INTERACTIVE THERAPY SYSTEM DESIGN FOR CHILDREN WITH AUTISTIC SPECTRUM DISORDERS

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ABSTRACT

Children with autistic spectrum disorders (ASDs) experience difficulties in accessing medical treatment to help them develop specific social and communication skills because of lack of public welfare institutions, facilities, and system and government support. In particular, few children can access such treatment and the existing single-therapist clinics are inefficient with regard to cost and time. Therefore, new methods should be studied for developing various products, services, and systems for autistic children. This study discusses the potential use of an interactive design as assistive technology for such children. We utilize the experience gained in the collaborative design of the interactive therapy system (ITS). The key methods include a collaborative design with rapid interactive prototyping, heuristic evaluation, user-centered process, VR technology, tangible interface, and scenario-based contents. We applied these methods to the ITS and proved the efficiency of interactive design as an assistive technology through clinical experimentation.

Keywords: **Autism, Interactive Design, Assistive Technology, Therapy**

1. INTRODUCTION

Autistic spectrum disorders (ASDs, autism) encompass a wide continuum of associated cognitive and neurobehavioral disorders, including the core-defining features of impaired socialization, impaired verbal and nonverbal communication, and restricted and repetitive patterns of behavior [1]. Between 60,000 and 115,000 children under 15 years of age in the United States meet the diagnostic criteria for

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autism based on recent prevalence estimates of 10 to 20 cases per 10,000 people. Identifying children with autism and initiating intensive, early intervention during the preschool year results in improved outcomes for most young children with autism [2]. Geenspan and Wieder report that of 200 children with an early diagnosis of ASD who receive intensive medical attention for two years, 58% can form relationships with other people, express their feelings, and verbally communicate effectively [3]. Nevertheless, the parents of these children with ASDs have difficulty in seeking medical treatment because of lack of a public welfare institution, facilities, and system and government support. In particular, treatment is restricted to a few patients and existing single- therapist clinics and one-on-one therapy methods are inefficient methods with respect to the aspect of cost and time.

Therefore, research is necessary to create new methods for the development of various products, services, and systems for children with ASDs. This study discusses the potential use of interactive design for children with autism. Our discussions draw upon experience gained in the collaborative design of the therapy system for children with ASDs. The aim of this study is to explore the current interactive design methods, to apply the most effective process, method, and technology of an interactive design.

2. INTERACTIVE DESIGN AND AUTISM

2.1. Therapy Theories for children with ASDs

There have been many attempts to help children with ASDs develop specific social and communication skills. Because of the social difficulties, the emphasis has been placed on social and communicative competence regarding educational intervention [4]. The majority of these interventions have utilized behavioral and cognitive methodologies.

Early behavioral methodologies for teaching social skills to preschool children with autism focused on the application of operant conditioning principles. In highly structured, single-handed settings, children with autism receive repetitive drilling in particular behaviors in discrete blocks of trials (e.g., imitating hand waving or completing a puzzle). This approach aims to equip children with fundamental social building blocks from which they could learn, develop, and generalize for a broad range of social situations [5]. These interventions were often very effective in teaching children new behaviors or skills, but suffered from a lack of therapists, as well as the cost and time for a one-patient-to-one-therapist setting. Sensory integration therapy (SIT) is based on a theory developed by Ayres, which emphasizes the relationship between (A) sensory experiences and (B) motor and behavioral performance [6]. SIT is intended to focus directly on the neurological processing of sensory information as a foundation for the learning of higher-level (motor or academic) skills [7]. 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.

One of the most influential cognitive approaches to explain the social difficulties seen in autism is based on the "theory of mind" hypothesis. The term "theory of mind" (ToM) comes from the work of Premack and Woodruff, who used it to describe the ability to impute mental states to self and others [8]. The ToM hypothesis states that the social difficulties in people with ASDs arise through an inability to recognize or think about the mental states of the self and others [9].

2.2. Related Studies for Children with ASDs

The potential usefulness of interactive design for the autistic population has already being recognized [10] and various researchers have noted the possible benefits of interactive environments for people with ASDs. Trepagnier proposed that VR technology may be an ideal tool for allowing participants to practice behaviors in role-play situations [11]. Wann performed a realistic cost and benefit analysis for the development of a VR interactive system, which can make a unique and useful contribution [12]. Kaufmann et al. researched the potential and challenges of using collaborative augmented reality (AR) in education within the greater context of immersive virtual learning environments [13]. Lewis suggested that the gaming aspect of this method can easily be incorporated into interactive design for children with ASDs. The gaming approach contributes to motivation for maintaining time on task, and has been customized to suit individual children's needs [14]. Mowafy and Pollack have developed interactive scenario of simulated bus rides for children with ASDs to teach them to independently ride public transportation [15]. Hirose, Tanigucchi, Nakagaki, and Nihei developed a system that included computers and video conferencing. These children were able to communicate with their families in remote locations and play games interactively with other children in similar situations [16]. Gips, Betke, and Fleming have used a new technology called the Camera Mouse to provide computer access for disabled persons. The Camera Mouse is non-invasive and uses a standard video camera and room lighting to track slight movements of the head, thumb, or toe, whatever part of the body a disabled person can control [17].

2.3. Useful Methods of Interactive Design for Children with ASDs

Various methods of interactive design are used for solving the difficulties and problems that disabled persons and children with ASDs present. A number of methods have been proposed that may influence presence; these include: collaborative research with rapid prototype, VR and information technology, tangible interaction, and scenario-based design.

First, an interdisciplinary, collaborative set-up and heuristic guidance provide clear explanations of the target social skills and the most suitable methods for system design for disabled people. Rapid interactive prototyping can make it possible for collaborative researchers to develop the practical system needed to help children with ASDs practice and train with interactive technology [18]. Second, VR technology is frequently used as specific implement method [19]. There is certainly some encouraging evidence that interaction with another person with the use of VR-based tasks significantly improves learning outcomes. Third, applications involving a tangible interface and tangible interactive objects are very effective methods for children with ASDs. In particular, the inclusion of tangible representations of mental states (e.g., thought bubbles) helps children with ASDs pass false belief tasks [20]. Using tangible interactive objects is a suitable interaction method for children who exhibit an interest in reaction through constructing curiosity, because it requires more physical actions and psychological stimulus than a graphical user interface (GUI). Fourth, scenario-based task evaluation and presentation can improve the chances of generalizing skills across contexts. In addition, the inherent properties of VR as a specific interactive technology may facilitate the solving of problems in various contextual tasks from the virtual to the real world because of the shared features between virtual and real environments, in the form of realistic images and scenarios.

3. OBSERVATION ON CHILDREN WITH ASDS

We visited Seoul Metropolitan Children's Hospital, interviewed four therapists and five children who participated in clinic program, and observed the treatment process. The therapy of children with ASDs was divided into individual one-to-one therapy and group clinics (3–4 people). The sessions consisted of play-therapy, verbal-therapy, and music-therapy, focusing on programs to regulate the patient's inner and external vigilance and the cultivation of social interplay skills. Each therapy session was carried out for 30–40 minutes in turn. As a result of observations of children with ASDs, the purpose of therapy program included SIT to control physical readiness conditions and sociality cultivation therapy for interplay with other people.

We identified the features of therapy from the observations. First, all therapy programs have a common purpose, which is to learn about communication with other people and to expand this relationship. Second, all therapy programs need naturalness, a sense of stability, and enjoyment. These factors encourage children to participate positively through inducement and conversation, and then the therapy has a greater effect. Third, normal people feel reality through familiar interactions that come from previous experiences. Conversely, children with ASDs should learn about real interactions in a virtual interactive environment.

The above-mentioned observations and analysis discussion implies that an interactive therapy system (ITS) should perform the substance of established therapy programs and apply the interaction technology aggressively. System design requirements should include the following: a supportive therapy, an economical system structure, ease of maintenance and management, generation of various interactions, and effectiveness for repetitive therapy sessions. Interactive design can create therapy sessions that can save cost and time, work well for limited spaces, and enable the development of a high-quality interaction system that assures effective therapy. A system developer performed examinations with motion tracking, sensing technology, and display interaction for cost efficiency and simplicity of manufacture and management. A suitable tangible interface for children with ASDs also needs to be designed to develop interactions which are natural and enjoyable. In summary, by drawing on theoretical analysis along with observations regarding teaching social skills, it is possible to outline the key elements which should be included in a new interactive design.

4. INTERACTIVE THERAPY SYSTEM DESIGN

4.1. System Architecture Design

The ITS has three components: a coordination ability measurement, social skill training, and SIT. Our ITS consisted of a PC, a projector, a screen (200 cm × 150 cm), an infrared reflector, a digital camera, and tangible devices (e.g., stick, rotation board, trampoline). Participants can see the result of their actions on the screen as they perform the tasks. The platform is designed for children to interact with tangible devices in front of the screen. Both sides of the screen are blocked with a partition board so that children feel more comfortable and concentrate on the screen. The therapist can control the therapy process in real time with an operating monitor which is separated from the screen that the children are looking at.

This study has developed an ITS for practical use in a clinic-treatment setting, with a concern for equipment cost and efficiency to enhance popularization of the system. For these reasons, a PC and general office hardware have been used as the basic platform. All software for treatment was designed using Adobe Director and Microsoft Visual Basic. Video tracking was used for all scenarios, which record children with a 30 cm stick. The stick has a green LED on the top, which makes it easy for tracing. TrackThemColors Extra (Smoothware Design) was used to develop software for video tracking. The rotation board, controlling speed and range for the Twister and Pinwheel was made from game controller hardware and connected software using Joystick Extra. Figure 3 illustrates the stick and rotation board.

4.2. Interaction and Scenario Design

A scenario was developed by two main interaction designers in conjunction with two therapists, two psychologists, and an engineer. The interaction scenario was designed according to behavioral and cognitive therapy methodologies, including the ToM theory and SIT therapy. The application of the interaction scenario attempts to measure each child’s ability. The ITS consist of eight types of SIT scenarios, five types of social skills training scenarios (based on the ToM theory), and one type of visuomotor coordination ability assessment scenario (based on a behavioral approach).

4.2.1. Visuomotor Coordination Ability Assessment

The Visuomotor Coordination Ability Assessment is a program for measuring visuomotor coordination ability. The program involves breaking virtual balloons with a real stick; reinforcements are provided for success. The number of balloons increase and the type of reinforcement received differs at each increasingly difficult level.

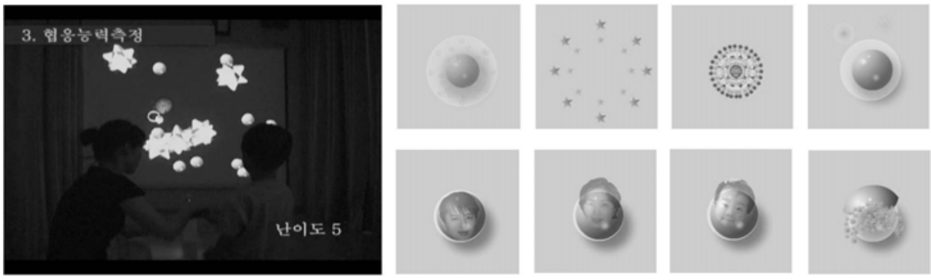

Figure 1: Examples of Visuomotor Coordination Ability Assessment and Visual Reinforcement

The types of reinforcement were selected based on the therapist's experiences and outcomes of parent surveys. These were then classified into auditory and visual substances [21]: participants received one reinforcement (from eight visual and ten auditory reinforcements) as a reward for breaking each balloon. Each participant completed 10 sessions for this activity.

4.2.2. Social Skills Training

Social skills training components were designed to minimize sound effects and background noise to allow for conversation between participants and the therapist to occur, 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. Participants completed 10 sessions.

"Spot-eyes-face looking training" refers to training autistic children to gaze at people's eyes. The therapist guides children through presented targets circulating from a spot, to the eyes, to the face, and back to the dot.

"Real face and graphic expression matching training" refers to training for understanding the emotions of people by looking at his or her face. The face of children with smiling, sad, angry and scary faces are put up on the screen by therapist. Children can learn about their feelings through designed facial pictures.

" Extensive training for facial expression" is also for improving the ability understanding facial expressions; the therapist lets children seek out a specific face among several different types of faces with a wand. The face chosen by the children follow the wand and become bigger with sound, while the remaining faces disappear from the screen. In this task, stopping and moving the face with the expression is possible.

"Following the spot with eye movement" refers to the practice of looking at the eyes of others. A cartoon character with big eyes appears on the screen and starts to follow the small dot turning around it with its eyes. Children are encouraged to look at the character's eyes by the therapist.

"Matching game with eye movement" refers to the training that teaches understanding of what other people are looking at. In the center of the screen, a cartoon character is looking at one of four objects. When the children indicate the correct object, the reinforcement becomes animated. For instance, the screen will present an animation of a hamburger being eaten when children correctly indicate that the hamburger was the object the character was looking at.

Figure 2: Examples of Social Skill Training: (a) Spot-eyes-face looking training and (b) Real face and graphic expression matching training.

Figure 3: Examples of Social Skill Training: (a) Extensive training for facial expression and following the spot with eye movement and (b) Matching game with eye movement.

4.2.3. Sensory Integration Therapy

Sensory integration therapy has attempted to stimulate the sense organs, making children stable at an awakening level for an effective treatment. 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 patient 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. The interactive images and movie clips were recorded in an amusement park and playground for providing a pleasant experience to children.

Figure 4: Examples of Sensory Integration Therapy

5. TEST AND EVALUATION

The first ITS prototype evaluation was carried out to assess the testing usability and system performance in a practical treatment environment; the first preliminary test was performed at Seoul Metropolitan Children's Hospital. The therapist performed a trial test with five children under the condition that the system producer and designer would be observing. Each child was given 5–8 minutes to participate in each program, and the therapist collected information about the feedback on the actions.

As a result of the clinical experiment, we found that it is possible to apply ITS for children with ASDs. ITS based on an interactive design overcame three main limitations of traditional therapy for autistic children: the limited number of places or situations that can be experienced in the therapy, poor repetition results from use of the same tools repeatedly, and the inefficiency of single-handed therapy methods. Children who participated in this research performed tasks using tangible devices without any particular difficulties. Moreover, children showed the greatest interest in the program with interactive contents while they were performing the tasks. Tangible interactions, such as the stick, trampoline, and interactive stepping floor, have to be used in many fields. Social skills training and coordination ability measurement showed a better efficacy than sensory integration or trampoline by providing a sense of reality. This was due to individual differences in the case of SIT. In addition, the contents of the problem solving tasks and recognition of social training and coordination ability tasks were more interesting to the children than any other tasks. This level of interest and effectiveness are due to scenario-based contents and tangible interaction. The social skills training program produced more interactive scenarios through conversations with the therapist. The sociable module could be made more interesting by including the transcripts or voices of these conversations.

Some limitations of our study need to be considered. There are differences in the preferences and adaptation levels of participants, even though they have the same symptoms [22]; therefore, the therapy should be individualized, but our program was not. Thus, in future trials, the therapy should be individualized to be more effective. The variety of content should also be individualized. During the 10 sessions of the test, many children became bored even though we had attempted to vary the contents. We used a wide and dark room to allow for a larger screen projection. This led to the room being too dark for face-to-face interactions, an indication that it is very important to consider the mental aspects of autistic children. It would be helpful to expand the interactive design area to the environment and space, and carefully consider the lighting and sound for face-to-face interactions. Some limitations in this study are apparently due to the use of ITS for assessment of autistic children for the first time. However, ITS might be a useful tool for assessing and treating the children with autistic in the clinical field.

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