How 3D Virtual Humans Built by Adolescents with ASD Affect Their 3D Interactions

Chao Mei
Department of Computer Science
University of Texas at San Antonio
One UTSA Circle
San Antonio, TX, USA 78249-0667 +1 (210) 872-8618
meichaomc@gmail.com

Lee Mason
Interdisciplinary Learning & Teaching
University of Texas at San Antonio
One UTSA Circle
San Antonio, TX, USA 78249-0667
+1 (210) 458-4524
Lee.Mason@utsa.edu

John Quarles
Department of Computer Science
University of Texas at San Antonio
One UTSA Circle
San Antonio, TX, USA 78249-0667
+1 (210) 458-7433
jpq@cs.utsa.edu

ABSTRACT

Training games have many potential benefits for autism spectrum disorder (ASD) intervention, such as increasing motivation and improving the abilities of performing daily living activities, due to their ability to simulate real world scenarios. A more motivating game may stimulate users to play the game more, and it may also result in users performing better in the game. Incorporating users' interests into the game could be a good way to build a motivating game, especially for users with ASD.

We propose a Customizable Virtual Human (CVH) which enables users with ASD to easily customize a virtual human and then interact with the CVH in a 3D interaction task. Previous work has shown that users with ASD may have less efficient hand-eye coordination in performing 3D interaction tasks than users without ASD. We developed a hand-eye coordination training game - Imagination Soccer - and presented a user study on adolescents with high functioning ASD to investigate the effects of CVHs. We compare the differences of participants' 3D interaction performances, game performances and user experiences (i.e. presence, involvement, and flow) under CVH and Non-customizable Virtual Human (with randomly generated appearances) conditions. As expected, the results indicated that for users with ASD, CVHs could effectively motivate them to play the game more, and offer a better user experience. Surprisingly, results also showed that the CVHs improved performance in the hand-eye-coordination task – users had higher success rate and blocked more soccer balls with the CVH than with a non-customizable virtual human.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Evaluation/methodology.

General Terms: Experimentation, Human Factors.

Keywords: customizable virtual human, autism spectrum disorder, 3D interactions.

ASSETS '15, October 26-28, 2015, Lisbon, Portugal

DOI: http://dx.doi.org/10.1145/2700648.2809863.

1. INTRODUCTION

For persons with ASD, 3D training games may have potential benefits, such as improving the abilities to perform daily living activities (e.g., crossing the street in a 3D virtual city [1]). Bekele et al. suggest that the main benefits of virtual reality games in ASD therapy are: the games have the ability to simulate real world scenarios in a carefully controlled and safe environment, as well as controlled stimuli presentation, objectivity and consistency, and gaming elements motivate task completion [2]. Games with 3D User Interfaces (3DUIs) could potentially expand the set of effective training tasks and thus, further enhance such benefits.

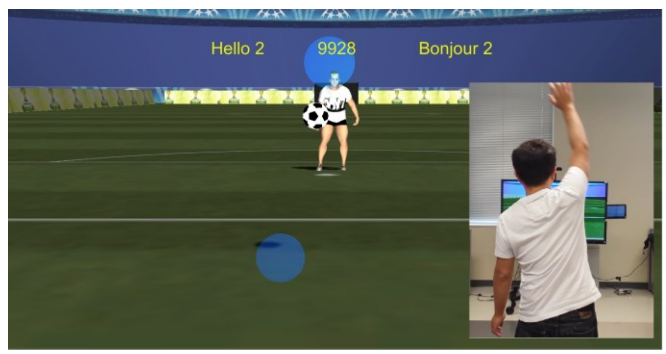

Figure 1. A user is trying to block the soccer ball kicked out by a user customized virtual human.

However, as indicated by Mei. et al [10], users with ASD showed less efficient hand-eye coordination in performing 3D interaction tasks. This could limit the benefits of 3D training games for ASD. A game that trains the hand-eye coordination in 3DUI may help users with ASD improve their 3D interaction performance.

A more motivating training game may stimulate users to try harder in the game. It may also result in users playing the game more, which could potentially improve daily lives for people living with ASD. Including users' interests in the game could be a good way to build a more motivating game. Existing 3D training games seldom take into consideration the fact that there is a wide variety of interests within ASD population. As indicated by Robert et al., everyone diagnosed with ASD is remarkably different [3]. Individuals with ASD often have very specific interests, some of which are uncommon, such as a certain alphabetical letter, washing machines, etc. Moreover, their interests are often restricted; topics outside of their specific interests often do not effectively capture their attention. The wide variety of individuals on the ASD spectrum makes it almost impossible to include all interests in 3D training games. Allowing customization and personalized content importation in the 3D training games could help address this issue and increase the game motivation and performances. Previous studies suggested that virtual humans with different appearances could evoke different reactions from general users [4-7]. However, it is not known how virtual human appearance customization would affect persons with ASD, or what effect it has on 3D interaction.

Therefore, our main research question is: how does a customizable appearance of the Virtual Human (VH) affect 3D interaction task performance and user experience for users with ASD? To investigate this question, we developed a Customizable Virtual Human (CVH) and a 3D hand-eye coordination training game - Imagination Soccer. To determine the training effects of the CVH and the game, we present a user study including adolescents who have a high ASD severity score, but were still considered as high functioning (IQ of 80 or above, and be able to speak, read and write). Specifically, we investigated: 1) if/how the CVH increases the 3D interaction performance for users with ASD, and if the CVH motivates them to play more rounds in the game, and 2)if the CVH improves the subjective user experience (i.e. presence, involvement, and flow) in the 3D training game with respect to users with ASD.

2. RELATED WORK

Our hypotheses about the potential benefits of CVH for persons with ASD were influenced by previous research in related areas: virtual humans, accessibility needs of the ASD population, customizable virtual humans/self-avatars, and the use of customization in existing ASD therapies.

2.1 Appearances of Virtual Humans

Many researchers have demonstrated that virtual humans with different appearances could evoke different reactions from users. For example, Vugt et al. reported that users respond more positively when they were exposed to virtual humans that had similar facial features to the users' faces, instead of dissimilar ones [5]. The concordance between the users' and VHs' appearances were also studied by Rivera-Gutierrez et al. [7]. They explored the effects of dynamic virtual humans on user perceptions of their interaction. The dynamic virtual humans selected their appearances according to user information such as weight, height and gender. Their results indicated that the concordance between the users' and the virtual humans' appearances positively affected the male users' perception of VH knowledge through the interaction but had negative effects on female users' perception of VH knowledge. Zanbaka et al. also reported the influence of the gender on virtual humans [4], they found that users were more persuaded by virtual humans of opposite sex. Moreover, Dan et al. conducted a study in which participants rated ergonomic posture of virtual humans [6]. The ratings were higher among the virtual humans with more realistic appearances, even though the appearances were not typically considered as a factor influencing ergonomic posture ratings. Various aspects of the VH's appearances have been shown to effectively influence users' responses. However, it is not known how virtual human appearances affect persons with ASD.

2.2 Special Accessibility Needs of ASD Population

The number of children diagnosed with Autism Spectrum Disorder (ASD) is increasing at an alarming rate. According to the Centers for Disease Control and Prevention (CDC), the prevalence of ASD in the United States has grown from 1 case per 150 children to 1 case per 68 children from the year 2000 to 2010. ASD is marked by impaired social communication and social interaction, accompanied by atypical patterns of behavior and interest [8].

Children with ASD have shown inefficient hand-eye coordination in the real world [9] and 3D interactions [10]. Hand-eye-coordination refers to the ability of the vision system to coordinate the information received through the eyes to control, guide, and direct the hands in the accomplishment of a given task, such as handwriting or catching a ball. Research has demonstrated a strong correlation between hand-eye coordination, learning abilities, and social communication skills [11]. Thus, ASD therapies have widely adopted hand-eye coordination training as a part of their curricula [12]. Practicing such abilities in a game could potentially assist with ASD therapies.

It has been well known that people with ASD have disabilities in identifying others' emotion. These disabilities have been found both for facial and bodily expressions in the real world. Such disabilities were also found in a Virtual Environment (VE). For example, Bekele et al. investigated how people with ASD responded to facial expressions in a VE [2]. The results suggested that people with ASD had facial emotion recognition deficiencies in VEs as well. Rather than the facial emotion recognition, a system is needed to evaluate and help improving the bodily emotion recognition ability, which, to our knowledge, has not been investigated in VE for people with ASD.

2.3 Customizable Virtual Humans

There are several research papers that have focused on customizing actions of VHs. These works presented several benefits of customization in VR applications. For example, Reategui et al.[13] demonstrated a virtual human that was able to present customized content in an online learning system. It was shown to have a positive impact in the users' acceptance of the system. SitePal [14] is an online application, it allows users to customize the interaction content with a speaking VH for their own websites. In a case study of SitePal, a college level course was designed with a virtual instructor built from this tool, and it resulted in higher grades of the students. However, they did not explore the effects of customizable appearances of VH.

There is minimal previous research regarding the benefits of appearance customization of virtual humans. However, we did find a paper that presented a drawback of it. Okita et al. [15] evaluated the learning process with virtual peers and showed that allowing students to customize their virtual peers led to lower performance on a test than non-customized peers. The reason could be that the customized appearance resulted in distraction. However, this result is not necessarily generalizable to the ASD population due to their different cognitive processes than the typically developed (TD) population.

2.4 Customizable Self-Avatars

Most of the research that explored virtual human appearance customization was focused on self-avatars – the representation of the user's own body in virtual reality. Customizable self-avatars are often found with interesting psychological effects and training benefits. Yee et al. found that self-avatar customizations changed users' preferences in games [16]. Bailey et al. conducted a study that demonstrated how avatar customization elicited the feeling of presence during game play. Bessiere et al.[17] explored the self-avatar identity presented in an online multiplayer game. In that game, players interacted with other online players through customized self-avatars. Results showed that players built their self-avatars more similarly to their ideal body rather than their actual bodies in real life. This correlation was stronger among those with lower psychological well-being. Ducheneaut et al.[18] compared different customization tools and suggested several factors that are important for a self-avatar customizing system, such as hair styles and colors.

These works inspired us in the design of our CVH, such as the variables that should be customizable (e.g., hair). However, self-avatars and virtual peers perform different roles in VEs. They could have a different impact on user experiences and it is unknown how this will impact ASD users' experiences.

2.5 Customization in ASD Therapy Software

Although we could not find research on virtual human appearance customizations for the ASD population, there is some research that investigated the customization of other aspects. For example, Robert et al. presented an algorithm that enabled the users with ASD to put images based on their interests into flash games. They suggested that users with ASD enjoyed customized games more than the non-customized version, but the effects of customization on ASD therapy have not been formally evaluated. Tartaro et al.[19] introduced a virtual peer who has an authorable storytelling process. It was able to support the development of communication and reciprocal social interaction skills of ASD children. These results further suggested that customizable virtual humans could potentially benefit ASD therapy.

3. OUR PROPOSED CONTRIBUTIONS

The effects of CVH in 3D training games with respect to ASD users are unknown. The main goal of our research is to find out the effects of CVH on 3D interaction performances and the effects on the motivation in 3D training games for ASD users. Specifically, this research provides novel insights into:

- How CVHs affect the performance of adolescent users with ASD in a 3D hand-eye coordination training game.
- The user experiences (i.e. presence, involvement, and flow) effects of CVH in a in a 3D training game for adolescent users with ASD.
- Generalizable guidelines for enabling future CVHs in 3D games for adolescents with ASD.

4. SYSTEM DESIGN

We developed a Customizable Virtual Human (CVH) and "Imagination Soccer" - a 3DUI-based game in which users play as a goalie in a soccer game with a CVH plays as a kicker. The ball catching task is adopted by many clinics as part of the therapy that helps improving hand-eye coordination for ASD patients. The game is designed to motivate training, improve hand-eye coordination in 3D interaction task, and increase bodily emotion recognition ability for ASD individuals.

4.1 Imagination Soccer Physical Set Up

Imagination Soccer is a VR game set up in an environment as shown in Figure 3. The system was equipped with one LED TV, one Microsoft Kinect sensor and a tablet. A laptop was used at the back end for controlling the system and rendering the graphics. The specifications of each piece of the system is listed as below:

The 55" LED TV is positioned at 1.2 meters above the ground, which makes view of the screen comfortable for most adolescents. We did not evaluate the 3DUI with immersive displays(e.g., a head mounted display), because they are not as easy to accesses as flat TVs. Moreover, we did not use a stereoscopic display since they are also not a widely available and require users to wear additional glasses, which could be distracting for some children with ASD. In addition, 2D displays can still present 3D content with very good 3D depth cues, and moreover, most of the 3D games of entertaining and training are still using the 2D displays. Therefore, for the 3D interactions in training games, we think it would be more reasonable to start doing the evaluation with an accessible setting rather than uncommon ones. We plan to investigate stereoscopic displays in future work.

The Microsoft Kinect is placed on top of the TV to track the users' motions. The tablet placed at the right side of the TV screen is used both as an input and output device. In the game, it displays a soccer ball on its screen. Users swipe the soccer ball off the touch screen in order to pass the ball to the virtual human on the screen, as shown in Figure.3(c). The position of the tablet is aligned with the virtual soccer ball on TV screen in order to provide the illusion of really sending the ball from the tablet back onto the TV screen. More details on the game process will be discussed in section. 4.3. A TOSHIBA Qosmio laptop was connected with the TV, Kinect and tablet through a HDMI cable, USB cable and local wireless network respectively.

4.2 Customizable Virtual Human

The CVH is designed to enable the users to implement an imaginary play companion, based on their individual interests. Users customize the CVH with a simple interface that is easy to learn (Figure 2.) and includes many variables that can be customized.

4.2.1 Customizable Variables

Users customize the CVH by modifying 9 variables. These 9 variables were partially inspired by a previous survey made by Ducheneaut et al.[18]. They made comparisons between different customization variables in games and the effect on user experiences. They suggested several factors that are important for a self-avatar customization system. We picked several popular ones that are related to the appearances of virtual humans (i.e. hair style and color, fat level, muscular level, height, skin color, and gender). Previous results were based on virtual self-avatars not a play companion, we also added some variables that could be relevant to a play companion (i.e. name, t-shirt pattern and age). The details of these variables are listed below:

- *Hair style and color* is selected from 23 different predefined hair models (i.e., 10 for male CVH, 13 for female CVH). Each hair model is in a different style or color.
- *Fat level, muscle level and height* are each set by any value from 0 (minimum level) to 100 (maximum level). They are continuous variables that morph the shape of the CVH's whole body.

- *Skin color* is selected from 2 options - light skin and dark skin.
- *Gender* is selected from 2 options - male and female.
- *Name* is set by typing any string, which appears during the game next to the score.
- *T-shirt patterns* can be customized in two ways: 1) Users search online for interesting images. The CVH automatically adjusts the image size and inserts it into a white t-shirt texture on the chest. 2) Additionally, users can select from 7 predefined t-shirt textures.
- *Age* is selected from 3 different age groups - little kids, teenagers and adults. In each age group, there are two initial models - male and female. Each initial model has different ranges for fat level, muscle level and height, according to the age and gender.

4.2.2 User Interface for CVH

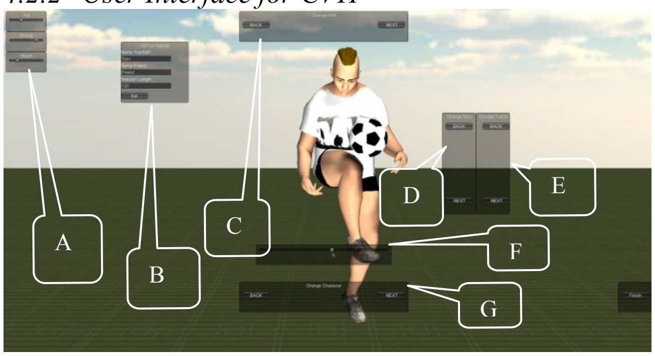

Figure 2. User Interface of CVH.

Each variable is set through a simple user interface that is easy to learn as shown in Figure 2. A VH stands in the middle and plays with a soccer ball. Users interact with three slider bars with mouse (Label A) to control the three continuous variables - fat level, muscle level and height. Age and gender (Label G), hair models (Label C), skin color (Label D) and t-shirt pattern (Label E) control were all composed from the combination of a "Last" and "Next" buttons to switch between each predefined whole body models, parts models, textures, and real-time generated textures. Users input their own name and the name of the VH through two textboxes (Label B). We positioned the control panels close to the VH's parts that they controlled (e.g. the hair control panel is placed on top of the virtual human's head). The user could observe the VH with 360 degree view using a slider bar (Label G).

4.3 Game Process

After the user finishes the customization of a virtual friend, the main game interface is presented on the TV screen (shown in Figure 1). The game trains the 3D hand-eye coordination by simulating a ball-catch scenario. It takes place in a soccer stadium. The virtual friend stands in front of the penalty kick mark with idle animation of breathing. The scoreboard is shown above the virtual friend with the names and scores of the friend and the user on it. The middle of the scoreboard shows the remaining time of the current round. The two blue discs are the representations of user's hands in the game. The user initially does a 'T' position to set the calibration before the start of the game. The initial distance of the two blue discs are mapped to the distance between the user's hands in the real world during the initial calibration. Thus, the user's arm length does not affect the difficultly level or playability of the game. The tablet is attached at the right side of the TV screen and it displays a 3D model of a soccer ball.

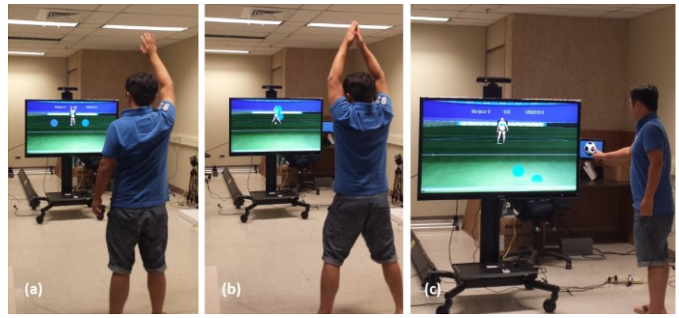

Figure 3. (a) Waving. (b) Jumping Jack. (c) Passing ball to VH.

Users stand approximately 2.5 meters in front of the TV screen as shown in Figure 3(a). The game can identify three kinds of motion input from users and touch input from the tablet. First, the game takes inputs from left and right hands' positions to control the two blue discs on the screen. Users position the discs by positioning their real hands. However, moving hands forward or backward does not affect the disc position in order to limit the difficulties brought by depth perception. The other two motion inputs are waving as shown in Figure 3(a) and jumping jacks, shown in Figure 3(b).

At the beginning of the game, the user does jumping jacks as a warm up activity. Jumping jacks are adopted by many clinics as part of the therapy that helps improving body coordination for ASD patients. Users' jumping jacks motions are captured and evaluated. If the user correctly performs a jumping jack, the virtual human does a jumping jack as well.

Users start the game by waving at the virtual friend, in order to indicate the user is ready to play. Next, the virtual friend waves back to the user and then kicks the ball. The target of each kick is selected from a set of equally divided 3x3 points on the TV screen. After the ball is kicked and flies for 2 sec., it hits a target location and disappears. The 2 sec. was decided through pilot studies in order to keep the game challenging, but still provide users enough time to react. The user takes these 2 seconds to judge the target through the trajectory of the ball, and then moves the discs to the target location to block the ball as shown in Figure 1. If the ball is blocked successfully, the user gets 1 point and the disc(s) that blocked the ball will flash red, otherwise the virtual friend gets 1 point. In response to a blocked ball or a missed ball, the virtual human plays various animations, showing either sad or happy emotions, respectively. The sound effects of cheering from the audience accompanies the sad animations. The sound effect of cheering from the virtual friend accompanies the happy animations. After each kick, the ball appears on the tablet, and the user needs to go to the tablet and swipe the ball in order to pass the ball back to the VH (Figure 3(c)). At the end of each round, the VH rewards the user by doing push-ups or dancing. For each point the user got, the virtual friend does a push-up. For every 5 points the user got, the virtual friend does a dance.

5. USER STUDY

We conducted user study with participants who were diagnosed with high functioning autism. In a randomized and counterbalanced within-subjects design (i.e. participants were their own controls), the participants interacted with both the CVH and a randomly assigned non-customizable VH (NCVH). The NCVH has same set of customizable variables as the CVH, however the value of the variables is randomly generated by computer and cannot be adjusted by users.

5.1 Hypotheses

Previous work suggested that including personalized content in a game may enable users with ASD to enjoy the game more than without personalized content[3]. Although this result was not formally evaluated, the authors suggest that this personalization could lead to more motivation in training. Moreover, other works have shown that ASD users are interested in defining behaviors of and interacting with virtual companions[19]. Thus, based on the literature, allowing customization of a virtual human in 3D training games may improve ASD users' overall user experience with the game and ultimately increase their motivation to continue rehabilitation.

The hypotheses are related to 3D interaction task performance and user experiences. Specifically our hypotheses are:

Hypothesis 1: Playing with CVHs will help participants to perform better and play more rounds in a 3D hand-eye coordination training game.

Hypothesis 2: CVHs will give the users a better user experience - specifically with respect to presence, involvement, and flow in the game.

Before the study, we were very confident that the CVHs would provide better user experiences for users, but less confident to say it would result in better game performance. The evidence in previous research lead us to the Hypothesis 2, but they did not clearly indicate Hypothesis 1. Due to a lack of previous work in performance effects, we designed this study to investigate a CVH's impact on both user experience and performance.

5.2 Participants

10 participants were recruited with the help of local support groups, research institutes and non-profit ASD support organizations from (removed for review), with ages ranging from 9 to 18 years. We recruited participants at adolescent ages because adolescence is an important time to develop many useful skills such as communication abilities and exercise abilities that can be potentially trained with 3D training games. Participants had been diagnosed with high functioning ASD. To eliminate the gender influence as a variable and the great gender disparity incidence rate of autism between male and female, in this current study, we did not recruit any female participants with ASD. All participants reported some prior experience and familiarity playing video games.

To be included in the study, participants with ASD had to score greater than 71 in the Gilliam Autism Rating Scale-3 (GARS-3) test. The GARS-3 questionnaire is used in identifying and estimating the severity of autism in participants. 71 is a threshold that indicates a severe autism. From their reports and our observation, these participants did not have any other disability that would limit understanding and performing the study tasks.

5.3 Study Processes

The study was conducted in an indoor lab. Only the experimenter, the participant, and the participant's guardian were allowed to present. The total duration of the study was about one and a half hours per participant, including training, customizing, performing tasks and resting. Each participant was paid 50 dollars.

5.3.1 Setup and Training

To initially setup the CVH, we first asked the users to find 3 images that they were interested in using. We used Google Image Search to find the images and save them in the game folder. The CVH automatically identified these images and generated new t-shirt textures with them. The online images were resized to fit on the chest part of the t-shirt. The new textures later appeared as customization options, when participants customized the t-shirt pattern of CVH.

We conducted a training session after the participant finished the image selection. The experimenter first showed a demo of how to perform a calibration 'T' pose with the hands, to block a ball, and to use the tablet to send the ball back. The participant then played for 3 kicks as training. The training was conducted without any virtual human so as to not bias the training.

5.3.2 Study Part 1: Time Limited Play

In the study part 1, users played with both CVH and NCVH for same amount of time. We mainly investigated how CVHs influence game performance (i.e. the 3D interaction performance) in this part. It included two sessions. Each session had time limit of 60 seconds. This time limit was determined from pilot studies - it was a time that would not make a participant feel too tired after a session. In these two sessions, the participants played one session with a CVH customized by themselves, and one session with a randomly assigned NCVH. The initial values of the customizable variables for the CVH and NCVH were all randomly set, however the variables of CVH could be adjusted by the participants and the initial variables for NCVH remained the same during the whole study. The order of the sessions was randomized for each participant. The two sessions were repeated twice. However the first two sessions were considered as warm up sessions and are not included in the study results. Between each session, users were required to have sufficient rest and finish the questionnaire regarding the user experiences in that session. If the coming session had a CVH, the participant was given the option to customize the CVH, before the session started.

In each session, the participant first stood on a playing line 2.5 meters away from the screen and did jumping jacks to warm up. The CVH/NCVH did a jumping jack reacting to each one the participant performed successfully. Participants could stop doing jumping jacks and start the game when they decided they were ready. In the game, participants first went to the tablet and swiped the ball to pass it to the CVH/NCVH. Then the participant went to back the playing line and waved their hand to tell the CVH/NCVH to start kicking. After the user blocked or missed the ball, the CVH/NCVH displayed happy or sad emotions accordingly with body animations and sound effects. Then the ball was displayed again on the tablet. The participant needed to go back to the tablet and repeat the above actions to finish another round. A scoreboard showed the scores of the participant and CVH/NCVH, the names of participant and CVH/NCVH, and remaining time. A blocked ball was counted as one point for the participant, while a missed ball was counted as one point for the CVH/NCVH.

After 60 seconds of playing time in a session, the CVH/NCVH rewarded the participant for the scores they earned. For each point the participant got, CVH/NCVH did a push up. For each 5 points the participant got, CVH/NCVH would do a dance. Therefore, participants were instructed to play as many rounds as possible within a session and were rewarded for playing more rounds. They were able to control the pace of the game by adjusting their walking/running speed when the game made them go back and forth between the tablet and the playing line.

5.3.3 Study Part 2: Free Play

In study part one, participants were given time limits to interact with CVH/NCVH to eliminate time and ordering as confounds in the study. However, we also wanted to investigate our research questions in a more realistic scenario that allowed participants to freely choose to play with the CVH or NCVH with no time limits, so that we could investigate how CVH affects the users' motivation to play the games. Thus, in part 2, participants had the freedom to play any number of sessions without any time limit on each single session. In each session, they also were free to select from NCVH or CVH and they had the freedom to customize/re-customize the CVH before each session played with it. The only mandatory rule in study part 2 was that the participant was required to play at least one kick-block under both conditions - NCVH and CVH. We expected the participants to feel more relaxed to play with these rules compared with the rules in part one.

The other settings were similar to study 1, except that instead of answering questionnaires between each session, participants answered questionnaires only when they switched between NCVH and CVH. We made this change in part 2 because too many questionnaires could have influenced the number of sessions they wanted to play. We also removed the requirement of doing jumping jacks before each session to maintain the participant's energy.

5.4 Metrics

The metrics include the participants' performances in the game, their subjective feedback, and pre/post study tests scores.

5.4.1 Game Performance

Success Rate: in each session, the Success Rate was calculated by Number of Blocks/ Number of Kicks (i.e., the percent of kicks that were blocked).

Number of Kicks and *Number of Blocks*: how many rounds were played during each session and in how many rounds did the participant successfully block the ball during each session.

5.4.2 Subjective Feedback

PIFF2 [20]: The Presence, Involvement, and Flow Framework 2 (PIFF2) is a validated questionnaire that measures many aspects of user experience specifically for video games. It is a set of 15 questions each answer was a ranking with a score range from 1 -7. The PIFF2 was answered after each session in study part 1: time limited play and when the participant switched between VH and CVH in study part 2: free play.

5.4.3 Pre/post Study Tests

Emotion Identification Score: Because the game included content showing the emotion of a VH, we investigated how effectively users could recognize emotion. Therefore, before part 1 and after part 2, we played three clips of animations in which a VH was expressing some emotion with its body. These animations came from the set of animations when the VH showed happy or sad emotions in reaction to user blocked or missed a ball. The participants were required to identify these emotions. We counted each correctly identified emotion as one point. The results remained unknown to the participants during the study.

6. RESULTS

We performed Paired t tests on normally distributed data (numerical data, such as *Success Rate*) or Wilcoxon signed rank tests where data did not have a normal distribution (ordinal data, such as the *PIFF2* questionnaire) to compare the differences of the measurements under different conditions, using Bonferroni correction where appropriate. The results are reported in this section with their related hypotheses.

6.1 Performance and Training

6.1.1 Study Part 1: Time Limited Play Performance

The first hypothesis is: Playing with CVHs will help participants to perform better and play more rounds in a 3D hand-eye coordination training game. We were less confident about this hypothesis. But surprisingly we found our study results support this hypothesis. *Success Rate*s was compared between the CVH and NCVH conditions to verify this hypothesis, since it is directly related to the 3D interaction performance. The order of CVH and NCVH was randomized in study part 1, so that *Success Rate*s would not be confounded by the order.

In study part 1: time limited play, the *Success Rate*s were compared with paired t tests. We found that the *Success Rate* was significantly higher under the condition of CVH ($M = 0.93$, $SD = 0.11$) than NCVH ($M = 0.86$, $SD = 0.22$) condition; $t(9) = 1.950$, $p = 0.041$(one tailed). Figure. 4 shows the distributions of the *Success Rate* over the two conditions.

6.1.2 Study Part 2: Free Play Performance

We did not compare the *Success Rate* in study part 2 (free play), since 1) part 1 and part 2 had different timing rules, 2) the initial *Success Rate* in part 2 could be potentially affected by the training effects from study part 1, and 3) some participants only played a single kick with NCVH in order to meet the study requirement in study part 2. In this study part, participants were free to switch back and forth to any VH and played without a time limit. Thus, the number of rounds with CVH and NCVH were not necessarily equal, it could depend on how they were motivated to play with the VH. Therefore, instead of *Success Rate*s, we compared - *Number of Kicks* under CVH and NVCH conditions. We found participants played significant more rounds during the sessions played with CVH ($M = 22.2$, $SD = 12.9$) than NCVH ($M = 10$, $SD = 9.5$); $t(9) = 2.110$, $p = 0.032$(one tailed). We also compared the *Number of Blocks* which could indicate their training progress in the game and be related to how many rewards (i.e. dancing, pushups) they can get from the VH. The results showed that *Number of Blocks* is significant higher under the condition of CVH ($M = 17.7$, $SD = 9.5$) than NCVH ($M = 7.9$, $SD = 7.4$) condition; $t(9) = 2.188$, $p = 0.028$(one tailed).

6.1.3 Emotion Recognition Training

Because the game included content showing the emotion of a VH, the emotion recognition could be another training benefit of the game. Therefore, we investigated the emotion recognition training effects as well. Instead of comparing results under the conditions of CVH and NCVH, we compared the *Emotion Identification Score*s prior to and post the whole study to investigate the training effects of emotion recognition in the game. The *Emotion Identification Score*s were tested with Wilcoxon test. We found significant increases on the *Emotion Identification Score*s in tests prior to and post the study (Z = 2.460, p = 0.007).

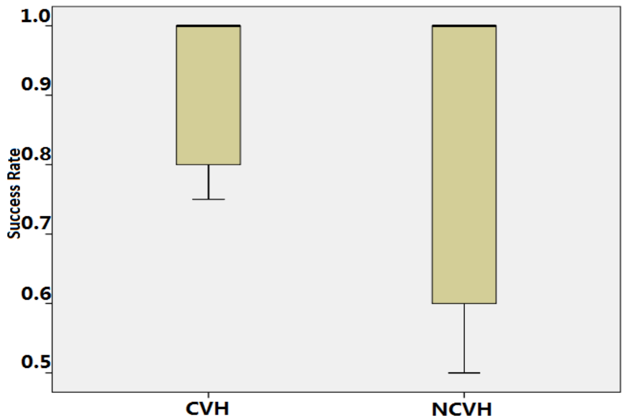

Figure 4. The box plots of the *Success Rate* over CVH and NCVH conditions in study part 1 (boxes are the range of quartiles, whiskers represent the min/max value outside the quartiles).

6.2 User Experience

The second hypothesis is: "CVHs will give the users a better user experience - specifically with respect to presence, involvement, and flow in the game". We performed Wilcoxon test on *PIFF2* questionnaire under the condition of playing with CVH/NCVH. We tested the *PIFF2* during the resting time after participants played with CVH and NCVH. In the study part 2 (free play), playing with CVH and NCVH for at least one round each was a mandatory in order to make sure this test was performed under both CVH and NCVH conditions.

In the comparison of Study Part 1 (time limited play), we found a significant difference on *PIFF2* questionnaire No.1: "I felt that I was one of the characters in the story of the game." - Role Engagement. Sense of role engagement was significantly increased (Z = -2.121 p = 0.017) under the condition of playing with CVH; a higher score for CVH condition on the item No.7: "I felt I could meet the demands of the playing situation." - Competence (Z = -1.897 p = 0.029); No. 12: "I was astonished and surprised at the game world" - Impressiveness (Z = -1.725 p = 0.042). In study part 2 (free play), we found a significant higher score for CVH on the item No.11: "I would recommend it to my friends" - Enjoyment (Z = -1.732 p = 0.041).

6.3 Post-interview

At the end of the study, we performed a short interview regarding CVH/NCVH. On interview question 1, "Which friend do you prefer to play with? Why?", 2 participants preferred NCVH, 8 preferred CVH. The 2 participants who preferred NCVH pointed out the same reason: they thought the NCVH was a better player. The main reason why participants preferred the CVH was that they liked the design. Two mentioned that they designed it to look like one of their real friends. The second question was regarding the importance of the customizable variables. The rank of customizable variables from more important to less important was: age, t-shirt pattern, body shape, hair style, height, gender and skin color. On the third interview question, "How difficult or easy was it to customize your friend (on a scale of very easy 1-7 very difficult)?". Most participants said it was very easy (1).The fourth interview question asked the participants to list a few more customization variables they would like to see in a future version of the game. Most of the answers were related to more detailed customization, such as shoes and accessories.

7. DISCUSSION

The main research question for this work is: how does a customizable appearance of the VH affect 3D interaction task performance and user experience for users with ASD? We proposed two hypotheses to investigate this question.

7.1 Performance and Training

The first hypothesis is: Playing with CVHs will help participants to perform better and play more rounds in a 3D hand-eye coordination training game. We used the *Success Rate* to reflect the hand-eye coordination ability in 3D interaction tasks. We found a significant increase on this measurement when users played with CVH in study part 1. This could mean that the CVH helped participants further improve training of hand-eye coordination and/or that participants tried harder with the CVH in study. Moreover, in study part 2, the significantly increased *Number of Kicks* in the CVH condition suggests that participants played more rounds with CVH. The *Number of Blocks* is significant higher under the condition of CVH. This measurement is based on the training goal progress they made in the game – i.e., performance of hand-eye coordination in 3DUI. During the study, we observed that most of the participants felt excited when they saw the VH dancing. As one parent said: "I never see him so excited in a game!". It is possible that participants enjoyed watching the CVH dancing, which motivated them to play more rounds and try harder with the CVH. These results support hypothesis 1.

In addition, significant higher *Emotion Identification Score*s were found in the post study test. Although they were evaluated on only a small set of bodily emotion expressions related to the game content, it sheds some light onto the potential of 3D training games.

As a limitation of the study, it is not clear if the bodily emotion recognition effects were related to CVH or NCVH, since all the participants had played under both conditions in the study.

7.2 User Experience

The second hypothesis is: "CVHs will give the users a better user experience - specifically with respect to presence, involvement, and flow in the game." We found in study part 1 (time limited play), that participants had significantly more feelings of role engagement, competence and impressiveness during the sessions played with CVH. In study part 2 (free play), participants had significant more feelings of enjoyment. Thus, these support hypothesis 2: the CVH will give the users with ASD a better user experience.

Although the results showed a better user experience brought by CVHs, it is possible that the different rules in time limited play and free play also contributed to user experiences. How the game rules influence on the user experiences could be another interesting future research question.

8. CONCLUSION

We developed a CVH that is easy for adolescents with ASD to customize a 3D Virtual Human, and a 3D hand-eye coordination training game - Imagination Soccer. In our study, we found that including customizable elements in a 3D hand-eye coordination training game could increase 3D interaction performance during the game and potentially help ASD participants to play more rounds in the a 3D training game. In addition, the CVH improved the user experience (i.e., presence, involvement, and flow) of ASD participants in the game. These results further motivate the usefulness of 3D training games for persons with ASD and highlight the need for more customization and personalization options for the ASD population.

Our findings suggest that for users with ASD, providing customizable content may result in increased motivation and/or effort, which may lead to improved performance of 3D interaction tasks.

In the future, we plan to enable more customization options for CVHs, such as customization of facial features and integrate CVHs into more 3D training games. The ultimate goal is to determine the most effective approaches to motivate the users in training games.

9. ACKNOWLEDGMENTS

We would like to thank the participants of our study and the local support groups that allowed us to recruit the participants.

10. REFERENCES

[1] AHRQ, 2013. Autism Spectrum Disorder—An Update.

[2] T. R. Goldsmith, 2008. Using Virtual Reality Enhanced Behavioral Skills Training to Teach Street-crossing Skills to Children and Adolescents with Autism Sectrum Disorders, *Doctoral dissertation, Western Michigan University*.

[3] E. Bekele, Z. Zheng, A. Swanson, J. Crittendon, Z. Warren, and N. Sarkar, 2013. Understanding How Adolescents with Autism Respond to Facial Expressions in Virtual Reality Environments, *IEEE Transactions on Visualization and Computer Graphics,* 19, 4, 711-720.

[4] R. Morris, C. Kirschbaum, and R. Picard, 2010. Broadening Accessibility Through Special Interests: A New Approach for Software Customization, *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility*.

[5] C. Zanbaka, P. Goolkasian, and L. Hodges, 2006. Can a virtual cat persuadeyou?: the role of gender and realism in speaker persuasiveness, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.

[6] H. C. V. Vugt, J. N. Bailenson, J. F. Hoorn, and E. A. Konijn, 2010. Effects of facial similarity on user responses to embodied agents, *ACM Transactions on Computer-Human Interaction,* 17, 2.

[7] D. Lämkull, L. Hanson, and R. Örtengren, 2007. The influence of virtual human model appearance on visual ergonomics posture evaluation, *Applied Ergonomics,* 38, 6, 713-722.

[8] D. Rivera-Gutierrez, R. Ferdig, J. Li, and B. Lok, 2014. Getting the Point Across: Exploring the Effects of Dynamic Virtual Humans in an Interactive Museum Exhibit on User Perceptions, *IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS,* 20, 4.

[9] A. Crippa, S. Forti, P. Perego, and M. Molteni, 2013. Eye-Hand Coordination in Children with High Functioning Autism and Asperger's Disorder Using a Gap-Overlap Paradigm, *Journal of Autism and Developmental Disorders,* 43, 4, 841-850.

[10] C. Mei, L. Mason, and J. Quarles, 2014. Usability Issues with 3D User Interfaces for Adolescents with High Functioning Autism, in *Proceedings of the 16th international ACM SIGACCESS conference on Computers and accessibility*.

[11] C. Yu and L. B. Smith, 2013. Joint Attention without Gaze Following: Human Infants and Their Parents Coordinate Visual Attention to Objects through Eye-Hand Coordination, *PLoS One,* 8, 1.

[12] N. S. P. Therapy, 2014. *Eye Hand Coordination*.

[13] E. Reategui, E. Boff, and J. A. C. b, 2008. Personalization in an interactive learning environment through a virtual character, *Computers & Education,* 51, 2, 530-544.

[14] O. Inc, 2014. "Sitepal,". DOI=*http://www.sitepal.com/*.

[15] S. Y. Okita, S. Turkay, M. Kim, and Y. Murai, 2013. Learning by teaching with virtual peers and the effects of technological design choices on learning, *Computers & Education,* 63, 176-196.

[16] N. Yee and J. Bailenson, 2007. The Proteus effect: the effect of transformed self-representation on behavior, *Health Communication Research,* 33, 3, 271–290.

[17] K. BESSIÈRE, F. SEAY, and S. KIESLER, 2007. The Ideal Elf: Identity Exploration in World of Warcraft, *CYBERPSYCHOLOGY & BEHAVIOR,* 10, 4, 530-535.

[18] N. Ducheneaut, M.-H. Wen, N. Yee, and G. Wadley, 2009. Body and Mind: A Study of Avatar Personalization in Three Virtual Worlds, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.

[19] A. Tartaro and J. Cassell, 2006. Authorable Virtual Peers for Autism Spectrum Disorders, in *Proceedings of the Combined workshop on Language-Enabled Educational Technology and Development and Evaluation for Robust Spoken Dialogue Systems at the 17th European Conference on Artificial Intellegence*.

[20] J. Takatalo, J. Häkkinen, J. Kaistinen, and G. Nyman, 2010. Presence, involvement, and flow in digital games, in *Evaluating user experience in games* ed: Springer. 23-46.