both research groups of hearing-impaired children (experimental and control groups). In contrast, after the practice, a clear difference was found between the experimental hearing-impaired group and the hearing-impaired control group in their ability to think flexibly, favoring the experimental group. A smaller but clear difference was found between the experimental group and the control group of hearing children; that is to say, the children in the experimental group improved their achievements significantly but did not reach the level of the hearing children in this index.

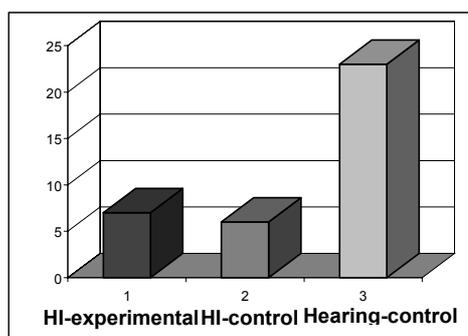


Figure 5. *IFT averages before intervention.*

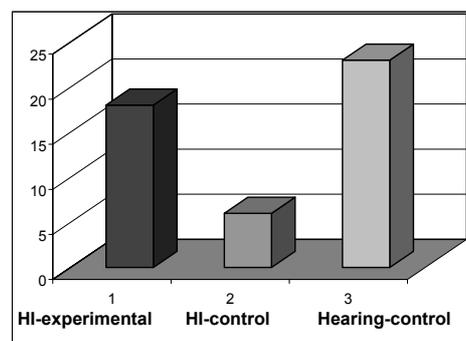


Figure 6. *IFT averages after the intervention.*

6. DISCUSSION

One of the objectives when educating hearing-impaired children is to stress with them the importance of nurturing independent thinking. One question to be 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.

Researchers have found that the functioning of the deaf improved following adequate learning, practicing and training (Gruler & Richard, 1990, Martin, 1991). Many of the current intervention programs do not exploit the vast possibilities available with today's technology, especially the innovative and attractive technology of VR. The uniqueness of this project is the use it makes of a virtual game that provides practice with spatial rotation, as a method for improving structural inductive processes and flexible of thinking with hearing-impaired children. As such, this has become one of the first attempts to use VR technology to improve the cognitive skills of deaf population.

The current research focused on two main fields- structural induction (ISI) and flexible thinking (IFT). The results of this study point to a distinct difference in structural induction's ability between hearing-impaired and normal hearing children before practicing, with the gap in favor of the normal hearing subjects. This finding reflects other studies that have similarly found that deaf and hard-of-hearing children have difficulties in the inductive processes and need assistance in this skill (Friedman, 1985; Hilleyeist & Epstein, 1991). The improvement of the structural inductive skills of the experimental group while exploiting a VR 3D game was such that no distinct difference remained between them and the normal hearing control group after the intervention. The hearing-impaired control group, however, who had no VR training, still maintained low scores. The gap between them and the normal hearing group remained the same even after the 2D practice.

The second research assumption was that hearing-impaired children tend to be rigid in their way of thinking, as compared to hearing children. This study found a clear difference in the ability to think flexibly between hearing-impaired children and hearing children before practicing, to the advantage of the hearing children. This finding is reinforced in previous studies which found that deaf and hard-of-hearing children possess lesser ability in creative imagination and have a tendency to rigidity in their thinking (Saraev & Koslov, 1993). After practice, the children in the experimental group improved in their ability to think flexibly with the help of the VR, and the gap between them and the hearing children narrowed. In contrast, the control group of hearing-impaired children continued to score poorly and the gap between them and the hearing children did not narrow. We can assume with caution that further practices might improve the results of the experimental group to the point where no noticeable difference will be between them and the group of the hearing children. This finding echoes that of Bunch (1987) who claimed that if hearing-impaired children are afforded opportunities to develop their potential and the teachers are provided with methods of encouraging creative thinking – deaf children will progress and will reach the level of hearing children.

These findings show a clear priority for the VR 3D intervention over a 2D "routine" one (not VR). We 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 hearing-impaired 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 limits his movements so the user of the technology is able to immerse within the learning environment (Pantelidis, 1995). This is how the deaf children were immersed in the game. They felt as if they themselves were moving the pieces, searching for the right ones, using inductive procedures and rotating them. This is to say that the abstract became less vague and more concrete. Different researches 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).

One key attribute of VR is 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 tool 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 stay a passive bystander (Bricken & Byrne, 1992; Heim, 1992; Osberg, 1995; Powers & Darrow, 1994). Indeed, hearing-impaired children require a more active involvement in learning processes than normal hearing children do (Marzam, 1998).

Another way to explain the results is in terms of transfer strategies or tendencies from one field to another in order to explain a certain problem or phenomenon (Tishman & Perkins, 1996). The results of this study point that a transfer occurs from a rotation activity to a structural induction activity and to a flexible thinking activity. It seems possible to link rotation and induction or flexible thinking via mental imaging—rotation, induction skills and the ability to think flexibly requires the use of imaging (Piaget, 1971; Millar, 1989; Daniels, 1984). It is possible that due to this link between the variables a positive transfer occurred.

A different explanation of these results is simply that this tool is a fun and motivating one. 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 subjects resulted in their persistence with the program and their eventual success.

7. SUMMARY

In conclusion, the results indicate that the achievements of the hearing-impaired in the structural inductive processes and flexible-thinking ability, using a virtual environment, has improved. Beyond this contribution, which is important in itself, the biggest contribution of this research was the enhancement of the structural induction skill to the point where hearing-impaired children reached the levels of normal hearing ones. Another important contribution is the advancement of the ability to think in a flexible way to the point where hearing-impaired children almost reached the level of hearing children. It appears beneficial to do further work in this area.

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