VR for ASD: Therapeutic Environments for Individuals on the Autism Spectrum

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Abstract

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects individuals on a large spectrum; some of these individuals are considered high functioning while others while others experience significant impairments in that impact their ability to function in their daily lives. One such symptom is sensory overload due to hypersensitivity, which is often crippling for individuals across the autism spectrum. This study looked into the viability of using a virtual underground transit environment to help individuals grow accustomed to noises and lights and to help these individuals function even when they are hypersensitive to their surroundings. Seven adults, five diagnosed with high functioning autism and two diagnosed with more significant impairments, test the program. It was found that the heart rate of the individuals on the spectrum had decreased while experiencing the environment and they also face no virtual reality sickness. These findings suggest that virtual reality environments can be a therapeutic and effective training mechanism for improving cognition, adaptability, and functioning in autism.

Keywords

Autism Spectrum Disorder, Sensory Overloading, Social Interaction, Virtual Reality

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is characterized by difficulties with social communication and interaction, verbal and nonverbal communication, and repetitive behaviors (Amir, et al, 1999). ASD affects individuals on a large spectrum (Lord, et al, 2000; Tsai, 1992; Rutter, 1978; Strickland, 1998; Bölte & Hallmayer, 2011); some people with high functioning ASD have little impact in their daily functioning while others experience significant impairments including little to no language skills and intellectual disability. Sensory overloading occurs when individuals diagnosed with ASD have difficulty processing everyday sensory information, which then in turn affects behavior by causing stress, anxiety, and even physical pain at times (The UK National Autistic Society, 2016; Hendricks & Wehman, 2009). The effects of hypersensitivity to sights, sounds, balance, and spatial awareness can be crippling when attempting to perform day-to-day activities. Studies in the past have quantified social cognition, and interpersonal functional skills over time, using an array of non-technological advanced methods, and have provided researchers with mixed results. The methods behind this sort of research have been predominantly broken down in the following categories: observational techniques (scenario based conversations) (Howlin & Yates, 1999), self-rated questionnaires (Hillier, et al, 2007), and the recording and quantification of social performance measures (Golan & Baron-Cohen, 2006). Though this portion of research on ASD has provided significant insights on the development of possible interventions, it is limited in that it fails to address concerns outside of group based social aptitude.

To address some concerns of testing individual independence, social interactions/behavior in a large group setting, and specifically independence in the group environment there has been a push to use virtual reality (VR) as a new generational intervention tool. VR has shown relative success in improving social competence and helping individuals develop coping mechanisms to diagnosed severe paranoia (Autism Speaker, 2014; Oxford University 2016; Freeman, et al, 2016). With recent developments in VR technologies, such as potable headsets, ASD research involving VR environments is dispersed. Early studies seem to be focusing on the utilization of VR by children/adolescents, diagnosed with ASD, as a way to develop social cognition skills from an early age. These early VR utilization studies focused on research ranging from teaching basic skills, such as street-crossing (Josman, et al 2008), to social interaction skills, such as emotion recognition and social convention (Cheng & Ye, 2010; Parsons, et al, 2004). These studies, using older VR technologies, demonstrated two different things at the time. First being that the overall hypothesis put forward, that VR environments can be used to practice social cognition, was supported by numerous studies. Secondly, it also opened up a whole new array of opportunities for research today by demonstrating that most individuals with ASD can grasp the concept of VR, use and enjoy it, and implement it as a method of practice and personal development.

However, these early studies presented their own limitations as VR technology became more sophisticated over time, in both interaction and data collection. Current VR technologies hold the key to developing efficient and realistic intervention tools for autistic individuals by providing an accommodating audio/visual platform to safely develop overall cognitive functionality. Very few published studies focus on VR training as intervention techniques for adults, and of those few all of them focus on improving upon social interactions. The *VR for ASD: Therapeutic Environments* (*VR-ASD:TE*) is a training ecosystem developed as an intervention tool for all individuals, diagnosed with ASD, with sensory hypersensitivity. The initial and primary goal of developing this platform was to provide autistic individuals an environment to slowly grow accustomed to an underground transit system, such as the New York City Subway. A secondary aim was to measure and record the changes in the user's heart rate while he or she was immersed in the environment.

Discussion

Why VR Could Be Useful

The strengths of a VR ecosystem greatly complement the need of interventions, which focus on an autistic individual's independence in crowd settings. The VR ecosystem, allows for the development of an intervention to help master interaction in specific scenarios, provides the following adaptive functionality:

1. <u>A Visual and Auditory World</u>: Oftentimes hypersensitivity/sensory overload is due to an increased influx of information from the eyes and ears to the brain. Current VR ecosystems account for primarily visual and auditory responses, which allow the user to focus on increasing comfort level.

2. <u>Safer Learning Situation</u>: The user is able to develop/practice coping mechanisms in the comfort of their own safe space, as a VR ecosystem is more forgiving and less hazardous, initially, than the real world.

3. <u>Adjustable Input Stimuli</u>: Since no two profiles of ASD are the same the threshold for input stimuli varies from person to person; a virtual environment can be modified to operate on a sliding scale based on user ability and comfort. This allows for an individualized treatment approach using dynamic environments to cater to the changing patterns of development.

4. <u>Continuous Development</u>: VR ecosystems being built today can be constantly updated to reflect the changes in society, which allows for a shorter duration between testing groups and ultimately a larger data set to analyze.

Participants

Seven participants, all above the age of 18, participated in the alpha testing of the VR environment; five of the eight participants were affiliated with a Goodwill Dayhabilitation Service in Long Island City (LIC), NY and the other two were affiliated with a Goodwill Dayhabilitation Service in Harlem, NY. Each participant volunteered and provided verbal consent to participate in the alpha testing. All participants were diagnosed as having ASD. The five individuals tested in Long Island City were considered “high-functioning”— the individuals were capable of some degree of communicatory and motor dexterity, but still possessed difficulties with verbal cues and day-to-day conversation. The individuals tested in Harlem, NY had more significant communication and social functioning deficits than the individuals tested in Long Island City — their verbal communication was more varied and infrequent. This claim was confirmed by each individual’s supervisor at his or her respective Goodwill location. Table 1 summarizes some information of the seven participants.

Table 1. Alpha tester characteristics: some information of the seven participants

Tester	Age	ASD Condition	Location	Notes
A	20	More significant impairments	Goodwill Harlem	Problem with crowded trains; More impairment in social behaviors
B	21	More significant impairments	Goodwill Harlem	More impairment in social behaviors
C	> 18	High Functioning	Goodwill LIC	Problem with bright/flickering lights
D	> 18	High Functioning	Goodwill LIC	Doesn’t like going into crowded places
E	> 18	High Functioning	Goodwill LIC	
F	> 18	High Functioning	Goodwill LIC	
G	> 18	High Functioning	Goodwill LIC	

Materials

The VR environment was developed using Unity3D a cross-platform game engine and editor available to the public. The study utilized Unity (Personal) 5.2.5 run on Microsoft Windows 10, 8Gb of ram, graphics cards of Nvidia 960M 2Gb, Intel I7 processor at 2.6GHz. The VR environment was rendered on an Oculus DK2; Oculus Development Kit 2 is a virtual reality headset that comes with a 60fps camera that is used for positional tracking. The heart rate was monitored using a Fitbit Charge HR.

A cross-OS standalone project was created in Unity followed by an integration of underground transit system assets and humanoid models to design the environment for this study. Using Unity’s built-in standard shader, which allows for physical effects such as diffuse lighting energy based conservation, and high dynamic range, the environment was made to look as realistic as possible. The physical appearance of the humanoid models was diversified, and they were able to walk from one location to another on the subway platform. The user’s character was moved by a standard QWERTY keyboard, which could be operated by the user or someone else.

Intervention Method

The VR-ASD:TE was developed to provide a realistic virtual environment for autistic individuals to adjust to as the amount of sensory information being passed to the user increased in increments over time. The alpha testing was done one user at a time. The user first put on the Fitbit device, which calibrated and started storing information on the individual’s initial heart rate. After the Fitbit started collecting data, the VR environment was rendered onto the Oculus headset, while the headset is still connected to the laptop on which Unity is running.

A train arrival event/scenario (Figure 1) was constructed to serve three directives: (1) To make the environment seem more realistic with the typical examples of sensory overload instances; (2) To have the humanoid models move and reposition themselves as if they are about to board the train once it comes to a stop. (3) To be the first instance to check for in the Fitbit time log to see a potential change in heart rate. Figure 2 shows a VR screenshot of an empty train car. This is the initial stage in order to slowly ease the user into the VR environment setting. Figure 3 shows a train car with a dozen of “passengers”.

Fig. 1. VR screenshot of the train arrival event.

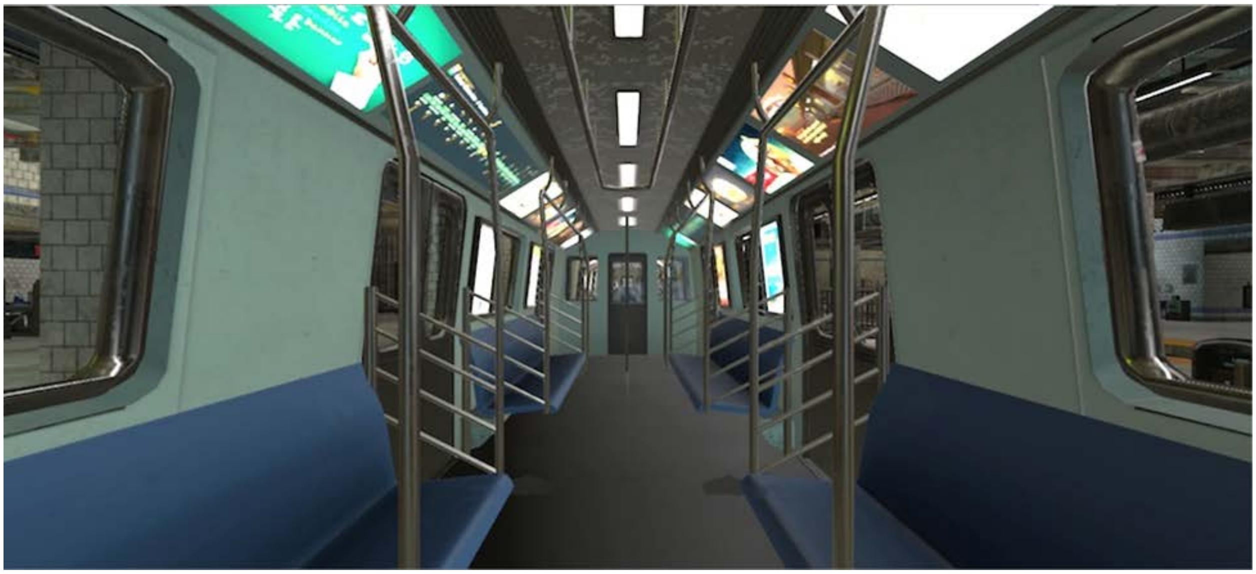

Fig. 2. VR screenshot of an empty train car. This is the initial stage in order to slowly ease the user into the VR environment setting.

Fig. 3. A train car with rendered passengers.

After the train arrival event a second person moves the user, using the keyboard, to board a car on the train. This is where the alpha test branches out; each user does this process a total of four times, with each time the number of people in the car, that the user enters, is increasing. The change in heart-rate was monitored each iteration to see at which level the user was the most uncomfortable and how long it took the user to readjust to the new surrounding.

Table 2 describes a generalized autism spectrum condition and then pinpoints on the events occurring in the environment that might make the user uncomfortable. A VR environment should be created in order to mimic a real-world location and situation that are commonly experienced by individuals who use public transit on a daily basis. At the moment, we only simulated the realistic scenes with platforms, train cars (still or in motion), and various densities of passengers on the car, but other events (such as audio and touch) shall be simulated in the future.

Table 2. Events in the VR-ASD:TE that potentially trigger autism spectrum conditions.

Autism Spectrum Conditions	**Causes of condition triggering due to event in environment**
Auditory Hypersensitivity/ Hyperhearing (e.g., frightened by sudden unpredictable sounds)	• Loud background noises (such as people chattering, something falling down, loudspeaker announcements and crying baby) • Screeching when a train comes to a halt
Visual Hypersensitivity/ Hypervision (Including: vision too acute and sharp; pulsating lights; colors overpowering and too bright)	• Incoming train headlights • Flickering bulb • Random events (such as colorful balloons)
Hypertactile (Fear of being touched, sometimes slightest touch can cause anxiety)	• Crowding by the train doors when the train arrives (The VR:ASD:TE being used doesn't cover haptic feedback, however some individuals get anxiety from just thinking about being touched
Vestibular Hypersensitivity (Including: difficulty changing direction; fearful when their feet leave the ground)	The user won't actually be walking into anything physically but with a realistic looking environment they feel the fear while: • Walking over the gap between the platform and the train • Maneuvering through the crowd to board a train

Measurements and Results

To assess the performance and the effectiveness of the VR-ASD:TE intervention, only two sets of data were gathered in our current test: (1) heart rate before, during, and after immersion into the environment at all 4 levels, and (2) user feedback on the environment. Heart-rate monitoring has been a measurement device which has been previously used to assess VR induced symptoms and to gauge anxiety levels of the user (Cobb, et al, 1999).

Subject A was the only participant who went through the entire alpha program, of four levels, with continuous measurements of heart rate on the Fitbit device. Subject B tried out the level four scenarios, which is the densely crowded train. Subjects C through G tested the environment and provided feedback and personal experiences. Figures 4 through 7 are the graphs of Subject A’s heart-rate while going through each of the four intensities in the alpha program. Figure 8 is a graph of Subject B’s heart rate while going through level four of the alpha program.

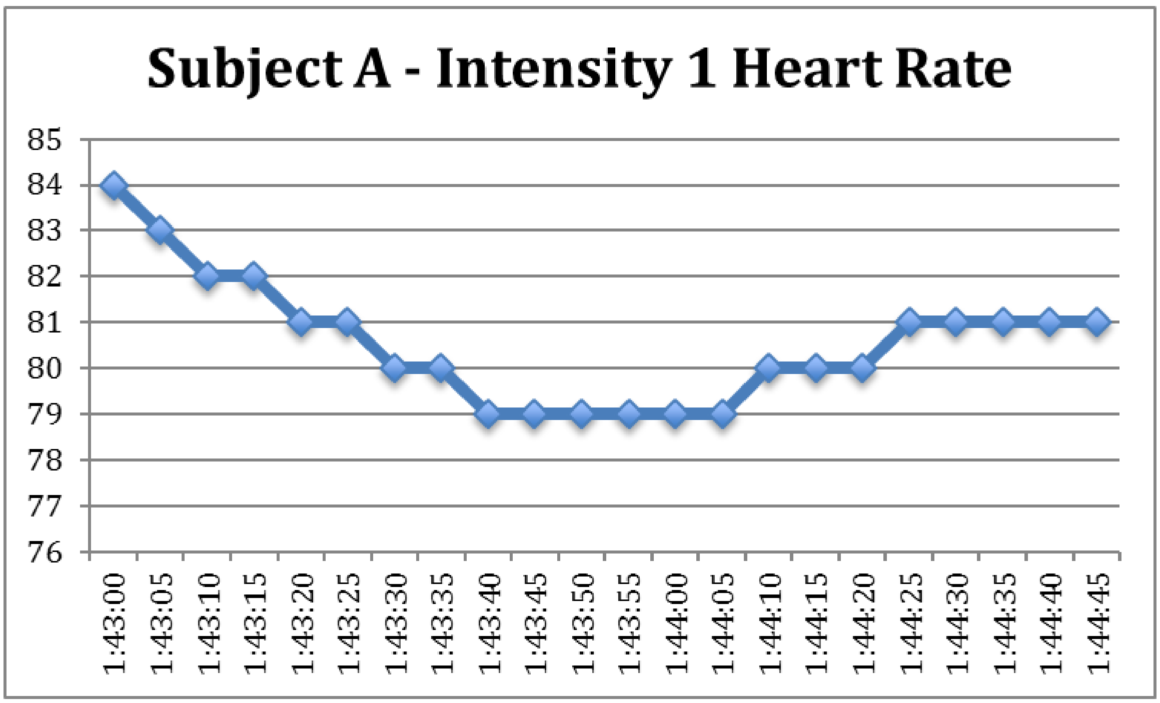

Fig. 4. Subject A - Intensity 1 - No people on train - 1:42 to 1:45. Response: No Problem

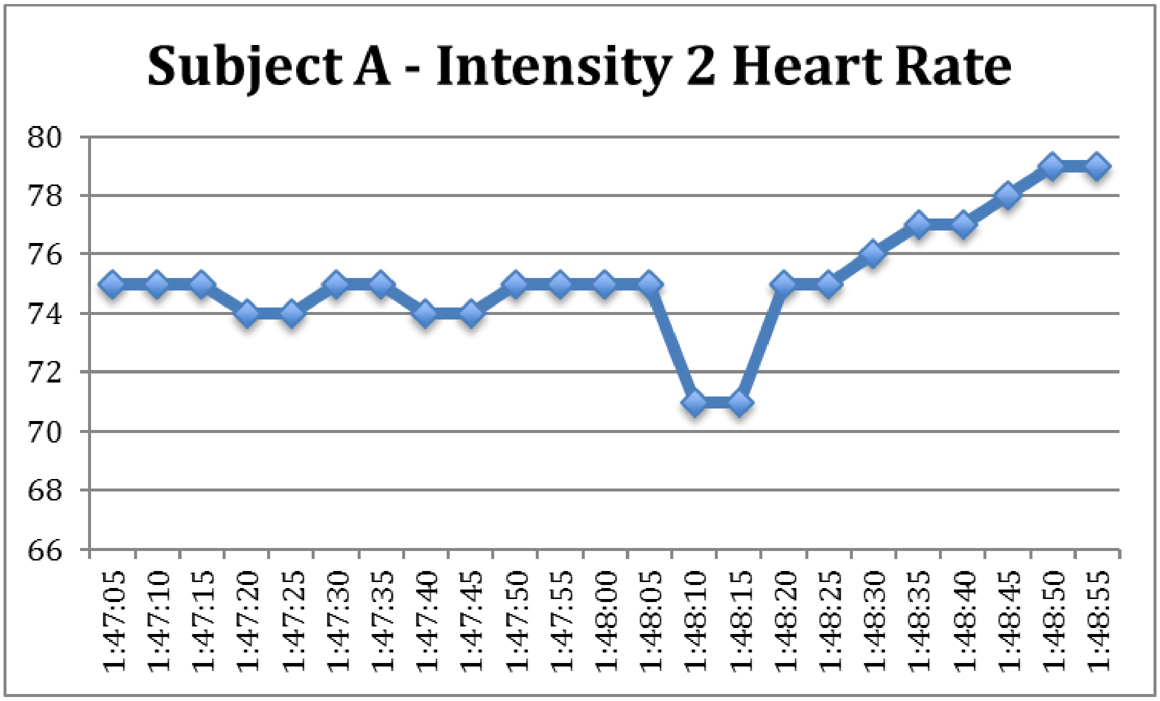

Fig. 5. Subject A - Intensity 2 - Handful of people on the train - 1:47-1:49.

Response: No Problem

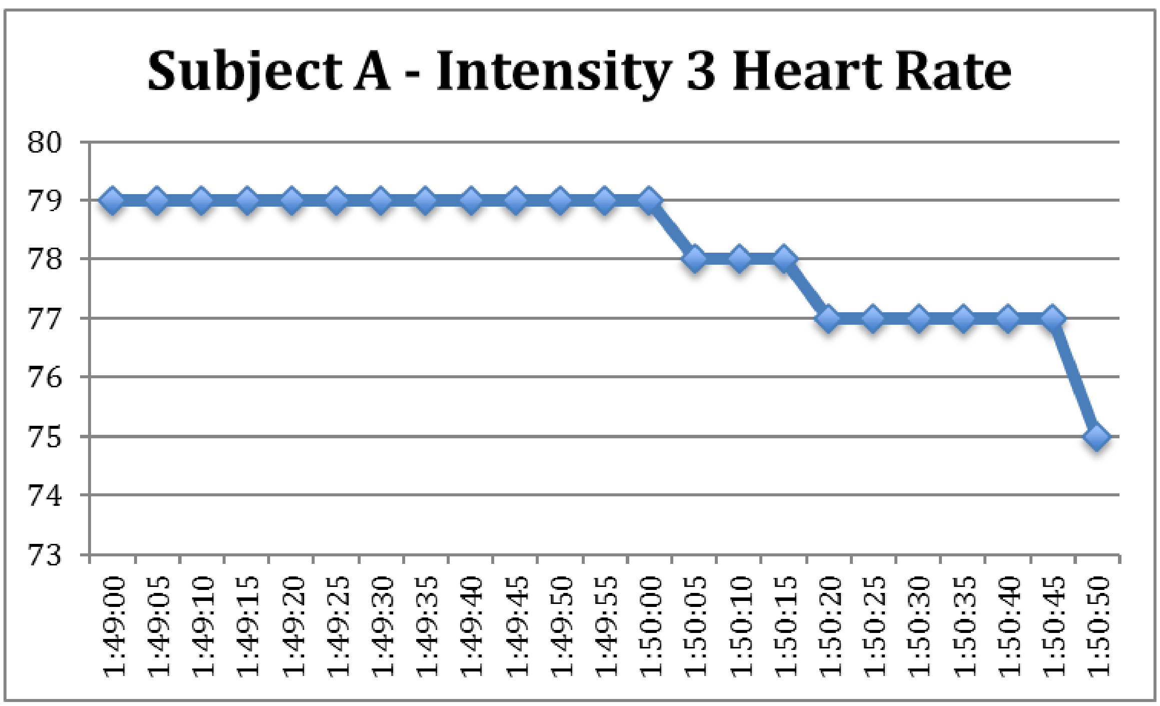

Fig. 6. Subject A - Intensity 3 - A dozen people on the train - 1:49 to 1:51.

Response: Manageable/OK

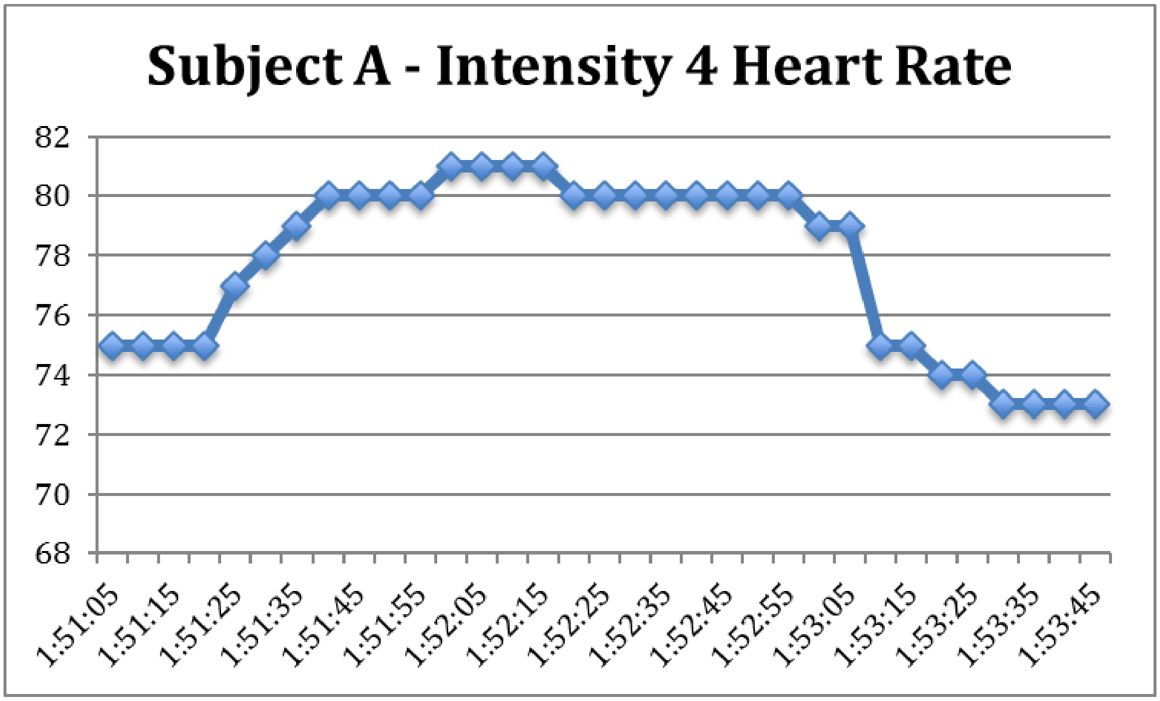

Fig. 7. Subject A - Intensity 4 - Very Crowded - 1:51 to 1:54.

Response: Little uncomfortable

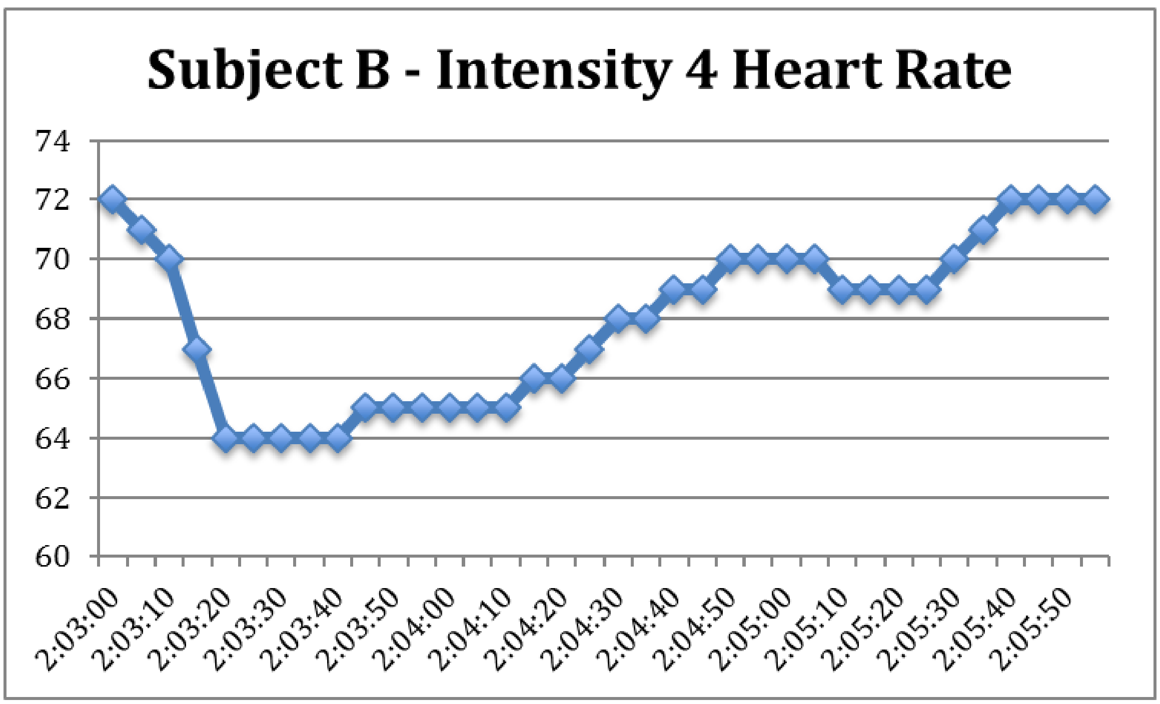

Fig. 8. Subject B - Intensity 4 - Very Crowded - 2:03 to 2:06.

Response: No problem

Adjusting to the VR environment did not take a long time for any of the participants; it is notable that none of the participants mentioned nausea or dizziness when using the VR headset, a complaint commonly cited by neurotypical individuals. ASD conditions mentioned by participants A, C, D mimicked their reactions to the different scenarios presented to them in the environment. They were all excited to be trying out the headset and were very enthusiastic about the process. The verbal feedback received from the participants at the end of the sessions was resoundingly positive, where they all mentioned that they would be willing to test the environment again more thoroughly.

Conclusion

This alpha test is among one of the first projects to take a dive into the use of VR to help people with Autism acclimate to unfavorable and somewhat triggering surroundings. The VR-ASD: TE was developed as a base case with tiered interventions specifically for hypersensitive individuals, which fully utilizes the benefits provided by VR platforms. By implementing an environment which takes most symptoms of hypersensitivity into consideration, the VR-ASD:TE helps individuals slowly grow used to scenarios which would have previously caused anxiety. Even just after a few minutes in the environment, the participants were at ease with their surroundings. These responses from the participants support the idea of implementing and further developing VR environments for the use of cognitive development and for the use of developing coping mechanisms.

Results of the current study found that an intervention to slowly immerse autistic individuals into uncomfortable scenarios may help them build a tolerance to their hypersensitivity symptoms. Going through the heart-rate graphs (Figures 4-7) of Subject A, there is a clear increase in heart-rate at the beginning of each graph which then slowly begins to depreciate as

Subject A gets more and more accustomed to the scenario. The only scenario where Subject A's heart-rate remains high is at intensity level four in our alpha program (Figure 7), because Subject A has a problem with crowded trains to begin with. The decreasing heart-rate in the first three intensity levels may suggest a carryover where given enough 'training' sessions in the VR environment, Subject A can practice containing his or her anxiety in a surprising situation.

The results suggest that VR-ASD:TE can offer a therapeutic VR training platform for cognitive development for autistic individuals who also experience symptoms of hypersensitivity. Further control trials are required to validate the preliminary findings presented in this paper. In addition, a larger and more diverse sample size is needed to gauge the needs of individuals across the entire spectrum and further develop VR-ASD:TE to those needs.

This VR environment was also limited by the lack of a desktop machine available at the site of test to run an Oculus Rift headset. Further research and studies on the cognitive development of autistic individuals should incorporate well-documented procedures and more of a deep dive with a seamless transition between intensity levels. Further research into another form of measurement to gauge anxiety would greatly support the theory of an increased heart-rate implies unease.

Overall the current study and alpha test provides a basis for future testing of the intersection between VR and cognitive development in autistic individuals. The future implementations of headset VR to enhance cognitive development will allows autistic individuals to immerse themselves fully into a safe and controlled environment. VR-ASD:TE will be further developed into a truly visually realistic and immersive approach to helping build a higher tolerance to hypersensitivity and in result increase an individual's cognitive function.

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