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ORIGINAL ARTICLE

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Reducing blood draw phobia in an adult with autism spectrum disorder using low-cost virtual reality exposure therapy

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Abstract

Background: Needle phobias are common in children and adults worldwide. One effective intervention for this phobia is exposure therapy where a participant is gradually exposed to increasing levels of the fear-evoking stimulus while differential reinforcement is applied. This intervention, however, may be difficult to implement with some medical procedures as it may be difficult to obtain unfettered access to medical facilities and equipment for the purposes of exposure. Virtual reality may overcome these obstacles.

Methods: In this investigation, the present authors developed a low-cost virtual reality-based exposure therapy which was used with an adult male with autism spectrum disorder and a history of extreme needle phobia. The effectiveness of this intervention was evaluated using a changing criterions design with generalization probes.

Results: The intervention quickly increased the participant's compliance in the analogue training setting and the effects were generalized across settings and behaviours, and maintained over time.

Conclusions: The findings indicate combining virtual reality with exposure therapy may produce an effective intervention for medical phobias. The intervention package may remove barriers associate with traditional exposure therapy and was low-cost which may increase access to the intervention.

KEYWORDS

autism spectrum disorder, exposure therapy, needle phobia, systematic desensitization, virtual reality

1 | INTRODUCTION

Needle phobias are common in both children and adults and affect roughly 10% of the world's population (Hamilton, 1995). Although widespread, fear of needles exists on a continuum ranging from little to no fear of needles to extreme phobia (McMurty et al., 2015). Instances of extreme phobia may lead to non-compliance with medical procedures or avoidance of health care needs altogether (Hamilton, 1995; McMurty et al., 2015). Individuals with intellectual and developmental disabilities may be at even greater risk of extreme needle phobia as they may not understand the importance of the medical procedure (Wolff & Symons, 2013). For these individuals who exhibit severe avoidance responses, the medical course of action is often to employ highly restrictive procedures such as physical restraint, sedation or general anaesthesia (e.g., Braff & Nealon, 1979).

One common alternative to restrictive procedures for specific phobias is exposure therapy which generally involves gradually introducing an individual to increasing intensities of the fear-evoking stimulus. For example, if a person exhibited an avoidance response to snakes that person might be gradually exposed to a snake (e.g., viewing a picture or video of a snake, in a room with a snake, sitting

next to a snake, holding a snake). The intervention may further be combined with other treatment components. Reinforcement may be provided contingent on the absence of avoidance behaviour (differential reinforcement of other behaviours [DRO]; e.g., Hagopian, Crockett, & Keeney, 2001) or the presence of alternative non-avoidance behaviour (differential reinforcement of alternative behaviour [DRA]; e.g., Gillis, Natof, Locksin, & Romanczyk, 2009; Shabani & Fisher, 2006). Further, exposure therapy is commonly combined with other broad intervention components such as delivering instructions or modelling, and the intervention may be provided in a variety of formats including in vivo, imaginal or virtual (McMurty et al., 2015). During in vivo exposure therapy, a person may be required to experience the fear-evoking stimulus in real life, whereas in imaginal exposure therapy the person would form a mental image of the stimulus and in virtual exposure therapy the person would view a digital representation of the stimulus.

Exposure therapy has been used with a variety of phobias such as animal-related phobias (e.g., Gotestam & Hokstad, 2002), flying phobias (e.g., Walder, McCracken, Herbert, James, & Brewitt, 1987) or fear of enclosed spaces (e.g., Ost, Alm, Brandberg, & Breitholtz, 2001). However, it may be difficult to safely apply the procedure to certain phobias, particularly those that are related to medical procedures. For example, applying traditional exposure therapy to a phobia of needles or blood draws may be difficult because the intervention may require access to medical equipment (e.g., needles, vacutainers to hold blood), medical knowledge (e.g., how to draw blood safely), medical waste disposal options (i.e., where to dispose of blood) and medical settings (i.e., a doctor's office). Further, repeated practice may be precluded because time must elapse between each needle insertion to prevent any physical damage to the client. Such barriers may limit treatment effectiveness or preclude the use of traditional exposure therapy altogether.

It may be possible to overcome these treatment barriers by using virtual reality technology to simulate the medical procedure. Virtual reality exposure therapy (VRET) is an alternative intervention to traditional in vivo exposure therapy because VRET allows for the precise control of the intensity, quality, frequency and duration of exposure (Emmelkamp, 2005). Further, VRET may prove useful for individuals for whom imaginal exposure therapy may be difficult, such as individuals with intellectual or developmental disabilities. At its core, VRET incorporates technology (video, audio and/or tactile input) to realistically simulate a three-dimensional environment. Exposure therapy incorporating virtual reality has been shown to be as effective as traditional exposure therapy and capable of leading to meaningful behaviour change (Morina, Ijntema, Meyerbroker, & Emmelkamp, 2015).

Virtual reality exposure therapy has been used with the general population to treat a variety of specific phobias such as fear of heights and flying (Rothbaum & Hodges, 1999) and public speaking (Slater, Pertaub, Barker, & Clark, 2006). Only one study was found that focused on using virtual reality to treat specific phobias in individuals with autism spectrum disorder (ASD). Maskey, Lowry, Rodgers, McConchie, and Parr (2014) used a virtual reality environment, combined with exposure therapy and cognitive behaviour therapy, to effectively decrease the specific phobias of participants aged 7–13 years old with a diagnosis of ASD. The researchers exposed participants to various virtual simulations using a "Blue Room" which is a proprietary technology that creates a fully immersive and interactive simulation displayed within an entire room. No headset or goggles are required, and participants may freely roam the environment. Although this intervention was effective for eight of nine participants, and treatment gains were maintained at 12 months, this technology may not be available to the average consumer and requires extensive resources and planning.

In contrast to interactive environments such as the "Blue Room" are technologies that create simulations displayed using a headset. These may be entirely computer simulated or can rely on relatively inexpensive equipment that creates immersive or spherical 360-degree video (Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2016). If 360-degree headset technology can be effectively used in VRET applications, this option may afford several advantages compared to simulated interactive environments. First, 360-degree headset technology is much more affordable and readily available for purchase by families and clinicians. Second, the headset technology treatment can be applied anywhere which eliminates the need to travel to only those few locations specially outfitted with the necessary virtual reality technology. Finally, headset technology may enable treatment to be delivered at any time which minimizes the need for scheduling treatments sessions associated with scarcer more expensive virtual reality technology. Thus, 360-degree video headset technology may represent a more viable VRET option for families and practitioners working with individuals with ASD and specific phobias. The purpose of this study was to investigate the effects of a low-cost treatment package consisting of VRET and DRO on the compliance behaviour of an adult with ASD and a severe needle phobia related to medically necessary blood draws.

2 | METHOD

2.1 | Participant

Eman was a 26-year-old Caucasian male diagnosed with ASD and moderate intellectual disability who lived at home with his parents. Eman could communicate using simple sentences but required significant programming to teach most functional and daily-living skills. He received in-home applied behaviour analysis therapy provided by a team of therapists and overseen by a Board Certified Behavior Analyst®.

Eman's parents and staff reported that his fear of needles presented significant challenges and limited his ability to engage in routine medical procedures. He required regular blood draws as part of his annual physical evaluation. When blood draws were attempted, he was referred to a specialized paediatric phlebotomy laboratory. No children could be scheduled during Eman's blood draws because his behaviour related to the medical procedure frightened other patients. These blood draws typically required five or more adults to

physically restrain Eman long enough to draw blood. Eman would physically resist the entire procedure.

Prior to this intervention, another attempt at exposure therapy plus DRO was made but did not include virtual reality. A therapist simulated the entire blood draw procedure and used a paperclip to poke Eman's arm to simulate the needle. The procedure was conducted in Eman's basement which did not resemble a doctor's office. The therapist did describe the simulated medical procedure (e.g., stating that blood was going to be drawn), and Eman and the therapist were positioned across from one another as would be the case during a real blood draw, but little systematic effort was made to make the basement setting resemble a doctor's office. Reinforcement was provided for the absence of avoidance behaviour. The treatment package produced compliance in the basement setting; however, the treatment effects did not generalize to the doctor's office and he was unable to tolerate an actual blood draw.

All procedures were approved by a University Institutional Review Board prior to the start of this study, written and verbal informed consent were obtained from Eman's guardian, and verbal assent was obtained from Eman.

2.2 | Materials and setting

All VRET DRO baseline and treatment sessions were conducted in a 4.57 × 7.62 m room in the basement of Eman's home. Doctor baseline and generalization sessions were conducted in Eman's doctor's office which contained standard general practitioner medical equipment such as a stool, chairs and an examination table. Both the doctor's office and the basement settings included blood draw equipment such as nitrile medical examination gloves, alcohol prep pads, cotton balls, a tourniquet, band-aids, needles and blood collection tubes. The needle and tubes were never used in Eman's basement but were present so Eman anticipated a blood draw. Additionally, a cardboard outline of an arm was created to indicate where Eman should place his arm during the blood draw and was present in both settings. The basement also included one Apple Pencil stylus used to simulate the needle insertion, a television, preferred edibles, as well as the virtual reality (VR) equipment which consisted of a Tzumi Dream Vision VR Headset (~$10), an iPhone 6s to display the VR video, and an Insta360 One VR camera (~$250).

A 360-degree video of a blood draw was developed using the Insta360 One VR camera. The VR camera is equipped with two lenses that simultaneously record two 180-degree video images which combined to produce one 360-degree video of the doctor's office and blood draw procedure. Eman's father submitted himself to an actual blood draw completed by Eman's regular nurse. During the blood draw, the father held the camera at chest level and recorded the entire blood draw procedure. When displayed on the iPhone 6s, a stereoscopic video was created. Two separate video images were automatically generated and displayed—one for the right eye and one for the left eye. When viewed simultaneously, the effect was an image that appeared three dimensional. When viewing the 360-degree video with the VR headset, the user could effectively look in any direction and would see a 3D, 360-degree view of the room, including the nurse and Eman's father's right arm which was undergoing a blood draw.

2.3 | Task analysis

A blood draw task analysis was developed based on the video of the actual blood draw taken by Eman's father. A phlebotomist (second author) reviewed the task analysis to ensure it replicated the typical steps of a blood draw. These steps included (a) therapist gathers and displays medical equipment, (b) therapist puts on nitrile gloves, (c) Eman told to place arm on cardboard outline, (d) therapist holds tourniquet, (e) therapist applies tourniquet to Eman's arm, (f) Eman told to make a fist, (g) therapist palpates vein, (h) therapist applies alcohol swab to arm at injection area, (i) therapist applies stylus to Eman's arm and presses down firmly simulating needle injection, (j) therapist removes stylus and applies cotton ball and band-aid to Eman's arm. The only step of the task analysis that was atypical for a blood draw was the incorporation of the cardboard outline.

2.4 | Response measurement and reliability

The primary dependent variable was the terminal step achieved on the task analysis for each session. If Eman did not engage in avoidance behaviour, the terminal step achieved was the goal task analysis step for that session. If Eman did engage in avoidance behaviour, the terminal step achieved was the last successful task analysis step prior to avoidance behaviour. Avoidance behaviour was defined as moving his arm 3 cm in any direction from the cardboard outline, saying “no” or “stop” or any variation thereof, attempting to physically intervene in the blood draw procedure (e.g., grabbing medical equipment, pushing the stylus or needle away) or removing the VR headset.

All baseline, treatment and generalization sessions were video recorded to determine interobserver agreement and treatment integrity. Two observers independently recorded the terminal blood draw step achieved on each session for 83% of all sessions including baseline, treatment and generalization phases. The two complete data sets were then compared. An agreement was scored if both observers independently recorded the same terminal blood draw step achieved, and a disagreement was scored if the recorded step differed between observers. The total number of agreements was divided by the number of agreements plus disagreements. Interobserver agreement was calculated at 100%. Treatment integrity was assessed by developing a list of steps the therapist should engage in during each session. This included (a) therapist puts cardboard outline in place and Eman told to place arm on board, (b) therapist attaches VR headset, (c) therapist starts video at the beginning, (d) therapist counts to 10, (e) therapists ends the programme upon success or avoidance behaviour and (f) therapist tells Eman “all done” when successful and provides a preferred item. Sessions were scored to determine whether the therapist

was accurately implementing this procedure each session. Overall treatment integrity was assessed across 100% of all treatment sessions and resulted in a score of 98%. The only step with errors was step 6. On three separate occasions for this step, Eman was not told "all done" though the preferred item was appropriately provided.

2.5 | Procedures

A changing criterion design with two baselines and a final generalization phase was used to evaluate the effects of the treatment package on Eman's phobic responses to blood draws. The two initial baselines were conducted to determine baseline levels of compliance both in the doctor's office as well as during virtual reality exposure.

2.5.1 | Baselines

Doctor Office baseline sessions were conducted in the office of Eman's general practitioner and the blood draw was attempted by Eman's regular nurse. When Eman entered the examination room, the cardboard outline was placed on a table and Eman was asked to place his arm on the table. The nurse then began the regular procedure of drawing blood. If no avoidance behaviour occurred, the blood draw would be completed. If Eman exhibited avoidance behaviour at any point, the session was ended and no further blood draws were attempted that day.

Virtual reality baseline sessions were conducted in Eman's basement using the VR video of the blood draw. Eman was asked to sit in a chair in his basement and place his arm on the cardboard outline located on a table positioned in front of the chair. All medical supplies were clearly visible on the table. The VR headset was fastened to Eman, and the video began playing. As Eman viewed the blood draw simulation, a therapist observed a TV monitor which simultaneously played the video. The therapist attempted to replicate the sensation that should accompany the VR video. For example, when the video displayed the tourniquet being applied, the therapist would apply a tourniquet in real-time. Eman could not see the therapist when wearing the VR headset. If no avoidance behaviour occurred, the simulated blood draw would be completed. If Eman exhibited avoidance behaviour at any point, the session was ended.

2.5.2 | Virtual reality exposure therapy differential reinforcement of other behaviours

The training procedure was similar to the VR baseline with the exception that a differential reinforcement of other behaviours procedure was added. This procedure provided reinforcement as long as no avoidance behaviour occurred during a session. Prior to each session, the therapist identified a target step which was the step at which Eman would earn a preferred edible (a slice of apple with peanut butter which was an item Eman commonly requested). Eman was told he was to keep his arm on the cardboard outline until the therapist counted to 10, at which point he would receive the preferred edible. Each session began with the therapist gathering the medical equipment and asking Eman to place his arm on the cardboard outline. The therapist then started the video and began slowly counting from 1 to 10 while observing the TV monitor to view the simulated blood draw procedure (the video had previously been slowed down to make the simulation easier for a therapist to follow). Given Eman's communication level and lack of knowledge regarding blood draw procedure, counting from 1 to 10 out loud was incorporated so Eman could more readily predict when he was allowed to move his arm again and still receive the preferred edible. The therapist paced the counting so that the number 10 was reached at the same moment as the target step of the blood draw. For example, if the goal on a given session was to reach the point where the tourniquet was applied, the therapist would slowly count and reach 10 at the moment the tourniquet was applied as determined by observing the TV monitor. If Eman did not exhibit any avoidance behaviour during the counting, the session was ended and a small preferred edible was provided. If Eman did exhibit avoidance behaviour, the session ended and a new session began approximately 1 min later and began again with Step 1. As target steps were met, the therapist gradually increased the number of successful steps required for reinforcement according to the changing criterion design. At least one session without avoidance behaviour was required before the criterion for reinforcement was changed from one criterion to the next. Training continued until Eman was able to successfully complete the entire VR simulated blood draw for four consecutive sessions without exhibiting avoidance behaviour. No more than four sessions were conducted on a given day.

2.5.3 | Maintenance and generalization assessment

Following completion of the training procedure, four generalization probes were conducted with generalization probes scheduled approximately one week apart. All probes were conducted in the same doctor's office as during the original baseline, and the cardboard outline was used during all sessions. All other training components, including counting from 1 to 10 and the delivery of the preferred edible, were absent during generalization and maintenance probes with the exception of the cardboard outline. The cardboard outline continued to be used to replicate the original baseline phase and to promote generalization.

During the first generalization probe, a real blood draw was attempted using the same nurse that was present during the initial baseline and in the training video. During the second generalization probe, a new nurse administered the blood draw. During the third generalization probe, the blood draw was attempted using the Eman's left arm rather than his right arm which had been used during all previous sessions. During the fourth generalization probe, a new therapist accompanied Eman on the blood draw. Maintenance was assessed with a follow-up probe conducted one month after the fourth generalization probe.

3 | RESULTS AND DISCUSSION

Results are provided in Figure 1. During both baseline phases (Doctor Office and VR), Eman was unable to successfully complete either a real or simulated blood draw. He would comply with all requests up to and including placing his arm on the cardboard outline but would engage in avoidance behaviour as soon as the nurse picked up the tourniquet. All baseline sessions ended in premature termination with Eman complying up through Step 3. Once treatment was initiated, and reinforcement was made contingent on the absence of avoidance behaviour, Eman successfully completed 11 of the 14 training sessions. Avoidance behaviour was exhibited on sessions 8, 11 and 12. Presumably, these were the steps that were the most aversive for Eman. Session 8 was the first time the therapist picked up the tourniquet which was the step that resulted in termination for all baseline sessions. During sessions 11 and 12, the goal was to use an alcohol prep pad on Eman's arm in preparation for needle insertion simulated through firm application of the stylus. All other sessions were successful, and Eman met mastery criteria in only 14 sessions. Following mastery, a real blood draw was scheduled with the same nurse who appeared in the training video. Eman successfully allowed his blood to be drawn. During subsequent blood draws, generalization of treatment effects was assessed by having a new nurse administer the blood draw, using Eman's left (non-training) arm for a blood draw, having a new therapist accompany Eman to the blood draw to ensure there was no therapist control and conducting a 1-month follow-up. During all generalization and maintenance probes, Eman complied with all task analysis steps and successfully completed each blood draw.

Overall, this study demonstrates the utility of a low-cost VRET DRO in increasing compliance with a medically necessary blood draw procedure for an adult with ASD who had a severe needle phobia related to blood draws. There are several unique advantages of VRET over traditional exposure. First, traditional exposure therapy may be difficult to perform on phobias that occur in specific settings that are difficult or expensive to replicate, such as a doctor's office outfitted with medical equipment. This might limit treatment opportunities and may hinder generalization to non-treatment settings and may explain the failure of Eman's previous traditional blood draw exposure therapy to generalize from his basement to an examination room. Virtual reality overcomes these obstacles as specific environments, including medical staff, may be duplicated through simple 360-degree video software which enables therapy to be provided anywhere and at any time. Further, this technology has

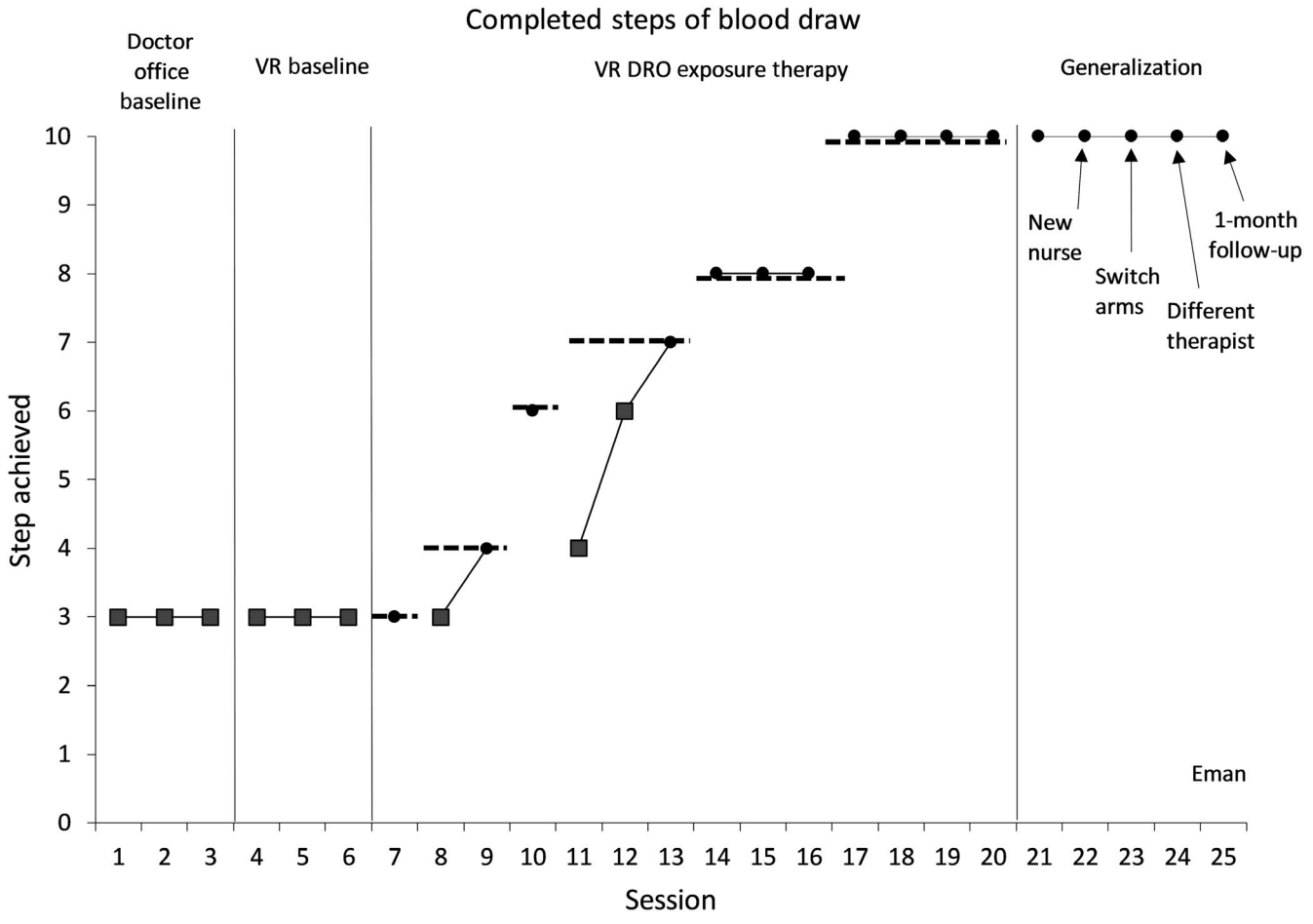

FIGURE 1 Successful steps of the blood draw each session. Squares indicate sessions that were terminated early due to avoidance behaviour. Closed circles indicate sessions that were successfully completed. Dashed lines indicate the treatment goal for that session

become quite affordable and all equipment used in this study (minus the iPhone 6s) was acquired for <$300.

Additionally, VRET may be particularly suited to medical phobias where the medical procedure requires specific expertise such as is required to perform a blood draw. Our VRET procedure required only that a trained phlebotomist complete the procedure once for the purposes of creating a video recording of the procedure. This video can then be replayed repeatedly without risk of physical damage or discomfort to the client.

Further, VRET may be an appropriate intervention for specific phobias presented by individuals with ASD who may be over- or under-sensitive to different environmental sensory stimuli. For example, in a doctor's office a person with ASD may react negatively not only to a needle used for a blood draw but also to the brightness of the room, the sound of medical equipment or aspects of a waiting room. In traditional exposure therapy, it would be difficult to control all of these variables while focusing on the needle phobia. In VRET, the brightness of the room may be digitally controlled, audio may be increased or decreased, and a waiting room is eliminated allowing the therapist to focus on specific variables for exposure therapy. Although this was not necessary for the participant in this study, it is a practical extension of the technology used.

Finally, the recorded nature of this intervention may make it unnecessary to continually recreate training scenarios. Medical procedures are largely standardized and blood draws, for example, are generally the same from office to office. It could be possible for 360-degree videos of medical procedures to be shared across therapists which would further decrease the expense of the VRET intervention as no recording equipment would be necessary.

There are several limitations and directions for future research. One possible limitation is that the second author on this study, who was also the therapist, is a trained phlebotomist. It is unclear if the present authors would have obtained the same extent of generalization across settings, people and behaviour that the present authors observed if an untrained medical professional served as the therapist. However, considering the generalization of treatment effects observed in previous research (e.g., Hagopian et al., 2001) where an untrained medical professional served as the therapist, it seems likely that our procedures produced the generalization effects—not simply the use of a trained phlebotomist as the therapist. However, future researchers may consider comparing the extent to which treatment effects generalize when a trained versus untrained medical professional serve as the therapist. A second limitation is that our changing criterion design could have been strengthened. In our design, the present authors employed three different criterion phase lengths, two different magnitudes of criterion changes, and six different criterion changes overall. Our design could have been strengthened, however, by remaining at various criterion for more consecutive sessions and further varying the magnitude of criterion changes to further demonstrate experimental control.

One important consideration with the use of virtual reality technology is the distinction between exposure and distraction-based interventions. Distraction-based virtual reality interventions immerse a participant in a simulated world and a medical procedure is applied while the participant is distracted. Research has demonstrated that individuals may be more likely to accept a medical procedure involving needles, and rate the procedure as less painful, using distraction-based virtual reality compared to no intervention (Kenney & Milling, 2016). One concern with this use of virtual reality is that the participant may never learn to accept the medical intervention in the absence of distraction. In contrast to a distraction-based approach, VRET simulates the precise conditions that evoke resistance to the medical procedure and teaches the individual to willingly accept the medical intervention. Although both approaches increase the likelihood of medical compliance, VRET may increase the likelihood of generality to the real world through programming common stimuli (Stokes & Baer, 1977) between the training and generalization settings. The long-term effects of distraction-based virtual reality and VRET should be investigated in future research.

Future research should also investigate this VRET intervention across a larger group of participants and diverse medical procedures given that this intervention was conducted with one individual. It also may be beneficial to investigate factors affecting the generality of this intervention. The extent to which similarity between arms (Eman's and the arm portrayed in the video) is necessary, for example, is unknown. It is unclear whether similarity is critical or whether simply repeatedly viewing a blood draw would produce the same effects. Future research may also attempt to determine the mechanisms responsible for the effectiveness of this and similar DRO-based exposure therapy interventions. In the present study, for example, avoidance behaviour effectively delayed the opportunity for reinforcement and this was signalled when the therapist ceased counting and the session was terminated. It could be possible for this signal to become a conditioned punisher which then functioned to decrease avoidance behaviour. Whether this signal was necessary or not is unclear but may have played an important role in the intervention. Future research should focus on identifying the utility and mechanism of each component of similar DRO-based exposure therapy interventions. Further, as with any treatment package, a component analysis would be beneficial to determine whether the entire treatment package is necessary or whether specific elements of the overall package are sufficient to produce the effects. Finally, Eman had a history with the VR headset as it was used as a reinforcer prior to this study. Future research should investigate the effects of this intervention on individuals without this history.

Virtual reality has been around for decades but only recently has the technology become practical or affordable for the individual consumer. The technology is increasingly mobile and can now take on a variety of forms from fully computer-generated and interactive to immersive or spherical videos (as with the VRET used in this study). As an intervention option for individuals with ASD and other developmental disabilities who exhibit specific phobias, this technology is particularly promising but remains under researched.

CONFLICT OF INTEREST

Author James Meindl declares that he has no conflict of interest. Author Serena Saba declares that she has no conflict of interest. Author Mackenzie Gray declares that she has no conflict of interest. Author Laurie Stuebing declares that she has no conflict of interest. Author Angela Jarvis declares that she has no conflict of interest.

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