Vocational Rehabilitation of Individuals with Disabilities Using Virtual Reality

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ABSTRACT
In this paper, a system for vocational training and assessment of individuals with severe disabilities is presented. This system is currently in its iteration phase. The system aims at providing effective vocational training to three groups of individuals with disabilities: autism spectrum disorder (ASD), traumatic brain injury (TBI) and severe mobility impairment, such as spinal cord injury (SCI). System components and training modules are presented in the paper. A user study was performed with 5 individuals with ASD and 1 individual with TBI, with accompanying expert job coaches. User study results and the observations of the job coaches indicate that VR4VR system is promising in providing very effective vocational training to individuals with severe cognitive disabilities. Since training module for physical disabilities is currently under development, it could not be included in the user study.

Keywords
Vocational rehabilitation, virtual reality, autism spectrum disorder.

1. INTRODUCTION
The US Census Bureau reports that 54.4 million of U.S. population has disabilities, of which 64% is severe [2]. 2012 data reveals that employment rate of individuals with disabilities have a ratio of 3:10 as compared to employment rate of individuals without disabilities [3]. Employment is an important aspect of life which provides individuals with economic independence, satisfaction and better quality of life [11, 15]. As unemployed population with disabilities was interviewed, 66% stated that they would prefer getting employed if they had the chance [9].

We believe that easily accessible training would help in improving the employment rate of individuals with disabilities. To take part in improving the chances of individuals with disabilities to gain employment, we proposed a virtual reality system for vocational rehabilitation of individuals with disabilities (VR4VR). Our VR4VR uses several modules on different skills for training and assessment of individuals with disabilities using immersive virtual reality. The long-term goal is to provide a low cost, easily accessible and effective training environment for individuals with disabilities and to help increase their employment rate.

Virtual reality (VR) offers several advantages such as: safe training, customizable scenarios, real time prompts and distractions, repetitive training, automated data collection for reflection, wide range of modules, real time feedback, system scalability and reduced transportation costs. Of course, these advantages are not to claim that VR offers better training than conventional job training with one to one job coaches. VR can be utilized as an adjunct to conventional job training and create more possibilities for more people in the same amount of time. A training program that utilizes VR first, then one to one complementary training and assessment with a job coach seems suitable for a sophisticated training.

Our VR4VR caters to three disability groups: autism spectrum disorder (ASD), traumatic brain injury (TBI) and severe mobility impairment. The system uses immersive virtual reality to train individuals on transferrable skills with seven training modules of cleaning, loading the back of a truck, money management, shelving, environmental awareness, social skills, and object manipulation with an assistive robot. A user study was performed with five individuals with ASD and one individual with TBI in the presence of accompanying job coaches. The results are promising in terms of effective usage of virtual reality for training individuals with severe disabilities. This paper presents the VR4VR system, training modules and user study results. We also share the observations of the job coaches who are experts in vocational training of individuals with severe disabilities. A previous version of our system can be seen in [1].

2. RELATED WORK
Vocational training with virtual reality is an emerging area because of the several advantages it offers over conventional job training. The key works on vocational training using virtual reality technologies are presented in this section.

Tsang and Man worked on vocational training of individuals with schizophrenia using virtual reality environments [13]. Wade et al. developed an adaptive driving training system with immersive virtual reality [14]. Smith et al. proposed a job interview training system for individuals with ASD with immersive virtual reality environments [12].

Some studies concentrated on providing assistive technological devices as a real time vocational assistant to individuals with disabilities. Chang et al. worked on a system that provides employees with handheld assistive palm computers that creates context aware prompts [4]. A follow up study by Chang et al.

provided context aware prompts on a large display to assist individuals with disabilities in vocational tasks [5]. Mechling and Ortega-Hurndon developed a system that provides video based instructions for teaching vocational tasks to individuals with disabilities [8].

As compared to the previous works in the area of vocational rehabilitation using virtual reality, the novelty of our system can be stated as: (1) Several off the shelf components that are incorporated seamlessly, (2) Several vocational skills, (3) Several real time distractions, and (4) Real time tangible interaction in real world and virtual reality.

3. VR4VR SYSTEM

The proposed VR4VR system utilizes several hardware components to provide and immersive training with several options. A VR2200 head mounted display (HMD) with 1024x768 resolution was used as the viewing device of the motion tracking system. For motion tracking, an optical system with 12 OptiTrack Flex: V100 cameras was used. For interaction, tangible objects equipped with optical markers that can be tracked real time by the system were used. As an alternative training model, a large 180º curved curtain screen was used as a display device along with input devices such as mouse, haptic device, and touchscreen tablet computer. A server computer with AMD FX-8150 8-Core Processor, 16 GB Memory and AMD FirePro W600 Graphics Card was used to run the software.

In the VR4VR software, there are several immersive virtual environments such as warehouse, outdoor parking lot, grocery store, cash register area, office space and outdoor street. The training is achieved with three levels for each module: tutorial level, training level, distracters level. Distracters are composed of common daily life and work place events that are related to the scenario environments: lightning, announcements, complaining customers, traffic noise and fireworks. Distracters can be in the form of 3D animation, 2D visual, sound or a combination of those. The aim of the distracters is to help individuals with cognitive disabilities overcome their fears or irritations over them. The distracters can be applied automatically or in real time by the job coaches. The system has a remote control system for the job coaches that allows for several actions such as running/stopping simulation, applying distracters, tracking remaining tasks/instances, and reviewing trainee reports.

4. TRAINING AND ASSESSMENT MODULES

VR4VR offers seven different modules for vocational training and assessment of the individuals with severe disabilities. The modules are designed to train individuals on transferrable skills of cleaning, loading the back of a truck, money management, shelving, environmental awareness, social skills and object manipulation with an assistive robot. All six modules other than object manipulation with an assistive robot were designed for individuals with cognitive disabilities. The skills for the modules were designed following discussions with the job coaches and the prevalence among employment of individuals with disabilities [10, 7].

Each module has their own three levels: tutorial level, training level and distracters level. Tutorial level aims at teaching the user the task they will be practicing on. Training level allows for the repetition of the learned task without any environmental distractions. Distracters level aims at preparing the users to perform vocational tasks in the presence of real world distractions. Pictures of shelving, money management and object manipulation with an assistive robot skills can be seen in Figure 1, Figure 2 and Figure 3 respectively.

Each module offers three different subtasks with their own three levels. Training subtasks for each module is presented in Table 1. Object manipulation with an assistive robot module is currently under development. All other modules are finished.

Table 1. Subtasks offered in each training module of VR4VR system

Graphics	Top
Cleaning	• Vacuum cleaning • Mopping • Litter collection
Loading the Back of a Truck	• Loading identical boxes • Loading labeled boxes • Loading within a short timeframe
Money Management	• Recognizing coins and bills • Counting money • Providing change
Shelving	• Aligning boxes • Orders/deliveries with graphical labels • Orders/deliveries with item codes
Environmental Awareness	• Navigating around stationary objects • Navigating around moving people • Navigating around moving cars
Social Skills	• Basic personal information questions • Intermediate job experience questions • Advanced reasoning questions
Object Manipulation with Assistive Robot	• Robot navigation • Arm control • Object manipulation

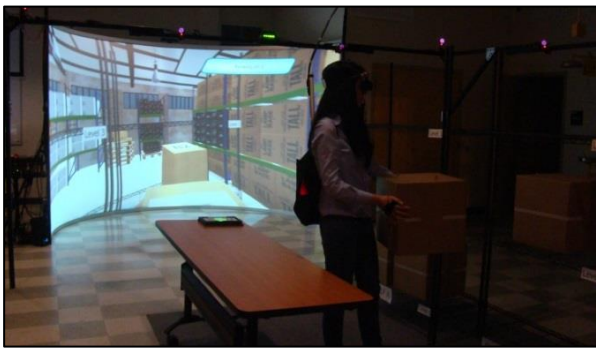

Figure 1. Training on shelving skills in a virtual warehouse environment with tracked boxes

5. USER STUDY

5.1 Research Question

Our research question is about validating the usage of virtual reality technologies for vocational training of individuals with severe disabilities: “Can immersive virtual reality be used effectively for vocational training and assessment of individuals with severe disabilities?”

5.2 Participants

Currently, we are performing user studies to validate our research question. In this paper, we will present results of the users who participated in the user study so far, along with the observations of the job coaches. In total, three job coaches participated in the study. Six participants (five with ASD and one with TBI) participated in the user study. Demographics were as follows: all male, mean age of 24.6, no prior virtual reality experience.

The study was performed under IRB Study #Pro00013008. Subjects were recruited via posters, e-mail announcements, job coaches and clinicaltrials.gov webpage announcements. All participants signed an informed consent form before participating in the study. The users completed six skills of cleaning, loading the back of a truck, money management, shelving, environmental awareness and social skills in two sessions of two hours. Job coaches accompanied the users during all testing sessions. The two sessions were scheduled on different days.

Figure 2. Training on money management skills in a virtual grocery store with a touchscreen computer

Figure 3. Object manipulation with an assistive robot skill in a virtual warehouse environment

5.3 Results

To validate the usability of our system by individuals with disabilities, our first measure of success was the successful completion of a level. In VR4VR system, if a user cannot complete a level within five minutes, the level is considered as failed. The percentages of participants who completed levels of the trained skills successfully are presented in Figure 4.

In each level, 4-8 instances of the practiced task are requested. The number of tasks per level is decided by the system randomly within this range during run time. Average time to complete the levels that the user completed successfully was measured. Since the levels may contain different number of instances, this score was normalized by dividing the time by number of instances per level. The normalized results for average time to complete each level of each skill are presented in Figure 5.

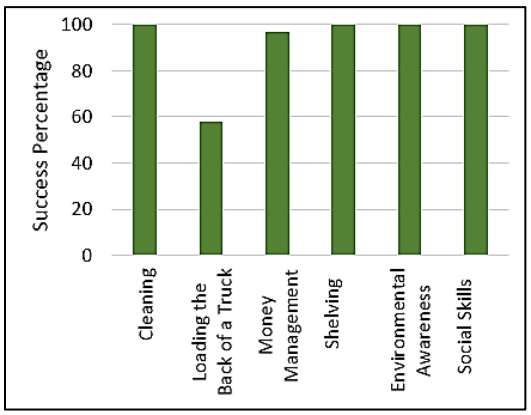

Figure 4. Percentage of participants who completed the levels successfully

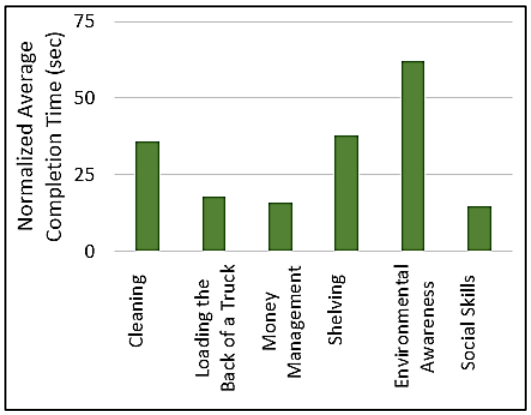

Figure 5. Average completion time results normalized by instances per level

6. DISCUSSION

The results indicated that the users with ASD and TBI were able to complete the tasks within the VR4VR system successfully.

All users completed the cleaning, shelving, environmental awareness and social skills successfully. The lowest completion rate was in loading the back of a truck skill, which was criticized by the job coaches to be cognitively too demanding for these special groups. This skill will be updated to include more free space to make it less cognitively demanding for individuals with ASD and TBI. Only one individual with ASD was not able to complete the money management levels successfully, which may be a personal deficiency to be trained on. We perceive successful completion rates as our VR4VR system's being effectively usable by individuals with disabilities.

As average completion times are reviewed, environmental awareness, shelving and cleaning skills are more demanding in time as compared to other three. We believe this is due to the design of these skills in requiring navigation. The time to virtually move from one point to another increases the skill completion times. However, the job coaches stated that requiring navigation is a positive part of

the training which prepares the individuals for real life job environments. So, no update will be made in regards to the navigational requirements.

We did not observe any acceptability issues for HMD, wearable markers and any other controlling device. All participants stated that they would come back again to train with the VR4VR system. The participants with ASD stated positive comments on the enjoyment VR training provided to them, which overlaps with the tech savvy characteristic of this population [6].

The job coaches stated that VR4VR system is promising in providing very effective training and convenient assessment for individuals with ASD and TBI. They observed improvement in participants on the trained skills. The job coaches also noted that the most effective usage of virtual reality training would be first training the individual on VR for a period of time and then training them conventionally with a job coach for a shorter time.

7. CONCLUSION AND FURURE WORK

In this paper, we discussed VR4VR system which provides vocational training and assessment to individuals with severe disabilities of ASD, TBI and severe mobility impairment. The paper presents system properties, training modules, user study results of 5 ASD and 1 TBI individuals and observations of the job coaches during the user studies. User study results, statements of the participants and the job coaches indicate that VR4VR system is promising in providing effective training and convenient assessment to individuals with cognitive disabilities. As future work, we will test the system with more participants and update the system according to results and suggestions of the job coaches. The object manipulation with an assistive robot is currently under development. This module will be completed soon and included in user studies.

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