A Collaborative Virtual Reality Supermarket Training Application to Teach Shopping Skills to Young Individuals with Autism Spectrum Disorder

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Abstract
This paper presents a collaborative head-mounted display-based virtual reality application designed to teach the daily living skills of shopping to children and adolescents diagnosed with Autism Spectrum Disorder (ASD). Students and teachers can join the same virtual supermarket using HMDs and work together to complete a shopping trip. Results from an explorative study on eight adolescents with ASD are presented, and future potentials of the interventions are discussed in the paper.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Virtual Reality; Human computer interaction(HCI)—interaction paradigms—Virtual Reality—Virtual worlds training simulations

1 Introduction
Daily living skills (DLS) such as shopping, money management, transportation, and meal preparation are required for independent and high-quality adulthood. Studies show that individuals diagnosed with autism spectrum disorder (ASD) can have reduced DLS and often depend on support from parents or social agencies upon adulthood [7–9].

Therefore, to help individuals with ASD achieve a higher quality of life, it is essential to develop interventions to teach DLS to this target group. Furthermore, studies show that DLS development in individuals with ASD decreases gradually during the transition to adulthood, pinpointing the importance of interventions to be taken place during childhood and early adolescence [22]. According to a literature review by Wang, Spillane [25], the most common methods to teach DLS skills to children diagnosed with ASD are video-modeling and social stories. Video modeling refers to a method where the child watches a video of another child performing correct targeted behavior [13]. Social stories refer to visual scripts designed to be used by a teacher, parent, or therapist to teach skills about specific social and everyday living skills to a child diagnosed with ASD [10]. Video-modelling and social stories both rely on visually mediated information. According to Quill et al., children diagnosed with ASD attend more to visually mediated information compared to verbally mediated information [19]. Additionally, Christy and Daneshvar argue that due to the individuals diagnosed with ASD’s reduced social and communication skills, they often feel more comfortable attending to drawing or videos than a teacher or therapist [5]. Hume et al. study supports this statement by concluding that DLS teaching interventions that do not mainly rely on direct communication with a teacher are the most effective [12].

In general, computer-based learning interventions have shown to be beneficial for individuals diagnosed with ASD compared to human-mediated interventions [12] [26]. With the increasing number of high-end and affordable VR head-mounted displays (HMD), the technology is entering its prime time. However, exploring the potentials of VR to help children with ASD learn DLS began more than 20 years ago. In 1996, one of the first known studies to investigate the opportunities to use VR to teach DLS to children diagnosed with ASD was published by Strickland et al. [21]. In this study, Strickland et al. investigated whether children diagnosed with ASD can tolerate HMD based VR and whether they can have a meaningful interaction with a virtual environment. Two children diagnosed with ASD were given the task of spotting cars in the virtual environment and saying out loud the car’s color. The results indicated that the children accepted and enjoyed using the technology. At the same time, they were capable of fulfilling the tasks given to them. Ever since this pioneering study within ASD and VR, several studies have investigated the possibilities to use virtual environments to teach DLS to children and adolescents diagnosed with ASD.

One of these studies conducted by Adjorlu et al. investigated whether a virtual supermarket can be used to teach specific parts of shopping skills to children diagnosed with ASD [1]. Using HMDs, children diagnosed with ASD could navigate a supermarket designed to look familiar to a Danish supermarket with real-life products that were scanned and placed on the virtual shelves. The children’s task was to navigate the virtual supermarket and find the items on a virtual shopping list. While immersed in the virtual environment using the HMD, the children held a VR controller in one hand and a real-life shopping basket in the other hand. A VR sensor was attached to the shopping basket to map its position to the virtual shopping basket in the VR application. Using the hand with the controller, they could grab objects from the virtual shelves and place them in their virtual shopping basket. By performing the same physical movements required to pick items in the virtual supermarket as the ones required in the real-life supermarket, procedural skills were trained by the child diagnosed with ASD. Locating and picking up the items on the virtual shopping list in the virtual supermarket was the user’s only task in this application. The VR application’s effectiveness in teaching shopping skills was evaluated via an in-between study. The experiment group trained with the VR application for seven sessions spread over two weeks while the control group received traditional DLS lectures without VR. Pre- and post-measurement of the participants’ shopping skills were measured via trips to a real-world supermarket. The results showed improvement in the participants’ shopping skills in a real supermarket after VR training sessions. This study shows VR’s potential to teach navigation and item localization in a supermarket to children diagnosed with ASD. However, purchasing and money skills, which are essential parts of a shopping experience, were not part of the above mentioned VR DLS training intervention. Another study conducted by Adjorlu and Serafín investigated VR’s potential to teach money skills to adolescents diagnosed with ASD. In collaboration with teachers at a special school for adolescents with mental disorders, a VR money skills training application was developed through a user-centered design. In a virtual park environment, the users were introduced to a set of virtual coins and bills followed by a set of tasks in which they were asked to place a specific amount of money upon a table. Five adolescents diagnosed with ASD participated in a study within which their ability to use coins and bills was evaluated pre-and-post VR training. Results indicate that VR can teach money DLS
to adolescents diagnosed with ASD. In this study, we present a VR intervention designed to teach a combination of shopping and money skills to adolescents diagnosed with ASD. Shopping skills are known to be one of the essential skills for having independent adulthood for individuals diagnosed with ASD [16] [4] [11]. As an example, teachers working with children diagnosed with ASD daily were asked what set of skills they imagined could benefit the most from being taught to their students using VR, and one of the most common answers was shopping skills [3]. An interactive virtual supermarket environment can allow the users to practice the procedural sequence of actions required when shopping: from picking up products and groceries on a shopping list to paying for them using money. Practicing the procedures required to finish a shopping trip by performing tasks such as picking up an item from a shelf, placing it in the shopping basket, and then walking to a checkout register to pay for the item creates a platform for experimental learning: learning through reflections on doing. Finally, shopping is often a social experience as one will have to enter environments crowded with other costumers and shop employees. This might be a social anxiety-inducing experience for children with ASD [14]. Therefore, in this paper, the VR supermarket DLS training application will also create a platform to practice social interactions in a supermarket by exposing the user to other virtual avatars in the VE.

2 Method

2.1 User-centered design

Creating an application for teaching DLS skills to children and adolescents diagnosed with ASD required the knowledge and expertise of teachers experienced in working with this target group. Three teachers working with children diagnosed with ASD were involved in the VR DLS training application’s design process. The teachers were already familiar with the VR supermarket and money training interventions described in the introduction [1, 2]. They were presented with the idea of one VR intervention that attempted to teach all the procedures involved during the shopping scenario: from picking up items in a supermarket as described in [1] to pay for the items using money as described in [2]. The teachers stated that in addition to not providing one platform to practice all phases of a shopping scenario, the two interventions described in [1] and [2] had another major limitation: The lack of the ability for the teachers to control their students’ learning experience. The teachers stated that the VR intervention enables experimental learning, where their students can perform an action, receive feedback, and reflect upon this feedback. However, students with ASD can lack the ability to self-reflect and need their teachers’ help to understand better the tasks at hand and the consequences of their actions. This statement is supported by studies showing that children with ASD have a reduced ability to reflect upon themselves compared to their typically developed peers [15]. Therefore, in addition to allowing the students to practice all phases of a shopping scenario, the teachers asked for the ability to be co-present with their students in the virtual supermarket. According to the teachers, this would allow them to guide and help their students learn the desired skill while reflecting upon their actions. They want to be co-present with their student in VR while wearing a HMD and be able to see each other’s avatars and communicate with them using voice and gestures. Additionally, they asked for the ability to have VR training sessions with a group of their students simultaneously instead of having one student at a time. According to the teachers, cooperative learning can help them develop social skills and work with their social anxieties while practicing shopping DLS in the virtual supermarket. The students should be given tasks to solve together, and, under the teacher’s guidance, share these tasks, and communicate on how to solve them. Together with the teachers, a set of tasks were designed for the virtual supermarket. The student’s main task in the virtual supermarket will be to purchase a set of items listed on a virtual shopping list. This primary task is divided into a series of sub-tasks. These sub-tasks include:

- Read out the items on a virtual shopping list and present them to the rest of the students
- Locate the items on the virtual shelves together
- Carry around the virtual shopping basket in which the items can be placed
- Use a pan balance to measure the right amount of fruit and vegetables on the shopping list and put them in the shopping basket
- Pay for the purchased items using virtual money that represents real-world coins and bills

Weighing fruits on a virtual pan balance in addition to using virtual money would, according to the teachers, help them teach basic math skills to their students. The balance model is a commonly used didactic tool to introduce and teach linear equations [17, 18]. Studies have shown that the model can be used to enhance understanding of the concept of equality in general [17]. Recent studies show that this effect can be transferred to VR [6]. Therefore, the model can be used in the virtual supermarket to support the students in simple mathematical operations required to match the quantities of certain products in the shopping list. Depending on the students’ competency level and severity of ASD, the difficulty can easily be adjusted (e.g., to represent magnitudes or multitudes of products).

2.2 The VR DLS application

The authors developed a VR DLS training intervention using the Unity3D engine for the Oculus Quest 2 HMD based on the teachers’ comments. Network functionality was implemented, allowing students and teachers to simultaneously join the virtual environment, controlling a virtual avatar each, using real head and hands movements. A virtual supermarket was created with various virtual products on its shelves, as seen in figures 1 and 2.

When starting the application, the students will begin close to the entrance next to a virtual shopping list and a virtual shopping basket. Using continuous locomotion, the user can navigate the virtual environment (VE) by moving the thumbstick on the Oculus Touch controllers. Additionally, the users can pick up items such as the shopping basket, shopping list, products and coins, and bills using the controller’s grab button. Once a user grabs an object in the VE, other users can see the change of position and rotation in their VE. Additionally, the users can hand the interactive products to each
other. Interactive products can be placed in the basket by grabbing them, moving them inside the basket, and releasing them. This will result in the interactive product being snapped to the shopping basket until the user again reaches in and grabs it and moves it out of the basket.

One of the items on the shopping list is 400 grams of fruit. For this purpose, the authors designed and implemented a virtual pan balance, as seen in figure 4, allowing the students to work together to weigh 400 grams of fruit. A fruit bag was placed next to the balance, in which the students could place the right amount of fruit in after weighting it using the balance.

Finally, the students can walk to a self-checkout machine to scan their items and then pay for them using virtual coins and notes that represent real-world coins and bills (see figure 5).

Each item can be scanned by moving it towards the scanning area, resulting in a scanning sound followed by the name and the price of that specific item appearing on a screen on the self-checkout machine. The scanned objects can be placed inside a virtual shopping cart on the other side of the self-checkout cashier machine after being scanned. Money can be grabbed using the touch controllers from the virtual wallet and placed inside the slots in the virtual self-checkout cashier machine. Three buttons are placed on the virtual self-checkout machine. One delete the last item button, a delete all items button, and a pay button.

If the students press the pay button while the right amount of virtual money has been placed inside the coins and note slots, a specific sound will be played as a signifier, communicating the experience’s end. No mechanics were implemented to returned changes to the students if they inserted more money than required in the self-checkout machine.

During the whole experience, the participants can verbally communicate with each other using voice over IP (VoIP).

2.3 Exploratory evaluation
A simple exploratory study was conducted at "Specialisterne," an educational center for adolescents diagnosed with ASD in Copenhagen. The educational center focuses on IT, and all of their students have experience using VR HMDs at the school. A total of eight male students diagnosed with ASD between the ages of 16 to 22 tried the VR DLS training application. Due to the General Data Protection Regulation, Specialisterne did not share any further demographic information about the participants were shared with the authors of the paper.

Three teachers, who were familiar to the students, ran the exploratory study. The VR DLS training application was installed on six Oculus Quest 2 HMDs. The study was conducted in a large classroom at the facilities of the educational center. The teachers had tried the application beforehand and were familiar with all of its functionalities.

One of the teachers used an Oculus Quest 2 HMD to join the virtual supermarket together with the students. Three VR supermarket training sessions were conducted, one with two participants and two sessions with three participants. The teacher was asked to brief the students in the same way during all three sessions. All three sessions were video-recorded using screen-recording from a user who joined the scene for observation.
3 Results

3.1 The first session

The first session with two students lasted 7 minutes and 16 seconds. After the teacher explained the task at hand, one of the students grabbed the virtual shopping list while the other student grabbed the virtual shopping basket. They then navigated the supermarket looking for the items on their shopping list and placing them in their shopping basket. This task was done without any issues by the students.

Once they reached the fruits to be weighted, the teachers pointed them toward the virtual balance and introduced them to its mechanics. They quickly got familiarized with the balance functionality. However, the biggest struggle was when trying to place the fruits inside the fruit bag. This mechanic included a bug that would result in the fruits not snapping to bag. After several attempts, the students managed to place the fruits in the bag and place the bag in the basket. The teacher then told them to go and scan and pay for the products using the self-checkout machine. The two students managed to effortlessly scan all the items except the fruit bag, which was not easy to move around again due to a bug. Finally, the teacher asked them to pay for the items using the virtual wallet. The students inserted the required bills inside the self-checkout machine and pressed the pay button. The teacher then ended the session.

3.2 The second session

The second session consisted of three students and lasted for 6 minutes and 35 seconds. The teacher once again described the task at hand, and the students began: one of the three grabbed the shopping list, one grabbed the shopping basket (see figure 7), while the last student was the first to talk and asked: what is the first item on the list. While they were looking for the items, one of the students stated that it is hard to see who is who since all of the avatars looked familiar. The teacher suggested that they each said their names and raised their hand to see who is who. The student who was neither holding the virtual shopping basket or list was the most socially dominating one, being the most talkative. He also commented: *I wish we each had our own shopping list.* Once the students reached the 400 grams of fruit on their shopping list, the teacher guided them towards the weight balance and introduced its concept to the students. One of the students commented: *Nobody uses such an old balance anymore.* The students managed to weigh the correct amount of fruit but placing them in the fruit bag was a buggy process, similarly to the first session. Once done, the teacher points them towards the self-checkout machine. There the students worked together and scanned everything except for a cola (see figure 6), which was initially stuck in the virtual shopping basket’s snapped zone and, due to a bug, would not come out. Once done, the students discuss which coins and bills to insert into the machine, press the pay button, and finish the experience.

3.3 The third session

Three students tried the application in the third and final session, which lasted 11 minutes and 6 seconds. This session began with the students entering the supermarket, and before the teacher could introduce them to the tasks at hand, they were already grabbing items from the virtual shelves and throwing them around in the scene. After some time, the teacher finally gathered all the students by the entrance and introduced them to the task. The students complained that they could not recognize who is who, and they also mentioned that they wish there were a shopping list there for each one of them instead of one shopping list they had to share. They shared the tasks by carrying the shopping basket, carrying the shopping list, and the last student localizing the items on the shelves. Once again, the teacher introduces them to the virtual pan balance when they reach the fruit on their shopping list. Here, a student places a 100-gram weight on one side, and another student places an apple on the other side of the balance board, which results in it showing equality between both sides. One of the students then concluded that if one apple is 100 grams, then four apples would be the 400 grams asked of them on their shopping list. The fruit bag was again buggy, causing the students to have difficulty placing four apples in it. The teacher asked the students to scan and pay for the items at the self-checkout machine. The students manage to scan all items together while 2 of them simultaneously place coins and bills into the self-checkout machine. They then press the pay button, and the teacher finished the experience.

4 Discussion and Conclusion

In this paper, we presented a VR DLS training application designed to be used as a tool to teach shopping skills to children and adolescents diagnosed with ASD. To our knowledge, previous studies utilizing immersive VR to help individuals diagnosed with ASD to
learn how to shop independently in a supermarket have either looked at localizing items or handling money. In the presented study, we aimed to combine both money skills and item localization and create a social experience similar to a real supermarket. Teachers working with this specific target group was involved in the design process via several online interviews, which resulted in two main requirements that were implemented in the application by the authors:

- The teachers should be able to be co-present in the VE together with the students
- Several students should be able to enter the VE together and work together to complete the shopping experience

Being in the same VE as their students allows the teachers to present the users with the assignment and provide feedback during the sessions. This, however, poses the question: Does the teacher need to be immersed in the VE using HMDs, or would it be sufficient if the teacher controls an avatar in the VE using a desktop interface instead. Using an HMD does offer several opportunities, such as expressing emotions using gestures and the ability to illustrate how to perform specific tasks such as picking up items from the virtual shelves or paying with the virtual coins and bills. Additionally, using an HMD can allow the teachers to take supermarket staff’s role, such as cashier, and customize the sessions according to the students’ needs. Since ASD describes a broad range of neurodevelopmental disorders, each student diagnosed with ASD can have different needs when learning a specific skill [23].

Future iterations of the described VR intervention can be used by a teacher working with children diagnosed with ASD, as a sandbox that can be shaped to meet the students’ wide variety of social and DLS needs. This, however, will need further involvement of the teachers in the design of future iterations of the application. The evaluation presented in this paper was a very limited study on a group of adolescents diagnosed with ASD. At the educational center Specialisterne, with a focus on IT, most of their students are on the high functioning side of the autism spectrum, resulting in all of them being capable of finishing the tasks required from them in the VE effortlessly. Additionally, no post-session questionnaire or interview was prepared for the students, and no information about each specific student was available to the authors due to the GDPR. The only data available was the observation of the teachers as well as screen recordings of the sessions. These did, however, provide some insights that can be used for future iterations of the intervention. Difficulties distinguishing the virtual avatars in the VE was commented on in the sessions where there were more than two students. Everyone joining the VE got the same exact avatar to control with floating heads and hands controlled with the Oculus Quest 2 HMDs and Touch controllers. Future iterations should, therefore, provide students with personalized avatars that look different from one another. Additionally, inverse kinematics can be implemented to visualize the avatar’s whole body instead of just the floating heads and hands, creating an increased sense of body ownership and immersion [24].

In future iterations, it may be desirable to embed a module of stealth assessment in the VR experience [20]. Stealth assessment on particular parameters related to students’ progression in DLS and social skills may provide teachers with quick insight into training status through short progression reports. Moreover, in regards to social skills, stealth assessment may present interesting observations on social interactions between users. Mapping social interactions between users could provide the teacher with an overview of relationships within a group of students to assess whether students experience social inclusion or exclusion.

Even though the participant in the limited and exploratory study presented in this paper managed to complete the tasks in the VE, children and adolescents on the lower functioning side of the autism spectrum might face more significant difficulties completing them.

Previous studies have illustrated that children and adolescents diagnosed with ASD can face difficulties understanding the concept of money [2] or paying for products in a real-world supermarket [1]. Additionally, children and adolescents diagnosed with ASD can have difficulties generalizing knowledge from one scenario to another. Therefore, future studies should investigate whether the VR DLS intervention skills proposed in this paper can be transferred to a real-world supermarket.

Another approach could be to create a VE of a classroom, where multiple students and a teacher can enter using HMDs. In the virtual classroom, the teacher can introduce the students to the concepts and skills required in a supermarket. There, he can present the student to virtual coins and bills, balance, and items but in a different VE than a supermarket. The student can also start performing some simple tasks in the VE classroom, such as weighing vegetables on a balance pan and getting introduced to virtual coins and bills. The teacher can then transport the students from the classroom VE to the supermarket VE and ask them to perform a shopping trip to investigate whether the transfer of knowledge is possible from one VE (classroom) to another (supermarket). Finally, studies can be conducted to investigate the transfer of knowledge from the VR experience to the real world. The authors developed a prototype of the classroom VE with assets relevant for learning to shop, as seen in figures 8, 9.

Similarly, the classroom VE can be used to introduce other DLS concepts than shopping, such as traffic safety followed by a trip to a VE of streets or public transportation followed by a trip to a VE of a bus stop. Using VR to help individuals with ASD achieve an independent and high quality of life during adulthood is a mission that is possible with the support of the VR research community and
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REFERENCES


