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Using A Motion-controlled Game to Teach Four Elementary School Children with Intellectual Disabilities to Improve Purchasing Skills

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Abstract. Individuals with intellectual disabilities (ID) may have difficulties in performing daily living tasks. Among other daily living tasks, independent purchasing skills are an essential life skill for people with ID. Four children in a special education class participated in the experiment. We employed the Kinect sensor to gamify purchasing skills. Specifically, a multiple baseline design was adopted to demonstrate the relation between game-based intervention and making purchases independently. Data showed that the percentage of correct task steps increased among all four participants. Social validity results showed the parents considered the video game was very useful and it had helped their children learn the purchasing skills effectively. Although the game is a highly accepted training tool for school-use, it currently remains error-prone. A more technically robust system will likely result in higher participant motivation and task performance.

Keywords: Kinect, intellectual disability, purchasing skills, video game

1 Introduction

Individuals with intellectual disabilities (ID) may have difficulties in performing daily living tasks [1-4]. Among other daily living tasks, independent purchasing skills are an essential life skill for people with ID and other disabilities [5-6]. Shopping is one area in which skills learned in school are used on a regular basis. Cihak and Grim [6] examined the use of counting-on math skills in conjunction with the next-dollar strategy to enhance independent purchasing skills for students with autism and intellectual disabilities. Burckley et al. [5] used iPad to implement visual cues and video prompting to teach shopping skills in the community to a young adult with an autism spectrum disorder and intellectual disability. The results showed visual cues and video prompting substantially increased the participant's shopping skills across three community locations. Lamash et al. [7] used virtual reality training to improve the implementation of a shopping task among adolescents with Autism Spectrum Disorder (ASD). They found the group who performed the intervention program mastered the targeted task significantly better than the control group who continued with the regular therapeutic program. In a study by Burton et al. [8], four adolescent male students used video self-modeling on an iPad solving mathematical problems to

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estimate the amount of money used to pay for a given item and the amount to receive in change. The results showed maintenance of acquired skills with little deterioration of job performance.

2 Related Work

Maintaining purchasing skills in children with ID is a significant task for the parents, carers, and teachers of the child [5-6]. To promote autonomy and self-confidence in independent living in the community, shopping skills should be accompanied by money skill education and should also involve promotion of other aspects of money skills [6]. However, the difficulties in verbal reasoning and short-term memory present both pragmatic and pedagogic challenges in teaching children with ID to make purchases (among other living skills) properly through traditional methods such as verbal instruction and memorization tasks [9]. Instructional strategies that incorporate visual supports (e.g., pictures, in vivo modeling, video modeling [VM]) are considered evidenced-based practices that have been used to teach students with ID [3-4, 10-19]. These technological interventions can help students with developmental disabilities become more independent and better prepared for adulthood by learning a variety of life skills such as shopping skills [5], personal hygiene activities [20-22], play [12], as well as functional [4, 13, 16-18], vocational [11, 14], academic [3, 15], and social skills [10]. Among the various visual supports available, VM has increased in popularity in the last three decades due to the advancement and availability of technology, the decreasing cost of producing videos, and its strategic efficiency in teaching people with developmental disabilities [23].

Developing skills in children with ID can also be achieved by game-based training, a strategy made possible by the recent advancements in sensor and human computer interaction technology [24]. Gaming (e.g., the use of Kinect in this study) is a relatively new aspect of training. The game has a seeming advantage of serving an enjoyable motivator during the interventions. Nevertheless, it has been utilized for skills development for not only people with ID, but also for other populations such as those with Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder, or cognitive impairments [25-28]. Gaming has a number of advantages compared with traditional learning. Specifically, this type of training can be directed toward the development of a particular skill by organizing exercises that are (or that gradually become) more challenging; is often perceived as enjoyable and motivating, which increases long-term adherence; and can in many cases be performed at home or at a central location, which increases the frequency of training [29].

The gamification of training involves the child playing a video game that engages him or her in a target behavior, with the goal of subsequently imitating it in real life. Gameplay demands focus and attention, motivates the user to practice, and provides the user with a sense of achievement, even if the user cannot perform that task in the real world [30-31]. Therefore, gamification has become a new candidate for an intervention strategy that can successfully teach a variety of skills to individuals with ID or other disabilities, including social skills [29, 32], personal hygiene [24], and academic learning [33].

In short, previous studies have supported the use of video games in special education. Particularly, recent studies employed gesture recognition technology such as Microsoft Kinect to prevent the children from having to wear intrusive body sensors [34-37]. Additionally, Kinect provides real-time three-dimensional (3D) anatomical landmark position data, and it is inexpensive, portable, and simple to set up. Studies have also shown that the Microsoft Kinect and 3D motion analysis systems have comparable intertrial reliability and excellent concurrent validity [38-40].

3 Method

Despite the importance of correct and independent shopping, no study has yet addressed how interactive game technology can be used to teach multistep purchasing skills to children with ID. In this study, we developed an interactive game that turns the training of purchasing skills into a fun learning experience. Specifically, we developed a game based on Kinect's gesture recognition technology, which has recently increased in popularity in the video game interaction design domain. In this study, participants were children who had not developed a thorough and correct purchasing skills, although they may think they have already done it right. Children can play the game at school under their teachers' supervision until their ability to make purchases correctly has become sufficiently independent.

Our study uses Kinect in the development of interactive games for children with ID to encourage engagement in the training of purchasing skills. The game was designed according to a purchasing task analysis, which outlined the task steps involved in performing the task and simulated them in the computer game. The purpose of this study was to examine whether game technology is an effective way to teach elementary students with ID to develop purchasing skills correctly and independently.

3.1 Participants

Four elementary school children with ID (Alice, Bart, Chris, and Diane) participated in this study. All of the children were enrolled in special education programs under the ID category, and their cognitive and adaptive functioning fell within the mild, moderate, or severe intellectual disability range. Specifically, the children were recruited based on the following criteria: (1) diagnosis of an intellectual disability, (2) an Individual Education Plan goal to improve adaptive behavior related to personal care, (3) no physical disability that would impede the performance of the skill, (4) ability to attend, (5) ability to understand the objects in the video game, (6) ability to recognize the model in the game was controlled by the children's body, and (7) agreeing to participate in the study. The measures relating to participant's skills are based on Full Scale Intelligence Quotient (FSIQ). The Full Scale IQ is a score derived from administration of selected subtests from the Wechsler Intelligence Scales designed to provide a measure of an individual's overall level of general cognitive and intellectual functioning [41].

The first participant, Alice, was 9 years old and in the fourth grade with FSIQ=69. Alice had limited verbal communication skills and understood a limited set of instructions. Her parents reported that Alice could make money combinations if the amount was less than 1000 dollars. The second participant, Bart, was 12 years old and in the sixth grade with FSIQ=47. He was able to buy certain usual items in his neighborhood. However, he could not decide whether the money he had was enough to purchase the item he needed if he had not purchased the item before. Chris was 11 years old and in the fifth grade. Chris had limited verbal skills and his pronunciation was difficult to understand. Like Bart, he was able to buy certain usual items in his neighborhood. For items not purchased before, he was not sure whether the money he had was enough. Diane was 10 years old and in the fourth grade. She could not understand oral instructions properly, and had difficulties with social adaptation. She did not have any experiences in community shopping, although she did receive a shopping course unit among other life skill training. None of the participants had previous experience with Kinect. All the four participants were given pseudonyms to protect their privacy, and informed consent was provided by the individual staff members involved in the study and the main caregivers on behalf of the children with ID.

3.2 Setting

All of the students attended a special education class for their school day to address functional or life skill difficulties. Nine other students with multiple disabilities were also present in their classroom. During the baseline, game-based intervention, and maintenance phases, the children independently took a test for money skills. The game-based intervention occurred only in the special education classroom. The Kinect sensor requires an area of 15 feet by 9 feet for motion capture of the player. Within this area furniture should be removed.

3.3 Materials

The game is called "Let's go shopping!" The game started by children selecting a favorite cartoon model by holding the hand over the selected model on the screen for 3 seconds. The game was had three training components. The first component trained the children to identify coins. The task started with identifying a 1, 5, or 10 dollar coin from two coins on the screen. The second component trained the skill of making money combinations. The task started by asking the child to prepare an amount of money, which was less than 100 dollars, by combinations of 1, 5, or 10 dollar coins. The third component trained the children to buy an item from a selection of three stores, i.e. drugstore, fruit shop, or convenience store. The child had to choose the right store before picking up the right item as requested by the game. Then two combinations of coins appeared on the screen. One combination was enough to complete the purchase of the selected item while the other was not. If the child chose the combination that was enough to buy the item, she or he would be reinforced positively by the game showing praises. If the other combination was chosen unfortunately, the child would be encouraged by the game saying “Please try again.” Points were scored when children made correct movements in front of the Kinect camera [40]. Kinect tracks human skeleton by detecting 20 skeleton joints and provides real-time three-dimensional (3D) anatomical landmark position data for the user to control the motion of the model in the video game. Fig. 1, Fig. 2, and Fig. 3 show the screenshot of the three components of the game.

Fig. 1. Game for children to identify coins

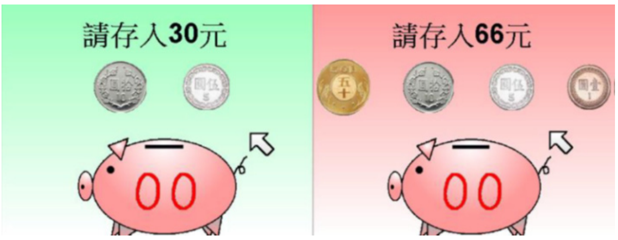

Fig. 2. Game for children to make money combinations

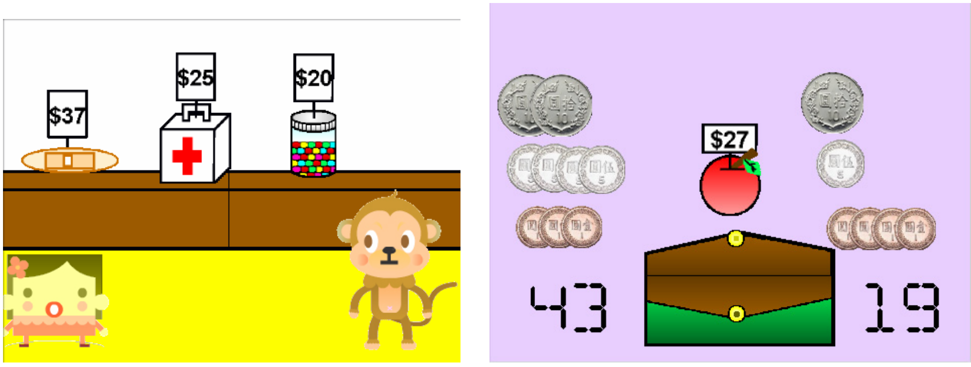

Fig. 3. Game for children to make purchases and decide whether money is enough

This study tested the proposed system in an urban special education class, which receives students with special needs from kindergarten through elementary school. The Kinect device was connected to a Lenovo Thinkpad T61 notebook computer, and the game software developed in-house was installed with Microsoft Windows 7. The computer had an audio module, which we used to deliver audio feedback, and an external 78-inch wall-mounted LCD screen that was used for visual interaction. The software was coded using Scratch, a block-based visual programming language targeted primarily at children [42]. The interactive interface with audio and video feedback was programmed to reinforce children’s motivation to engage in the training. For optimal performance of the Kinect sensor, the participants were required to stand approximately 3 feet in front of the Kinect module.

3.4 Experimental Conditions

A multiple baseline design [43] was adopted to demonstrate the relation between game-based intervention and the ability to make purchases independently. The experiment comprised four phases: (1) a baseline phase, in which sessions were performed to collect baseline data on the participants; (2) an intervention phase, in which the gaming system was used for training; (3) a maintenance phase, which was conducted 2 weeks after the intervention was finished and assessed the continued performance of the participants; and (4) a generalization phase, in which the children made real purchases at a community store.

During the baseline phase, children received assessment of their ability to make purchases independently. The assessment was based on a paper and pencil test prepared by special education teachers. For years, the test has been used as a standard to examine children's ability in making purchases. For the first session of the intervention phase, students were instructed on how to operate the Kinect-based training game. They were first directed to physically turn on the device and start the game by raising their hands. When students had problems going through various task steps in the game, the teacher used gestural or visual prompts. Pictures were used to prompt the children to stand within the range of the Kinect sensor, stand upright, or wave hands to start the game. Teachers were trained on how to prompt correct responding. Each child was required to finish every step in the game prior to initiating the intervention phase, and a session of game play took 10 min for each participant. The teacher supervised the children for the entire duration of the training session. Three sessions were scheduled for each child every week during the intervention phase. The participants used cues on the screen to complete the game play; in addition, picture-based feedback was used to enrich the training process and increase motivation to pay attention to the training process. Depending on the score of the game, the teacher either praised the student or encouraged her or him to continue. Children played the game by day at school for each session in the intervention phase and received the assessment independently 10 minutes after the game play.

The maintenance phase began 2 weeks after the intervention phase to determine whether the participants maintained the skills that they had acquired. During this phase, participants did not have the gaming system, but instead received the assessment directly as they had during the baseline phase. The maintenance phase was designed to examine whether the participants have acquired the targeted training skills and performed the acquired skills independently without the aid of technology. Therefore, the video game was removed during the entire maintenance phase.

3.5 Social Validity Measures

Social validity was evaluated through a survey, which assessed the participants' experience and success during the study. The survey was administered during a brief interview to each child's parents, with questions analyzing personal opinions regarding practical use of the video game. Open-ended and closed questions examined the parents' general thoughts regarding the video game and asked whether the game had helped their children learn the shopping skills. Other questions assessed whether the game changed the method by which each participant performed the task independently. Parents were also asked whether they would like to have their children participate in the future and what tasks would be helpful for their children to learn. Finally the interview addressed whether they had discussed the video game with anyone outside of school. One researcher asked each participant's parents the questions, and another audio recorded the verbal responses. Another survey was distributed to each teacher as a hard copy on which to write responses. These questions evaluated the participants' satisfaction and their perception of whether the video game was acceptable and useful with students. Social validity results would be based on interviewee responses to these questionnaires.

4 Results

This study assessed the effectiveness of the proposed system with regard to elementary-age children with ID acquiring the skills required to successfully make purchases independently. The assessment scores for each child is presented in Fig. 4. Overall, the children's independent performance in terms of task correctness immediately increased when the game intervention was introduced, and all of the participants acquired and maintained the skills necessary for the task completion. During the baseline phase, Alice received a mean score of 89; during the intervention and maintenance phases, her mean score immediately improved to 93 and then further increased to 98, respectively. During the generalization phase, she achieved 100% correctness in making real purchases. Bart's mean score during the baseline phase was 81; however, following the introduction of the intervention, his mean score immediately ascended to 88. Bart achieved a mean score of 95 during the maintenance phase. The mean score was 85 during the generalization phase. Chris's mean score was 65 during the baseline phase. During the intervention and maintenance phases, his mean score increased to 90 and then 94, respectively. He achieved a mean score of 89 during the generalization phase. During the baseline phase, Diane showed a mean score of 44. During the intervention phase, her mean score immediately improved to 92, and she demonstrated a mean score of 96 during the maintenance and generalization phases.

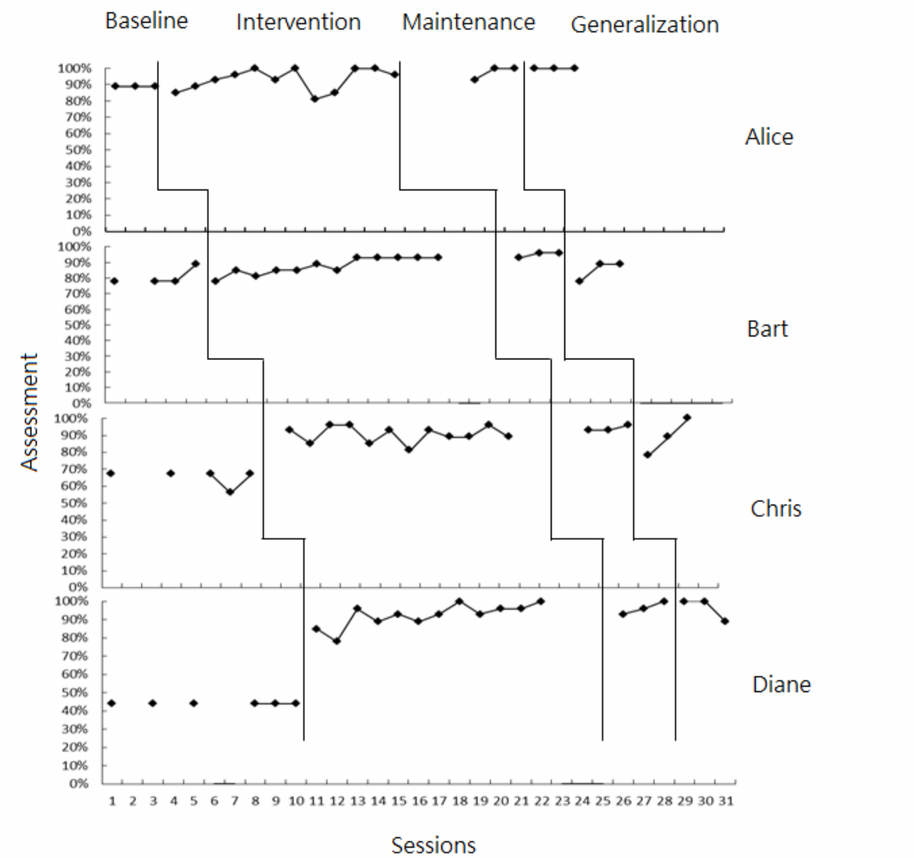

Fig. 4. Assessment of acquired skills during baseline, intervention, maintenance, and generalization

The parents thought the video game was very useful and it had helped their children learn the purchasing skills effectively. The game also changed the method by which their children made money combinations independently. Additionally, parents would like to have their children participate in the future and have advanced shopping skills and pedestrian safety listed in the game-based interventions also. Finally, parents discussed outside of school the video game with their friends who also had children with ID. They highly recommended the game and encouraged their friends to contact the teachers for more information.

According to the teachers, participants enjoyed playing the video game and found the game to be an enjoyable motivator. The teachers agreed that the video game improved independence and make teaching easier. The teachers expressed a wish for more time and resources to create additional video games for their students. They also found the video game to be up-to-date with current teaching methods. Teachers would like to use this method with their other students to reduce direct verbal prompting and other individual instruction. The teachers commented that education should include more technology where possible.

5 Discussions

For the four participants Alice, Bart, Chris, and Diane, the improvement in purchasing skills was demonstrated in the experiments. Furthermore, the results indicate that the proposed system, in conjunction with operant conditioning strategies, can facilitate the progress of children with ID making purchases independently. Across all the four participants, the skill maintained well in the absence of the video game. It might imply that the video game was a great instructional tool for the children with ID to learn visually and the sessions of interventions made a positive impact on acquiring the purchasing skills. However, more future studies are needed to investigate this issue. The data in the results suggest that these students were capable of generalizing from the contrived game simulation to the real shopping experiences under significantly different stimulus conditions.

For interventions that involve visual modeling, participants watch the training video first and perform the target behavior later by recalling the content in the training video [23]. However, the memory retention may not be sufficient to support the execution of the specific tasks for the population we address [24]. In contrast, the Kinect-based game intervention enabled participants to practice the target behavior while they played the game.

As this and other studies have demonstrated, even simple tasks can present complex challenges for some individuals with ID. Organizing tasks into a sequence of smaller steps or actions is an evidence-based practice for teaching new skills to students with severe developmental disabilities [44]. Moreover, having an understanding of all the steps involved for a particular task can assist in identifying those steps that require extra training and can help teach tasks in a logical progression [45]. The results of the present study show that the proposed game helped children with ID familiarize themselves with all the task steps involved in making purchases independently and, in particular, assisted them with the task steps where they needed extra practice.

One key limitation of this study is that the results are based on only four cases. Therefore, a general conclusion cannot be extrapolated regarding the efficacy of the proposed system. The lack of data on errors made during video game playing is also a limitation of the study. The lack of individualization is another limitation. It would be better if the task analysis could be individualized for some students because it is often the case that students may need more support with specific elements of a task analysis.

The future work includes the development of games with several difficulty levels that users can choose from for better individualization. It would be important to note whether participants were able to generalize skills to different settings (e.g. shopping malls), to different procedures for making purchases (e.g. using bills or credit cards instead of coins, and so on). Additionally, more interactive features should be added to enhance user experience. The effectiveness of this technology for people with other types of developmental disabilities should also be explored. One of the future research directions is to compare the conventional teaching method with the Kinect-based teaching method. On the other hand, we are considering modifications that might be made to the task analysis to make the game more inclusive for children with profound ID and make it easier to put on a task analysis.

6 Conclusions

To conclude, the proposed video game can be used for effective training of children with ID making purchases independently. The four participants in this study showed overall improvements in their task performance following the intervention. Although the game system is a promising and highly accepted training tool for school-use, it currently remains error-prone. A more technically robust system, combined with additional attractive games, would likely result in higher participant motivation and enhanced task performance. This would subsequently both reduce the need for parents or caregivers to motivate their children extrinsically and allow for field researchers to investigate the effectiveness of the system.

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