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The effect of virtual reality glasses on the behavior of children with autism spectrum disorder in the dental setting

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

By

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Abstract

THE EFFECT OF VIRTUAL REALITY GLASSES ON THE BEHAVIOR OF CHILDREN WITH AUTISM SPECTRUM DISORDER IN THE DENTAL SETTING

By: ROBERT LUNKA, DDS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University

Thesis Advisor: TEGYWYN H. BRICKHOUSE, DDS, PhD

Purpose: The study investigated if viewing a simulated dental exam on virtual reality glasses between two visits would desensitize participants with autism spectrum disorder to the dental environment and improve their anxiety and behavior.

Methods: This randomized prospective cohort study compared behavior between a Control Group and Experimental Group who wore the glasses between visits. Blinded raters watched video recordings of participants and assessed behavior using the Venham scale. Heart rate and post-visit questionnaires completed by guardians were also analyzed.

Results: Five subjects were enrolled (two in the Control and three in the Experimental groups). The median heart rate at visit one was 61 and reduced to 55 for visit two. The maximum heart rate was always observed in the waiting room (n=10, 100%). Raters agreed on anxiety scores for 10% of visits and 80% for behavior scores (k=0.2, 0.5 respectively). Guardians that completed the post-study surveys agreed (n=3, 100%) the glasses were easy to use, enjoyed by the child, and improved anxiety and cooperation at visit two.

Conclusion: Although not statistically significant, median heart rate deceased and behavior stayed the same or improved at the second visit in both groups. The maximum heart rate was observed in the waiting room at each visit. Post-visit questionnaires demonstrated high guardian satisfaction with the virtual reality simulation and they felt their child's anxiety and behavior improved at the second visit.

KEYWORDS: DENTAL CARE, AUTISM, DESENSITIZATION, VIRTUAL REALITY, AXNIETY, CHILDREN

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Introduction

Etiology

The etiology of autism is unknown and the range of differing abilities among individuals has led to the term "autism spectrum disorder" (ASD). [1] The prevalence of ASD in children aged 3-17 years is 1 in 91 and the reported number is increasing due to population growth, increased reporting and more accurate methods used for detection and diagnosis. [2,3]

Barriers to Care

The majority of evidence suggests that proportionally more individuals with intellectual disability have more untreated or undertreated tooth decay than those in the general population. [4] According to the 2001 National Survey of Children with Special Health Care Needs (SCHN), dental care was their largest unmet need for this population. [5] Regarding ASD, the prevalence of unmet dental needs is 12%-15% compared to 5% in typically developing children.[6]

Several barriers may contribute to inadequate health care for children with ASD. Patient-related factors that interfere with oral health and the ability to access or receive dental treatment include behavioral difficulties, dental fears, and limited ability to provide oral self-care. [7] Some reports show that between 13 and 75% of parents had problems obtaining dental care for their special needs children. One of these barriers was excessive patient fear of unfamiliar people or settings. [8] Furthermore, significantly more parents of children with ASD children rated their child's dental experience as "negative" in comparison to parents of typically developing children.[9]

Another barrier for individuals with ASD was difficulty in locating dentists willing to treat them. In fact, several parents report they have been refused treatment from a dental provider.[10] Dental education typically has limited clinical experiences for students treating patients with SHCN. Sixty percent of general dentists felt unprepared treating patients with special needs after

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dental school and the inadequate pre-doctoral training may contribute to their discomfort in treating this vulnerable patient population. [11,12]Surveys show that 10% of general dentists and 95% of pediatric dentists routinely treat patients with SHCN.[13]

There may be practice-based operational design, cost, and insurance barriers for dentists' ability to treat patients with SHCN. Some dentists may choose not to treat patients with SHCN because of insurance coverage and the time to manage these patients in the office. Many individuals with developmental disabilities are adults on Medicaid. In several states, Medicaid either provides no dental coverage for adults or only coverage for emergency treatment. In states where Medicaid does provide dental coverage, reimbursements are usually low, and provider participation is limited. [7] More time is typically needed to obtain an adequate medical history and consent for the proposed procedure. For some anxious individuals with ASD, a thorough exam in the clinic is not possible and the next step would require that they receive oral sedation or treatment in a surgical setting room under general anesthesia.[14] This comes with the risks and increased costs of general anesthesia and surgical facility fees. The barriers faced by the patient, guardian and dentist should therefore be addressed to improve access to dental care for the ASD individual and hopefully decrease the need for more advanced behavior guidance techniques (ABGT).

The AAPD has "Guidelines on Management of Dental Patients with Special Health Care Needs" which provides best practices on treating patients with developmental disabilities. [15] ASD is often associated with deficits in language and social interactions. Individuals may display a lack of eye contact, repetitive behavior and the need for a rigid routine.[8] The success of a pediatric dental appointment is largely dependent on communication with the patient and this may present a barrier for some children with ASD. Health care for individuals with special needs requires

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specialized knowledge, increased awareness and attention, adaptation, and accommodative measures beyond what may be considered routine. [15]

Sensory Issues

Sensory processing difficulties occur across all sensory domains (e.g., tactile, auditory, gustatory, visual) and information is processed by the brain atypically, resulting in over- or under-reactions to the stimulation. [16] There is a high prevalence of anxiety in children with ASD associated with unusual responses to sensory stimuli such as heightened reactions to light, unfamiliar sounds and touch.[17] Oversensitivity may result in fight, fright or flight reactions manifesting as physical withdrawal, vocal outbursts, tantrums, or attempts to block the stimuli. [18] Exposure to new environments with these stimuli, such as a dental office, may elicit anxiety in the patient and create challenges for the family and dental team. The success of a pediatric dental appointment is largely dependent on communication and health care for these individuals requires specialized knowledge, increased awareness and attention, and accommodative measures beyond what may be considered routine. [15]

Interventions

Several interventions are used for patients with ASD during their dental visit. Physicians sometimes prescribe antipsychotic medications to alleviate symptoms of irritability, distress, self-injurious behavior, aggression and delusions. [11] Advanced behavior guidance techniques (ABGT) such as protective stabilization, oral sedation and general anesthesia are often indicated for minor procedures.[14]

Occupational therapists use sensory-based treatments designed to provide individualized, controlled sensory experiences to help modulate responses to environmental inputs. The goals of these treatments are to improve sensory processing and self-regulation, to

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increase adaptive function, and to help the child participate in daily activities. [19] To train acceptable behaviors in the dental operatory, the D-Termined Program© utilizes familiarization and repetitive tasking. [20] Sensory adapted dental environments (SADE) that modify the environment in the dental operatory have shown promising results. Modifications include darkening the room, projecting slow moving color effects on the ceiling, playing rhythmic music and using weighted aprons. [21]

Flash cards [22] and dental stories[23] have also been shown to reduce anxiety[17] by capitalizing on the relatively strong visual spatial skills and inclination towards visual stimuli common in individuals with ASD.[24] The strength of the visual medium among many individuals with ASD has been demonstrated with electronic video screens (EVS) and virtual reality (VR) glasses. The relatively constrained viewing area limits peripheral stimulation, helping individuals focus on relevant stimuli.[25] Fakhruddin has shown a greater reduction in anxiety (based on heart rate) when children with ASD or Attention Deficit Hyperactivity Disorder (ADHD) watched cartoons on VR glasses compared to projections on the ceiling while performing sealants or restorations.[26,27] Another study showed that anxiety and behavior improved when watching cartoons on video goggles vs. hand-held EVS.[17] Ghadimi et al reported that although visual distraction improved self-reported anxiety in typically developing children, it did not change their observed behavior.[28]

Virtual Reality and Dental Care

Based on these studies, VR glasses were better than other modalities in improving behavior and anxiety, but the glasses were only used for distraction. So far, no studies using VR glasses as a means of desensitization for upcoming dental visits exist. Families often request desensitization visits before the initial exam to familiarize their child to the new environment. This incremental approach is useful in desensitizing the patient, but it requires more time from the family and dental

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team. The child may need to miss school or the parent take off work. Also, a dental team member must be available for the desensitization visits. Nelson showed that with the use of a desensitization program, it took an average of 1-2 visits for their population with ASD to have a basic exam completed with an dental mirror while seated in the dental chair.[6] Perhaps watching a simulation on VR glasses may provide some convenience by eliminating the need for desensitization visits. Patients could watch the simulation as often as necessary to familiarize themselves with the environment and make them more comfortable prior to their actual new patient exam. The purpose of this study is to examine if watching an immersive video simulation of a dental exam on VR glasses will improve the dental experience for children with ASD. We hypothesize that watching the VR simulation will reduce anxiety by familiarizing the individual to the environment and hopefully reduce the need for ABGT for minor procedures such as exams, dental prophylaxis and radiographs. If positive results are seen, this concept and technology can be used in other medical/ social settings and improve the quality of life for individuals with ASD.

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Methods

Research Design

This randomized prospective cohort study compared two groups of subjects with ASD: those who receive VR glasses after their initial exam and those in the control group who did not receive the VR glasses between visits. The study was conducted during lunch or after clinic hours to reduce distractions in the clinic.

Consent (and subject assent if appropriate) was obtained in the waiting room prior to initiating the study. The guardians were emailed the consent documents ahead of time so that they could review them prior to Visit 1. Families were informed about the randomization of the research and that there was a chance they may not receive the VR glasses after the first visit. At Visit 1 guardians completed a pre-assessment questionnaire (PAQ) in the clinic waiting room (WR). A Fitbit was placed on the participant's wrist to monitor heart rate (HR). The researcher then left the WR to power on the iPad video recorder mounted in the study room (SR). After returning, the participant, guardian and researcher walked to the SR together. The patient was instructed to sit in the dental chair. Tell-show-do (TSD) was implemented to lay the chair back, put on sunglasses, turn the operatory light on, perform a brief dental examination with a dental mirror and upright the dental chair. After the exam, the participant was led back to the WR. The Fitbit was left on while the researcher turned off the video recording in the SR. The researcher returned and the Fitbit was removed from the participant's wrist in the WR.

A randomization list then assigned the subject into one of two groups: Control Group 1 "Waitlist Group" (WLG), and Group 2 "Virtual Reality Group" (VRG) who received VR glasses to take home (**Error! Reference source not found.**). An immersive simulation video of a typical d

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ental exam in the same clinic at VCU was pre-loaded on the glasses. The guardians were given instructions on how to use the glasses and access the simulation video. Subjects were encouraged to wear the VR glasses as often as possible and record the number of times the video was watched. Several weeks later subjects from both groups returned for Visit 2. The same procedures in Visit 1 were performed, except guardians in the VRG also completed a post-visit questionnaire (PVQ). Individuals randomized to the WLG were offered a third visit to receive the VR glasses between Visit 2 and Visit 3. The VR glasses were returned to the researcher to be used for another participant. Participants received a monetary incentive for participation. Two researchers rated the exam videos using the Venham Anxiety and Behavior Scales (VABS). HR data and PVQ were compiled and analyzed

Sampling

Participants were recruited from local support groups for families affected by ASD and recruitment flyers were delivered to local schools and a nearby dental clinic (The Children's Hospital of Richmond, Brook Rd). Inclusion criteria were: 1) individuals diagnosed with ASD, 2) English speaking families3) the ability to tolerate wearing VR glasses (as determined by the guardian) and 4) participants who were not patients of record at the VCU Department of Pediatric Dentistry at VCU. Exclusion criteria included: 1) non-English speaking families, 2) individuals unable to tolerate wearing VR glasses due to behavioral or physical reasons (as judged by the guardian), 3) patients of record at VCU and 4) co-existing medical conditions preventing participation (eg cerebral palsy). Families contacted the researcher if interested in the study.

Instrumentation

Questionnaires

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The Pre-assessment Questionnaire (PAQ) asked about the child's dental history, methods of communication, expression of discomfort, sensitivities, characteristics of sensory processing, habits/fixations and how the child copes with transitions **Error! Reference source not found.Error! Reference source not found.**. Sensitivities were ranked on a 5-point Likert scale from "not very sensitive" to "very sensitive" and "Not applicable". The sensitivities listed were bright light, loud noises, textures and tastes. Guardians could also write comments to elaborate. The PVQ completed by guardians in the VRG contained answers on a 5-point Likert scale that ranged from "strongly agree" to "strongly disagree." Questions asked if the VR glasses were easy to use, the child enjoyed watching the video, they perceived an improvement in the child's anxiety, the child did better cooperating for the dental exam after watching the video, and if the caregiver would like to continue using the VR simulation to prepare their child for future dental visits **Error! Reference source not found.**. LEND (Leadership Education in Neurodevelopmental Disabilities) experts with expertise in ASD designed the questionnaires.

VR Glasses and Research Video

Two Oculus Go VR glasses (32 GB) were used. A 360 simulation video created by Dr. David Vu using a specialized camera (Xiaomi Mijia Mi Sphere) was downloaded on the VR glasses. The experience gave viewers the impression they were immersed at the VCU Pediatric Dentistry Clinic. In the video, the viewer followed the primary researcher from the WR to the SR. The viewer could look around the virtual room as they moved down the office hallways. The viewer then entered the SR and sat in the chair. Sunglasses were placed over their "eyes" and a virtual exam was performed. After the virtual exam, they were led down the hallway and escorted into the WR. For consistency, the same researcher in the simulation video performed all actual dental exams in the same room and matched the script on the video during the participants' visits.

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Written instructions on how to use the glasses and access the simulation video were given to families assigned to the VRG. Subjects should only wear the VR glasses while sitting down under their direct supervision of the caregiver to avoid injury. Families could email or call the primary researcher at any time with questions.

iPad Video Recorder

The video function on an iPad was used to record the participants' exams. The videos were stored on a password-protected Google Drive account accessible only to the researcher and committee members.

Venham Anxiety and Behavior Scales

Two separate calibrated examiners used the VABS to analyze the level of anxiety and behavior while watching video recordings of the subjects
. The videos were randomly coded with a lower-case letter in no particular order to ensure they were blinded to the visit number and patient's group (WLG or VRG). Calibration of inter-rater scoring was determined by watching a YouTube video ("Bella goes to the dentist" https://www.youtube.com/watch?v=rOLPkRh-lwM) and comparing results to the primary researcher's score. Any differences were discussed to achieve consistent scores.

Fitbit

A Fitbit modified with Velcro allowing easy placement and removal was used to record the HR. HR was recorded at specific moments during the visit: Maximum HR in the WR before the exam, entering the room, sitting in the dental chair, reclining the chair, turning on the overhead light, dental exam, up-righting the chair, leaving the SR and the maximum HR in the WR after the

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exam. A program created by Sean Kotrola (VCU) extracted and recorded HR from the Fitbit at 5-10 second intervals in real-time. HR readings for each patient were printed after each visit and the specific events mentioned above were identified on the HR printout by comparing the times on the participant's exam video.

Protection of Human Rights

Participants were excluded from participating if guardians felt they would be adversely affected by wearing the glasses or if the participants themselves did not want to participate. To protect confidentiality, patient information was only shared the research committee. Paper documentation was kept locked in a secure filing cabinet (opened only by the primary researcher who had the key). Other measurements were stored in a password-protected Google Drive account only accessible to the primary researcher and committee members. This research design was approved by the Institutional Review Board of Virginia Commonwealth University (#20015131)

Data Collection and Analysis

Change in HR from Visit 1 to Visit 2, maximum HR for each visit and behavior and anxiety ratings were analyzed. ANCOVA was planned to test for differences in behavior scores and HR between the two visits while adjusting for baseline values, the use of VR glasses and how often the simulation was watched. We hypothesized that subjects who had the VR experience would have improved measures at the second visit when compared to the controls. Secondary analysis would include by combining all subjects and testing for a difference before and after the VR glasses. Responses to questionnaires were analyzed using descriptive statistics.

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Results

Five subjects aged 7 to 23 years with a diagnosis of ASD were enrolled in the study Table 1. One (1) female and four (4) male subjects participated in the study and were recruited in a 4-month period, completing two visits each (October 23, 2019- February 17, 2020). Two subjects were randomized to the WLG and three to the VRG. None of the WL participants were able to receive VR glasses for a third visit due to Covid-19 limitations.

Detailed responses to the PAQ are shown in Table 4. All participants had a dentist they saw for routine care and all were mostly seen within six months. Regarding methods of communication, all communicated through spoken language. One subject also used pictures and pictures with text. Two used an assisted device to communicate. One parent wrote that their child sometimes needed questions reworded or explained in a different way when having trouble understanding.

Guardians were asked to describe how the individuals expressed discomfort. Three subjects cry, five speak and three gesture by pointing. One guardian said their child showed frustration or needed a break. Another child displayed anxiety while another child clenched their teeth and became aggressive when feeling "trapped."

Another scale on the pre-assessment questionnaire asked guardians about their child's sensitivities. Guardians responded on a scale from 1-5 (not very sensitive to very sensitive) or not applicable, regarding the child's sensitivity to: bright light, loud noises, textures, tastes. Regarding bright light, one guardian ranked 5, one ranked 4, one ranked 3, one ranked 1 and one ranked "not applicable." For loud noises, one ranked 5, three ranked 4 and one ranked 3. For texture, four

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guardians ranked their children 3, and one ranked their child a score of 2. Finally, for taste sensitivities, one individual was ranked 5, three were ranked 4 and one was ranked 1.

Guardians were asked if their child wore noise-reducing headphones to reduce overstimulation. One used them "half the time", three "seldomly" and one "never" wore them. Those that seldomly wore them either wore them during loud movies or during their last class at school.

Parents could describe any other characteristics in their child's sensory processing. One stated that their child would alert them to any aversions while another stated that explanations in advance were very helpful.

Four subjects had habits/fixations. One child sucks his/her fingers for comfort when upset. Another picked his/her skin. To relax or self-soothe, one subject flapped his/her arms while walking. Another participant followed the same "pattern" for events such as taking the same set of stairs at a particular venue.

One question asking how the child coped with transition or new environments had the following choices as answers: "easy going" or "preparation need". Two subjects were "easy going" while three needed preparation. One parent wrote that although verbal preparation is sufficient now, social stories were previously employed. Another parent prepares their child by repetitively specifying what was going to happen in detail. Another discussed that a slow progression was helpful. One guardian answered "easy going", but first had to explain everything with constant reassuring. Only one guardian simply answered their child was "easy going".

The range in HR (i.e. difference from max to min HR) at Visit 1 had a median of 61 (range: 35-65) and reduced to 55 (23-64) for Visit 2. This change was not statistically significant given the small sample size. Not enough data existed to support testing for differences between the WLG

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and VRG groups. The maximum HR was observed in the waiting room, either before or after the exam. Figure 4 and Figure 5 show the trend of maximum HR by each participant across the specific event stimuli. The maximum HR for the visit is indicated with an "x" marker.

Two blinded raters had inter-rater agreement on anxiety scores for 10% of visits and 80% for behavior scores (k=0.2, 0.5 respectively). Overall, all patients had low anxiety and good behavior and therefore it was difficult to demonstrate improvement with the VR glasses, especially with the limited sample size. No analyses were performed between groups due to the low scores and low inter-rater agreement. Complete results are given in Figure 6.

Three guardians in the VRG completed a Post-Visit Questionnaire (Table 5) and "Strongly Agreed" that they would like to continue to use the glasses before dental visits (n=3, 100%). All "Agreed" or "Strongly Agreed" that the glasses were easy to use, enjoyed by child, and improved anxiety and cooperation. Two of the guardians reported that the child watched the video twice and one reported five times. No analyses was performed for the number of times the simulation video was watched due to the small sample size.

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Discussion

The purpose of this study was to determine if a simulation on VR glasses could desensitize an individual to a specific dental environment and therefore reduce anxiety and improve behavior during clinical examination. Dental appointments are challenging for some individuals with ASD due to the response to stimuli typically present in dental offices. We hypothesized that an immersive video simulation of a dental exam watched on VR glasses would familiarize the individual to the dental office environment ahead of time, thus improving anxiety and behavior at the actual dental visit.

All subjects in this study communicated via spoken language indicating milder forms of ASD. Most participants also communicated with pictures, pictures with text and assisted devices demonstrating the inclination towards visual stimuli common in individuals with ASD.[24] Some children with more severe forms of ASD are nonverbal and/or gesture to communicate.

The degree and type of sensitivity and habits/fixations varied drastically for each participant in this study. Most subjects were more sensitive to loud noises, textures, tastes and wore headphones to alleviate auditory sensitivities. This study supports that each individual with ASD has unique sensitivities and methods for adjusting/ coping to new situations.

Supporting the idea that challenges exist when individuals with ASD enter new environments, most participants in this study needed preparation with detailed communication and repetitive reassurance prior to the transition. It seems that a simulation of the new experience on VR glasses as demonstrated in this study could address the individual's fears by allowing them to virtually experience the new environment in the comfort of their home prior to their actual transition. They would also have the benefit of mentally preparing themselves by watching the video as many times as needed. Better than an explanation, this would be the most accurate method

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of preparing the individual before their office visit since it represents an immersive simulation of the actual environment they would be experiencing. On the contrary, it is with understanding that the VR simulation may actually introduce fears to the child prior to their visit.

Although not statistically significant, overall median HR decreased for both groups at Visit 2, indicating participants were probably more familiar with the environment at the second visit. Consistency in research design was also maintained with the same provider in the VR simulation performing every exam. The HR may have changed if another researcher performed the exam or different rooms were used at each visit. There was not enough data to support testing for differences in HR change between the control and experimental groups using ANCOVA. The. highest HR for all visits occurred in the WR . Reasons for this include anticipating what's to come or even agitation from waiting. Several studies confirm that more time in the WR contributed to increased anxiety for the rest of the exam in individuals with ASD.[29,30]

Behavior and anxiety either stayed the same or improved between the two visits, though the sample size was not large enough to see significant results. Although calibrated, the two blinded researchers watching the videos were new to VABS and it was possible the criteria were not sensitive enough to discern between different levels of anxiety and behavior and were subjectively interpreted. The more familiar Frankl behavior scale may have shown stronger inter-rater agreement and produced different results. Also, all participants had good behavior and low anxiety at Visit 1, so any improvement would be minimal. If the changes were more drastic from one visit to the next, more consistent agreement may have been observed.

Although sample size was small, the PVQ demonstrated the guardians' overall high satisfaction with their child's VR experience and dental offices could potentially incorporate this new method desensitizing patients with ASD prior to their initial exam. The VR simulation may

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be an extra tool used by providers to benefit many patients by reducing ABGT for simple procedures and eliminating desensitization visits. It could also be used in any medical or social settings for any anxious patient.

Limitations

There were several limitations to this research. Since a new environment was necessary to adequately assess behavior and anxiety during a transition to a new office, only non-VCU patients were recruited. Permission was needed to distribute flyers which took time. The primary researcher also attended local support groups and many guardians felt their child would not tolerate wearing VR glasses. Children with more severe forms of ASD have difficulty communicating discomfort and subjecting them to a potentially unpleasant experience unwilfully would be unethical. Other families expressed interest in the study, but never followed up. The limitation in recruiting new participants due to the COVID-19 pandemic halted the ability to continue the clinical trial and WLG subjects were not able to participate in Visit 3.

Only brief dental exams were performed in the study. Texture and taste cannot be simulated on VR glasses and most subjects in this study had sensitivities to both, so other procedures may not have been tolerated well. Reports have shown that toothbrushing at home may be difficult for persons with ASD due to the aversion to the taste and texture associated with brushing.[10] Although the VR simulation seems promising for dental exams, it may not provide benefits prior to cleanings, radiographs or restorative procedures. Compliance watching the VR simulation at home may have been another limitation.

Future studies would include a similar design with more participants, better recruitment and using the familiar Frankl Scale. A VR program tracking participants' eye movements during sudden HR changes would also provide useful information.

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Conclusion

The VR simulation in this pilot study was designed to desensitize individuals with ASD in a specific dental environment. Although future research with a larger sample size is needed to examine the effectiveness of VR glasses on these individuals, based on this study, the following conclusions can be made:

1. Anxiety and Behavior stayed the same or improved for both groups using the Venham Anxiety and Behavior Scales between visits.

2. The maximum heart rate for each visit was seen in the waiting room, either before or after the dental examination.

3. For most participants, the median heart rate decreased at Visit 2 for both the control (WLG) and experimental groups (VR).

4. Post-visit questionnaires completed by guardians in the VR group show they want to continue using the VR glasses for their children before dental visits, the simulation video was easily accessible, the VR glasses were easy to use, the video simulation was enjoyed by the child and improved their anxiety and cooperation.

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Table 2: Venham Anxiety and Behavior Scale

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Anxiety rating scale

0. Relaxed, smiling, willing and able to converse.

1. Uneasy, concerned. During stressful procedure may protest briefly and quietly to indicate discomfort. Hands remain down or partially raised to signal discomfort. Child willing and able to interpret experience as requested. Tense facial expression, may have tears in eyes.

2. Child appears scared. Tone of voice, questions and answers reflect anxiety. During stressful procedure, verbal protest, (quiet) crying, hands tense and raised, (not interfering much — may touch dentist's hand or instrument, but not pull at it). Child interprets situation with reasonable accuracy and continues to work to cope with his/her anxiety.

3. Shows reluctance to enter situation, difficulty in correctly assessing situational threat. Pronounced verbal protest, crying. Using hands to try to stop procedure. Protest out of proportion to threat. Copes with situation with great reluctance.

4. Anxiety interferes with ability to assess situation. General crying not related to treatment. More prominent body movement. Child can be reached through verbal communication, and eventually with reluctance and great effort he or she begins the work of coping with the threat.

5. Child out of contact with the reality of the threat. General loud crying, unable to listen to verbal communication, makes no effort to cope with threat. Actively involved in escape behavior. Physical restraint required.

Behavior rating scale

0. Total cooperation, best possible working conditions, no crying or physical protest.

1. Mild, soft verbal protest or (quiet) crying as a signal of discomfort, but does not obstruct progress. Appropriate behavior for procedure, i.e., slight start at injection, "ow" during drilling if hurting, etc.

2. Protest more prominent. Both crying and hand signals. May move head around making it hard to administer treatment. Protest more distracting and troublesome. However, child still complies with request to cooperate.

3. Protest presents real problem to dentist. Complies with demands reluctantly, requiring extra effort by dentist. Body movement.

4. Protest disrupts procedure, requires that all of the dentist's attention be directed toward the child's behavior. Compliance eventually achieved after considerable effort by dentist, but without much actual physical restraint. (May require holding child's hands or the like to start). More prominent body movement.

5. General protest, no compliance or cooperation. Physical restaint is required.

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Table 3: Demographics of Study Subjects by Treatment Group

	VR (n=3)	WL (n=2)
Age (median, range)	14 (8-23)	11 (7-15)
Gender		
Male	2, 67%	2, 100%
Female	1, 33%	0, 0%

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Table 4: Summary of Responses to Guardian Pre-Visit Questionnaire

	n	%
Dental Home		
Yes	4	80%
No	1	20%
Last Visit		
Within 6 Months	4	80%
More than 6 Months	1	20%
Expressing Discomfort		
Crying	3	60%
Spoken Language	5	100%
Pointing	2	40%
Self-Injury	0	0%
Other	3	60%
Habits or Fixations		
Yes	4	80%
No	1	20%
Use of Headphones to Reduce Stimulation		
Never	1	20%
Seldom	3	60%
About half the time	1	20%
Light Sensitivity		
Not very sensitive (1)	1	20%
Moderately sensitive (2-4)	2	40%
Very Sensitive (5)	1	20%
Not Applicable	1	20%
Noise Sensitivity		
Not very sensitive (1)	0	0%
Moderately sensitive (2-4)	4	80%
Very Sensitive (5)	1	20%
Not Applicable	0	0%
Taste Sensitivity		
Not very sensitive (1)	1	20%
Moderately sensitive (2-4)	3	60%
Very Sensitive (5)	1	20%
Not Applicable	0	0%
Texture Sensitivity		
Not very sensitive (1)	0	0%
Moderately sensitive (2-4)	5	100%
Very Sensitive (5)	0	0%
Not Applicable	0	0%
Transitions		
Preparation Needed	4	80%
Easy going	1	20%
Communication		
Spoken Language	5	100%
Sign Language	0	0%
Pictures	1	20%
Pictures with Text	1	20%
Assistive device	1	20%
Gesturing or Pointing	1	20%
Other	2	40%

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Table 5: Summary of Responses to Guardian Post-Visit Questionnaire

		n	%
The Virtual Reality Video was easy for my child to use at home prior to a dental visit.			
	Strongly Agree	1	33%
	Agree	2	67%
My child enjoyed watching the Virtual Reality Video prior to the dental visit.			
	Strongly Agree	1	33%
	Agree	2	67%
The Virtual Reality Video improved my child"s anxiety during the routine dental exam.			
	Strongly Agree	1	33%
	Agree	2	67%
My child did better cooperating for dental exam AFTER watching the Virtual Reality Video.			
	Strongly Agree	1	33%
	Agree	2	67%
I would like to continue using the Virtual Reality Video to prepare my child for future dental visits.			
	Strongly Agree	3	100%
	Agree	0	0%

*None of the respondents answered below "Agree" for any of the questions

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Figure 1: Pre-assessment Questionnaire

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Virtual Reality and Dental Fear in Children with ASD
Preliminary Questionnaire

Please complete the survey below.

Thank you!

When was your child's last dental visit?

- ○ Within 6 months
- ○ More than 6 months
- ○ More than one year
- ○ More than 3 years

Does your child have a dentist for routine oral health care?

- ○ Yes
- ○ No

Please select ALL that apply to your child's communication.

- ○ Spoken language
- ○ Sign language
- ○ Pictures
- ○ Pictures with text
- ○ Assistive device
- ○ Gesturing or pointing
- ○ Echolalia
- ○ Other

Please describe any other communication methods your child uses:

Please select ALL that apply to your child's means of expressing discomfort:

- ○ Crying
- ○ Spoken language
- ○ Pointing
- ○ Self-injury
- ○ Others

Please describe any other means of expressing discomfort

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Please use the scale provided to describe any of your child's sensitivities.

	Not very Sensitive				Very Sensitive	Not applicable
Bright Light	○	○	○	○	○	○
Loud Noises	○	○	○	○	○	○
Textures	○	○	○	○	○	○
Tastes	○	○	○	○	○	○

Does your child wear noise reducing headphones to reduce overstimulation?

○ Always ○ Usually ○ About Half the Time ○ Seldom ○ Never

Please describe any other characteristics of your child's sensory processing:

Does your child have any habits or fixations?

○ Yes
○ No

Please describe any habits or fixations:

How does your child cope with transition or new environments?

○ Easy going
○ Preparation needed

Please describe how you prepare your child for transitions or new environments:

---

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Figure 2: Flowchart

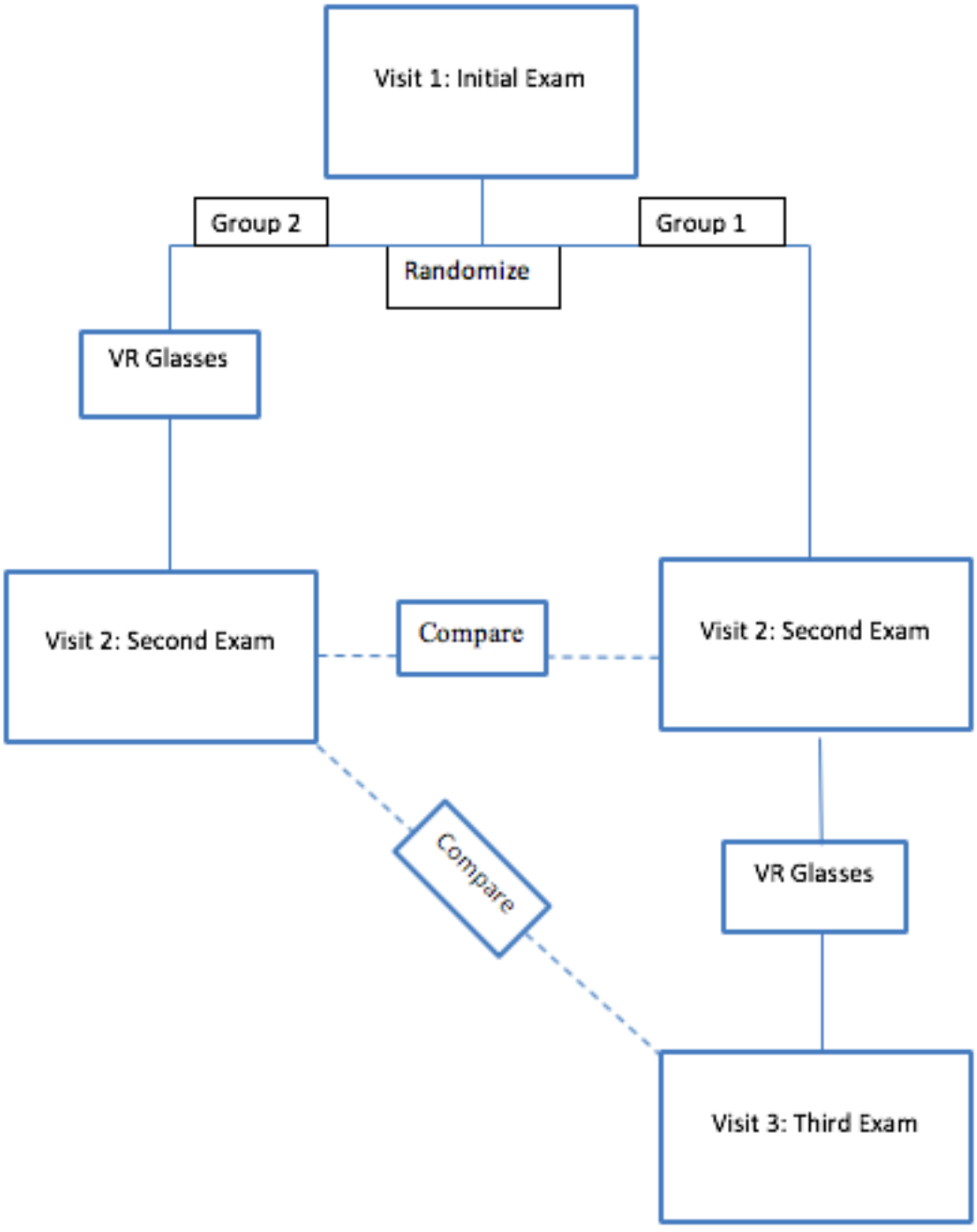

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Figure 3: Post-assessment Questionnaire

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Post-Visit Questionnaire

Please complete the survey below.

Thank you!

	Please indicate your agreement with each of the following statements:	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1)	The Virtual Reality Video was easy for my child to use at home prior to a dental visit.	○	○	○	○	○
2)	My child enjoyed watching the Virtual Reality Video prior to the dental visit.	○	○	○	○	○
3)	The Virtual Reality Video improved my child's anxiety during the routine dental exam.	○	○	○	○	○
4)	My child did better cooperating for dental exam AFTER watching the Virtual Reality Video.	○	○	○	○	○
5)	I would like to continue using the Virtual Reality Video to prepare my child for future dental visits.	○	○	○	○	○

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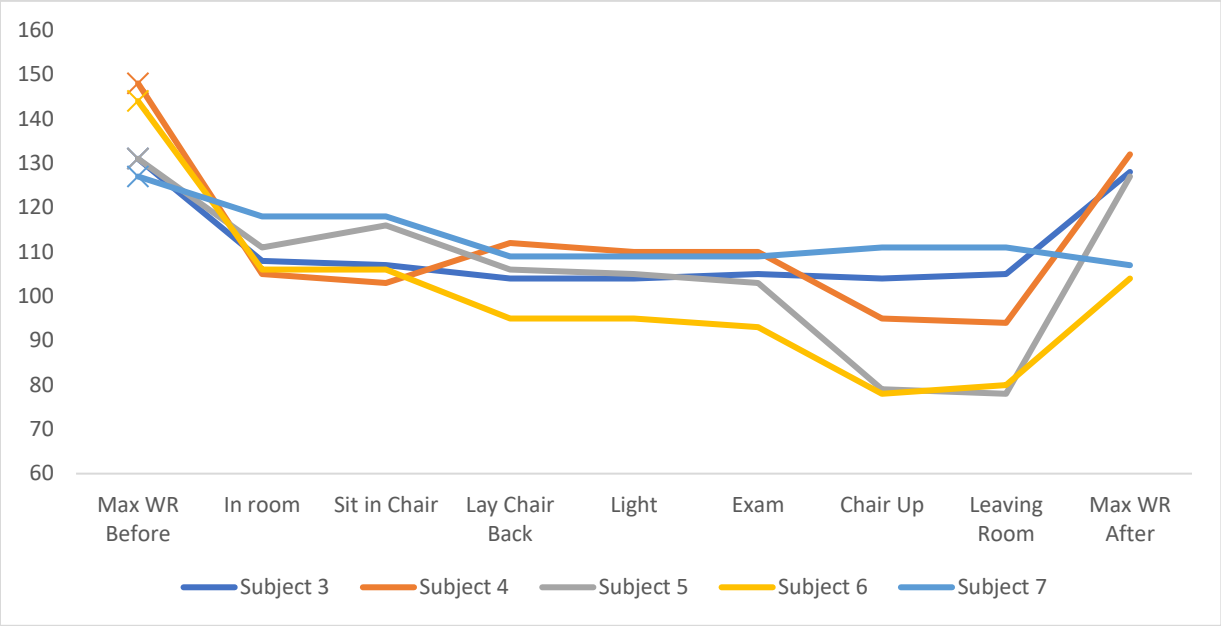
Figure 4: Heart Rate for Visit 1 Stimuli



Stimuli where maximum HR was observed is indicated with "X" marker

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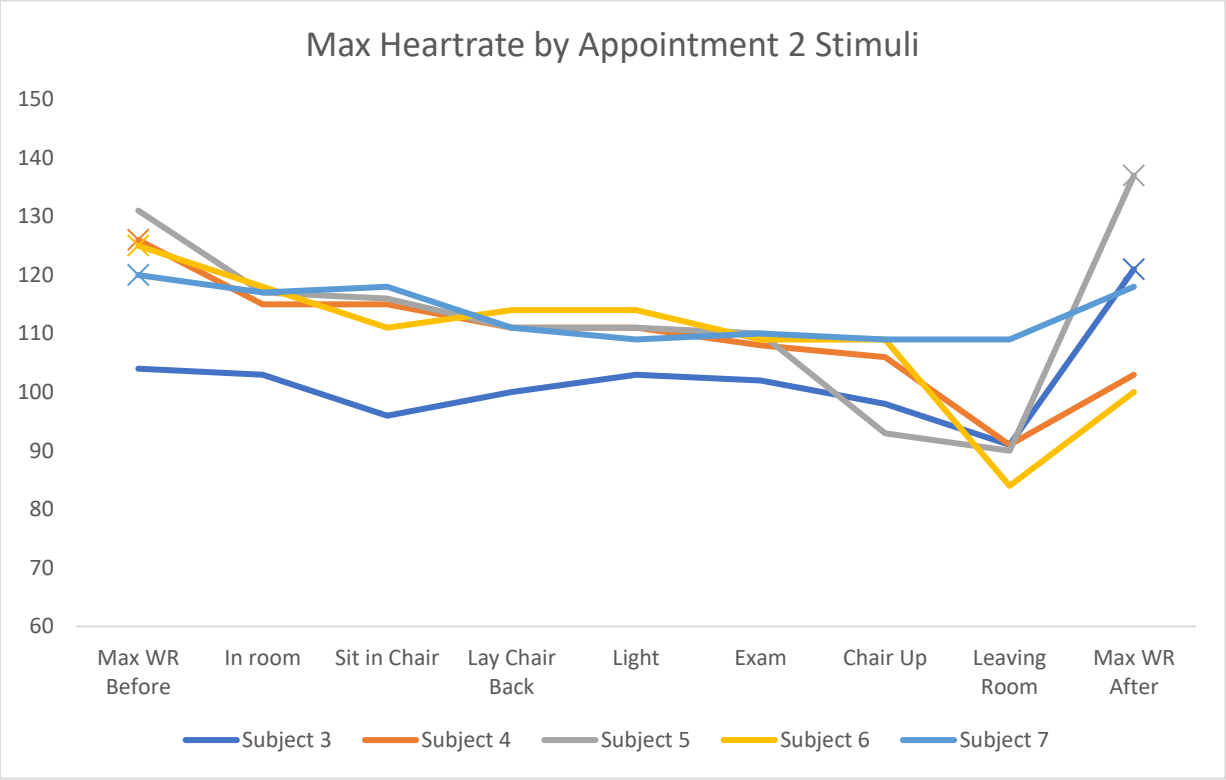
Figure 5: Heart Rate for Visit 2 Stimuli



Stimuli where maximum HR was observed is indicated with "X" marker

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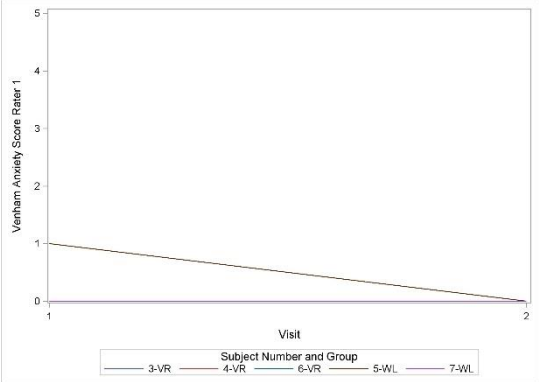
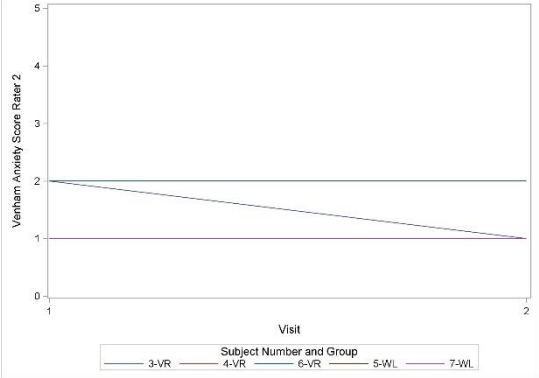
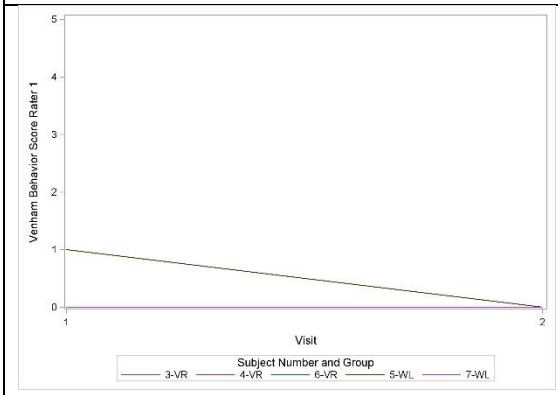
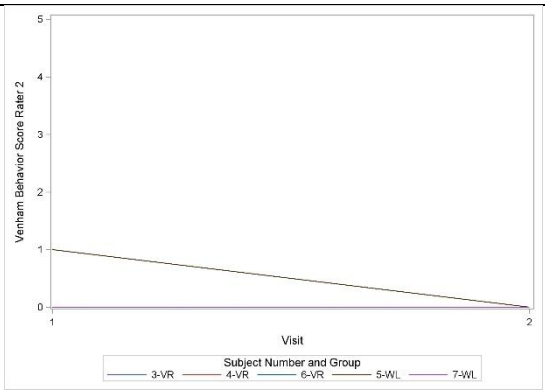
Figure 6: Venham Anxiety and Behavior Scores by Visit and Rater

Rater 1 (TB)	Rater 2 (WD)
Anxiety	Anxiety
	
Behavior	Behavior
	

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