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The Application of a Sensory Integration Treatment Based on Virtual Reality-Tangible Interaction for Children with Autistic Spectrum Disorder

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ABSTRACT

Children with autistic spectrum disorders have difficulties integrating motor and sensory experiences. It is important to address therapeutic interventions for these children. However, there are some limitations of the sensory integration therapy and the application of virtual reality for autistic children. SIT based on VR-TIS (VR-SIT) has three components: measurement of coordination ability, social skills training, sensory integration therapy. These components all originated from sensory integration therapy. A total of 12 autistic children and 20 healthy controls, all aged between five and six years, participated in this study. There are significant differences in autistic children and healthy controls for coordination ability measurement and social skill training. We found that it is possible to apply our system to the assessment of, and the therapy for, autistic children.

Keywords: *Autism, Virtual reality, Sensory integration, Virtual reality tangible interaction.*

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1. Introduction

Children with autistic spectrum disorders have difficulties integrating motor and sensory experiences (Baranek, 2002). These abnormalities of sensory processing affect all aspects of adaptive, cognitive, social, and academic functioning, and correlate with higher levels of stereotypic, rigid, and repetitive behaviors in autism (Baranek, Foster, & Berkson, 1997a ; Reynolds, Newsom, & Lovaas, 1974). It may therefore be important to address in therapeutic interventions for children with autistic spectrum disorders (Piek & Murray, 2004).

Sensory integration therapy (SIT) is based on a theory developed by Ayres, which emphasizes the relationship between sensory experiences, and motor and behavioral performance (Ayres, 1972). SIT is intended to focus directly on the neurological processing of sensory information as a foundation for learning of higher-level (motor or academic) skills (Baranek, 2002). There are some advantages of SIT. It is possible that unstructured therapy using role-play situations can provide social skills training by practicing intimacy with friends. However, most sensory integration therapies involve a therapist treating a child. In such instances the limitations of sensory integration therapy for autistic children are the length and cost of treatment. In addition, there are limitations on the number and variety of place that can be used for children in therapy to experience. So the therapy may become repetitive. Moreover SIT could be perceived be subjective and individual conclusion about evaluation of treatment's outcome.

Several studies have reported the clinical use of virtual reality (VR) technology for autistic children. Children with autism performed as well as controls on a computerized version of the WCST, but significantly worse than controls on the standard, non-computerized version. Pascualvaca and colleagues (Pascualvaca, Fantie, Papageorgiou, & Mirsky 1998) suggested that social/motivational factors could be responsible for the effect that is children with autism might prefer to receive feedback about their performance from a computer rather than from an examiner. Virtual environments for social skills training would best be used in collaboration with other people (Murray, 1997). Virtual reality technology is an exciting tool for allowing children with autism to practice behaviors in role-play situations, while providing a safe environment for rule learning and repetition of tasks (Pascualvaca et al.,1998).

However, some ethical and technical concerns surround the use of fully immersive virtual reality technology. For example the use of head-mounted displays (HMDs) can elicit ‘cyber sickness’ in some people (Cobb, Nichols, Ramsey, & Wilson, 1999).

Moreover, because HMDs place some limitations on the child's interaction with another person, the mixed and augmented reality is more useful for group interactions and sensory experiences.

The known limitations of pre-existing therapeutic intervention methods for autistic children may be reduced by sensory integration therapy based on the virtual reality – tangible interaction system (VR-TIS). VR-TIS is a system that connects the human body, the physical environment and a computer. It measures human behaviors accurately and makes sense of their behavior through visual feedback (Hornecker, 2004). Therefore this high-tech equipment can be useful for the detection and measurement of human responses, especially sensory integration. In addition tangible features are designed to make artificial barrier less apparent and more intuitive by mixing the synthetic virtual environment with the natural physical environment (Ko, Park, & Lee, 2002).

The purpose of this study was to develop a program of sensory integration therapy based on VR-TIS for the assessment and treatment of autistic children. We also aimed to verify that the program is an efficacious assessment and treatment for autistic children.

2. Methods

2.1 Participants

A total of 12 autistic children and 20 healthy controls, all aged between five and six years, participated in this study. All children in the autism group met the DSM-IV criteria for autism and were recruited from the outpatient unit at the Children's Hospital in Seoul. Unrelated healthy children were recruited from the kindergarten belonging to C University in Seoul, Korea.

The mean IQ of the 12 autistic children (two girls, ten boys) was 64. The mean social maturity scale (SMS) index was 73, and all were six years old. Of the 12 autistic children, one dropped out of the study. He would not enter the room in which was carried out treatment program after second session.

Healthy controls were recruited via questionnaire. For the teacher questionnaire, revised and interpreted IOWA (Iowa Social Competence Scales: Preschool form) teachers questions were used. The test for children was performed simply, using the symbol test from the intelligence quotient test (WISC). Children who were regarded as having normal social ability in both tests were recruited as healthy controls.

2.2 Instruments

SIT, based on VR-TIS (VR-SIT), has three components: coordination ability measurement; social skill training; and sensory integration therapy. Coordination ability, social skill, and sensory integration, which are fundamental to each component, are the deficient ability of autistic children. Therefore, application of our program attempted to measure each child's ability. These components are all derived from sensory integration therapy.

Our VR–TIS consisted of a Pentium IV PC, a projector, a screen (200 × 150 cm), an infrared reflector, a digital camera, and tangible devices (e.g., a stick, rotation board, trampoline). Participants can see the result of their actions on the screen as they perform the tasks.

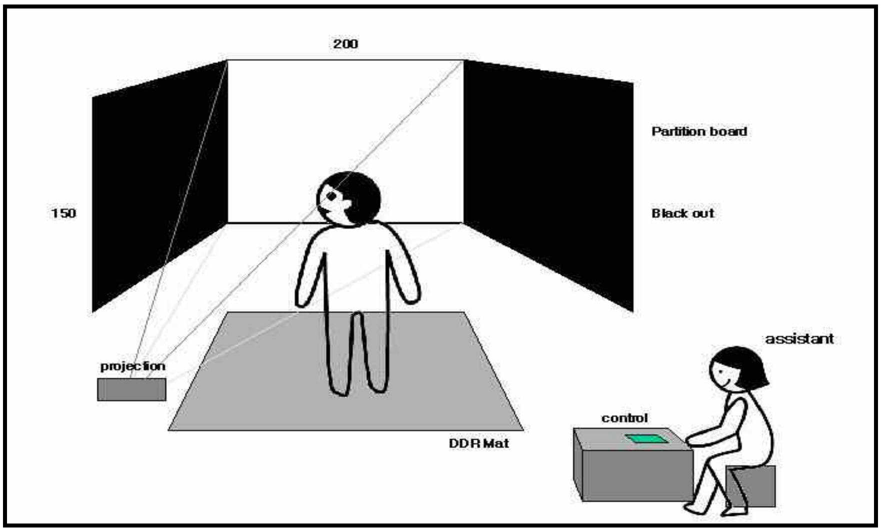

Figure 1: An example of the system construction

1) Visuomotor Coordination Ability Assessment

The Visuomotor Coordination Ability Assessment is a measuring program for visuomotor coordination ability, which does not require whole scenario, and only measures a specific phase. Levels can be controlled by the therapist. The program involves breaking virtual balloons with a real stick, and reinforcements are provided for success. And the number of balloons, the type of reinforcement became different by level. Reinforcement types were selected based on the therapist's experiences and outcomes of parent survey. These were then classified into auditory and visual substances (Dawson & Watling, 2000): participants received one of eight visual and ten auditory reinforcements as a reward for breaking each balloon. Participants completed 10 sessions.

	Visual reinforcements	Auditory reinforcements
1	Falling, like powder	Laughing
2	Falling, like water drop	Crying
3	Disappearing, like shining star	Angry or irritating sound
4	Exploding, like fireworks	Horror sound
5	Light rotation	Buzzing
6	Balloon changes into father's face	Chatting
7	Balloon changes into mother's face	Firing laser beam
8	Balloon changes into baby's face	Aircraft flying
9		Firecracker explosion
10		Water dropping

Table 1: Type of reinforcements

2) Social Skills Training

Social skills training contents were designed to minimize sound effect and background to allow conversation between participants and the therapist, and to allow the participants to concentrate on the graphic factors. It was designed to look like a game, and each of the five phases could be progressed through gradually. And Participants completed 10 sessions.

3) Sensory Integration Therapy

To measure the functions of sensory integration treatment effectively, images were developed from various rides in an amusement park. It was expected that exposing the client to such a range of vivid stimuli, which would be impractical or unsafe in the real world, would be beneficial. Conditions such as swaying from side to side, and backward and forward, stairs, screen rotation, user rotary motion (such as turning four sides or turning the screen), running, and trampoline, were used.

Step	Title	Contents
1	Spot-eyes-face looking training	To see light of the screen without interaction. If it is boring, one can skip it easily.
2	Real face and graphic expression selection training	Matching the expression on a graphic face to the expression on a real face.
3	Increasing the facial expression training	This is an interaction that can be controlled by a stick. The child selects a face from a number of facial expressions. If it is the face that the therapist wanted, the rewarding balloon is big and sound effect is big (such as smiling sound), and the balloon follows the child (Robert, & Helen,2004).
4	Looking the spot without sight	In the middle of the screen, a face is shown and the eyes are moving with a little spot. The eyes move to each of the four sides for three minutes.
5	Pointing the sight	There are four foods in each of four corners, and the question 'what does the child want?" is shown. If he/she gives the answer, there is a reward of the food being eaten on the screen (Robert, & Helen,2004).

Table 2: Composition of social skill training contents.

The intensity of each condition can be controlled. Among the 10 sessions, this program was progressed by 4 to 8, except 1 to 3 and 9 to 10.

2.3 Procedure

Demographic data were collected before the test was begun, by examining the records of the children and their degree of adaptation to the therapist. We also tested the children's sociability (SMS) and sensory integration and researched their preferred visual and auditory reinforcements. We then tested the sensory integration training, social skill training, and visuomotor coordination ability in 10 sessions. Although we had planned to test sociability and sensory integration again, we decided that administering the test after 10 treatment sessions would be affected by the repetition of the tests. It was also difficult to test the children because of their treatments in other fields. After the 10 times of the test, we discussed the usefulness of our system with the therapist and assistants.

2.4 Data analysis

We measured the reaction time of children in the tasks of stopping the balloon, moving the balloon, and reading the mind, to find the changes in reaction time and the adaptation of children to each task. We also measured the accuracy, the distance the stick was moved, and mean reaction time of coordination ability, to find the adaptation and improvement in the adaptation ability exercise in each session. Data were analyzed by a repeated-measure Analysis of Variance (ANOVA).

3. Results

3.1 Visuomotor Coordination Ability Assessment

We tested the Visuomotor Coordination Ability measurements of reaction accuracy, movement of the stick, and average reaction time by repeated measure ANOVA analysis. As repetition increased, the accuracy of the reaction increased, and the movement of the stick decreased. However, the mean reaction time changed greatly (a = 0.031, R^2 = 0.011). Measuring a variable of mean reaction time had no effect ($F(1,3)$ = 0.038, p = n.s.) the slope of the movement of the stick was high (a = -1.792, R^2 = 0.5961), however, there was no meaningful result because of higher varied amount for each session and children. This was same result as the report of the therapist that the children's interest was decreased by the repetition.

1) Movement of the Stick

Movement of the stick was efficient in later sessions. Although the movement was not great, accuracy improves and more space was used as the sessions progressed. Namely, there was difference of the sight.

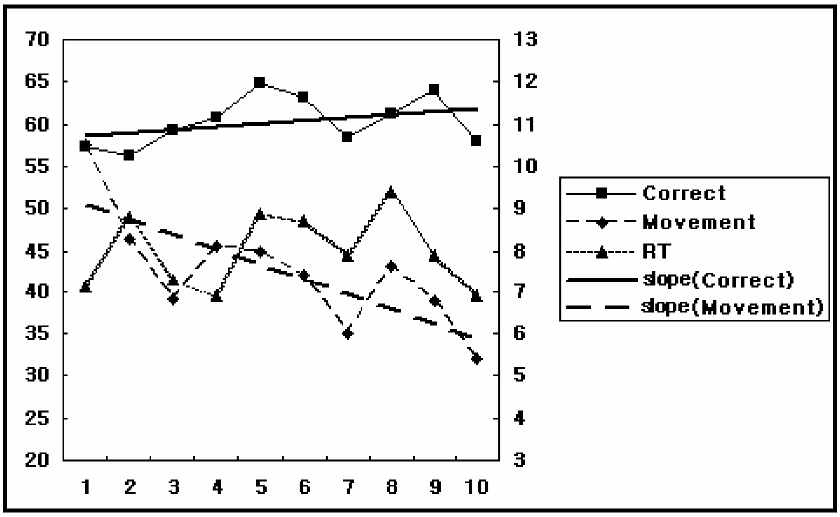

Figure 2: Variation of reaction accuracy, stick movement, and reaction time for coordination ability measurement program.

2) Comparison of the Visual and Auditory Reinforcements

Reaction accuracy was highest when reinforcement was a firecracker explosion sound with water dropping at the same time (60.2%), and then mother's smiling sound (59.7%). As we expected, the lowest accuracy was when reinforcement was the smiling sound with the laser sound of the star, which children with social disability abhor (53.3%, 51.9%).

3) Comparison to Healthy Control Children

Autistic children became more accurate due to their practice. However, there was no significant difference between autistic and healthy control children because the variance of the autistic children was so dramatic (t = 1.803, p = n.s.). Healthy control children showed more movement of the stick (t = 4.962, p < .01) But, it was better for the movement of the stick (t = 4.962, p < .01) and faster reaction times (t = 3.931, p < .01), indicating that they performed more efficiently than the autistic children.

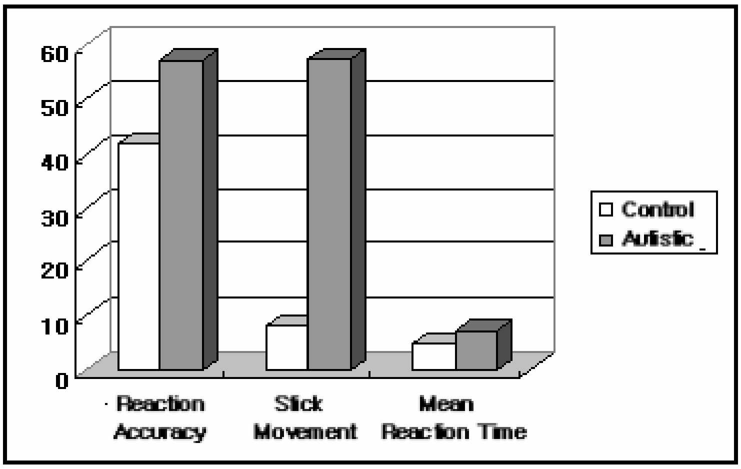

Figure 3: Comparison between groups for coordination ability

The following formula was used for principal component analysis of coordination abilities.

CA index = 0.797 X reaction accuracy – 0.799 X movement of stick
– 0.687 X mean reaction time

This formula was adapted to healthy control and autistic children. There was a significant difference between the autistic and healthy control children ($p < .01$), which implies that the autistic children had performed the tasks inefficiently.

3.2 Social Skills Training

We tested the reaction time of each child to the social skills training such as the stopping balloon, moving the balloon, and reading the mind. Repeated measure ANOVA for the 10 sessions was used.

As the number of sessions increased, the mean reaction time gradually decreased, but the variance was very high. Reading the mind (F (1,2) = 0.663, p = n.s.) and moving the balloon (F (2,3) = 10.401, p = 0.08) did not show any significant results: however on the stopping the balloon task, the reaction time (F (1,2) = 21.339, $p < .05$) and slope (a = -0.403, R^2 = 0.335) decreased as the sessions progressed.

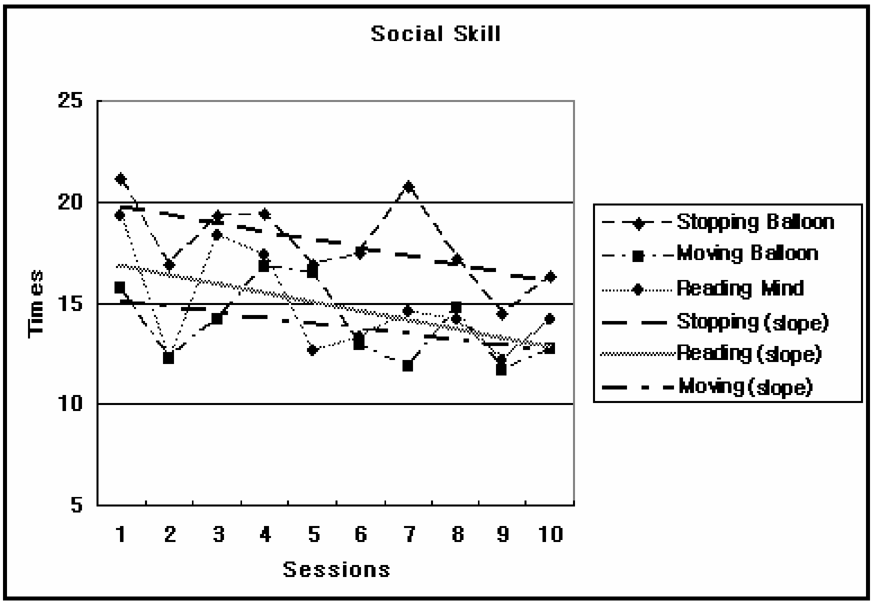

Figure 4: Variation of reaction time for the social skills training program.

1) Comparison to Healthy Control Children

We compared the autistic children with normal kindergarten children. It was difficult compare directly, because autistic children had practiced and adapted the system. However, it can be used to compare the difference of the two.

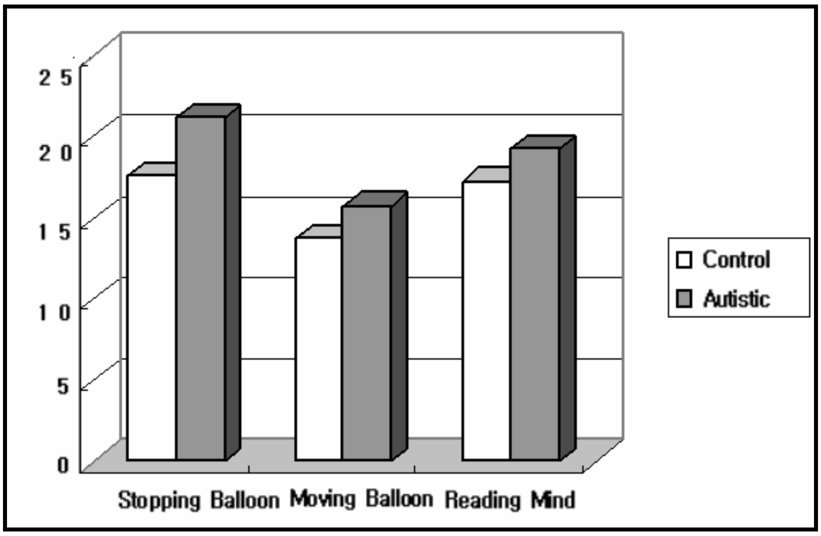

Figure 5: Comparison between groups for social skill program.

	Autistic	Control	t	P
Stopping Balloon	21.1±10.9	17.6±3.1	1.034	n.s.
Moving Balloon	15.8±5.1	13.8±3.1	1.105	n.s.
Reading Mind	19.3±9.7	17.3±4.8	0.601	n.s.

Table 3: Comparison between groups for social skill program.

As Table 3 shows, there was no significant difference between autistic children and healthy control children because autistic children had had practice time, but autistic children showed longer response times and higher standard deviations in each task.

3.3 Sensory Integration Therapy

Fewer sessions (3 to 8) and the limitation of the stimuli used for sensory integration training (primarily focused on vestibular organs) made the effects of SIT difficult to measure, which used the same measurement of sensory profile. Moreover, there are no variables that can be measured in research differ from the social skills training and coordination ability measurement. It is possible that to judge the effect of the sensory integration therapy, the overall impression of the effect of the sensory integration test immediately after those of sociability and coordination ability, and indirect observation of the interest of the children who engaged the sensory integration therapy program, could be used.

As in other forms of therapy, boredom had a large effect. The children had time to adapt but became bored easily. For example, a taste for foothold was decreased because repeated contents. On the other hand, preference for unrepeated stimuli such as running, increased as the sessions progressed. Thus, we can assume that the preference for tangible interaction had effect.

It did not affect the statistics of the sensory integration therapy about influence on social skill program and coordination ability that operated after the sensory integration therapy.

4. Discussion

Until now, there has been no research on autistic children using VR-TIS. From our research, however, we can see its possibilities. It may be difficult because autistic children have mental disabilities that affect their ability to participate (Luke & Tsai, 2003; Dahlgren & Trillingsgaard, 1996). However, all except one of our original participants were able to complete the tasks. There was s significant difference between healthy controls and autistic children. This implies that this program can be used to classify the normal and autistic children. But specifically we found that it is possible to apply our system of and therapy for, autistic children.

There are two main limitations of traditional SIT for autistic children: the number of places or situations that can be experienced by the therapy is limited, and repetition results from the use of the same tools repeatedly. However the SIT programs based on VR–TIS provides a good composition of various places, and we can easily change the places according to our needs. Real places in this research contain a variety of stimuli from unusual places, which addresses the original limitation of SIT.

Even though presence plays a significant role in virtual reality, it is not easy to generate and maintain presence in virtual space (Banos, Botella, Guerrero, Liano, Rey, & Alcaniz, 2005). Research results about efficient and meaningful therapeutic studies using virtual reality for children with autism and developmental disorders have been presented (Moore, McGrat, & Thorpe, 2000; Parsons & Mitchell, 2002; Trepagnier, 2002; North, 1996), but there have been difficulties in those virtual reality therapies in terms of presence and immersion According to our results, VR-TIS suggested the possibility of the new interaction. Children who participated in this research applying VR-TIS performed tasks using tangible devices without any particular difficulties. Moreover, children showed the great interest about the program with virtual reality while they were performing tasks. This can be interpreted as our program applying both virtual reality and tangible interaction system to embody presence adequately.

In this research, social skills training and coordination ability measurement had better effects than sensory integration or trampoline by giving the reality. This was caused by individual differences in the case of the sensory integration therapy (Baranek, Foster, & Berkson, 1997b). In addition, the contents of the problem solving and recognition of social training and coordination ability tasks were more interesting to the children than any other tasks. And, social skills training program produced more interaction by conversation with therapist than sensory integration therapy that represented reality.

Social skills training module can elicit various conversation, so it was useful in both before and after treatment, while measuring the coordination ability was more training module. By recognizing these special features of the modules, we can develop the applicability to other therapy programs. The sociable module could be made more interesting by including the transcripts or voices of these conversations.

However, some limitations of our study have to be considered. Firstly, there are differences in the preferences and adaptation levels of participants, even though they have the same symptoms (Parsons & Mitchell, 2002), so the therapy should be individualized but our program was not. Thus, in future trials, the therapy should be individualized to be more effective. The level of contents should also be individualized.

During the 10 sessions of the test, many children became bored even though we had tried to vary the contents. Also, during the adaptation test, in which the children were able to practice 2~4 times before the real test, some children tended to concentrate more and later became bored by the repetition. In future studies, we suggest that the adaptation tests e excluded and that new and more varied materials be developed.

Tangible interactions, such as the stick, trampoline, and interactive stepping floor, were used in many fields. The interactive stepping floor was used user rotary motion, swaying from side to side, and screen rotation (such as turning four sides or turning the screen). However, it was hard to offer a proper interaction because of the repetition that bored the children. Therefore, for tangible interaction, it would be more useful to use various tools rather than simple, multiprocess tools.

To allow a larger screen projection, we used a wide and dark room. This led to the room being too dark for face–to–face interaction. It is very important to consider the mental aspects for autistic children (Greenspan & Wieder, 1997). The layout of the therapy room was designed to be parallel with therapist and children, but it was sometimes difficult to see the children. It would be helpful to offer several pieces of furniture so that participants can be comfortable and can product their exercises without any inconvenience. We should also be careful with the lighting for face–to–face interactions.

Some limitations in this study are apparently due to the use of VR–TIS for assessment of autistic children for the first time. However, we believe that our findings have potential for the clinical field. We will address the identified limitations in future studies. Subsequently, VR–TIS might be a useful tool for assessing and treating those children with autistic and pervasive development disorders.

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