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Research Article

Real Enough: Using Virtual Public Speaking Environments to Evoke Feelings and Behaviors Targeted in Stuttering Assessment and Treatment

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Purpose: *Virtual reality environments* (VREs) are computer-generated, 3-dimensional worlds that allow users to experience situations similar to those encountered in the real world. The purpose of this study was to investigate VREs for potential use in assessing and treating persons who stutter (PWS) by determining the extent to which PWS's affective, behavioral, and cognitive measures in a VRE correlate with those same measures in a similar live environment.
Method: Ten PWS delivered speeches—first to a live audience and, on another day, to 2 virtual audiences (neutral and challenging audiences). Participants completed standard tests of communication apprehension and confidence prior to each condition, and frequency of stuttering was measured during each speech.
Results: Correlational analyses revealed significant, positive correlations between virtual and live conditions for affective and cognitive measures as well as for frequency of stuttering.
Conclusions: These findings suggest that virtual public speaking environments engender affective, behavioral, and cognitive reactions in PWS that correspond to those experienced in the real world. Therefore, the authentic, safe, and controlled environments provided by VREs may be useful for stuttering assessment and treatment.

Over 10 years ago, Yaruss (2001) lamented the lack of standardized, functional, "real-world" communication tasks for assessing stuttering treatment outcomes. This status remains today. The challenge is not unique to communication sciences and disorders; other fields such as geology, surgery, and teaching also struggle with "real-world assessment" (Gallagher et al., 2013; Güneralp & Marston, 2012; Lam, McNaught, & Cheng, 2008). Real-world practice is preferred to within-clinic practice because practicing in the real world is thought to improve generalization of newly learned skills and attitudes (Stokes & Baer, 1977; Venkatagiri, 2004). Unfortunately, real-world practice often includes ethical, financial, and logistical constraints (de Carvalho, Freire, & Nardi, 2010; Ebesutani, Bernstein, Chorpita, & Weisz, 2012; Santos Ruiz et al., 2010). Virtual reality environments (VREs) allow for repeated practice that is safe, confidential, and under the clinician's control.

VREs can enhance learning at all steps in the clinical learning process, from skill acquisition to retention and generalization. Holden (2005) suggests that practice in VREs is beneficial and may be superior to real-world practice due to the number of distractions in the real world that make it difficult for clients to distinguish "key aspects of the task on which to focus" (pp. 191–192). That is, early in treatment, clinicians can reduce distractions in order to improve learning. Later in treatment, clinicians can promote generalization by systematically reintroducing these distractions into the VRE as clients master various skills. Furthermore, practicing in VREs allows for immediate feedback on performance; this type of feedback is critical for learning (Huet, Jacobs, Camachon, Goulon, & Montagne, 2009) but is often difficult to provide in a timely fashion in real-world settings. In addition, VREs can be more time efficient and cost effective than real-world practice (de Carvalho et al., 2010; Jönsson et al., 2010).

Furthermore, the salience of the practice environment matters. Practicing in environments that have meaning for learners improves learning, motivation, and generalization of new skills to novel environments (Graybiel & Saka, 2004; Krakauer, Mazzoni, Ghazizadeh, Ravindran, & Shadmehr,

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2006; Robin, Toussaint, Blandin, & Proteau, 2005). In order for VREs to be useful in treatment, they must engender similar reactions to those seen in the real world. For example, a virtual audience VRE is only clinically useful if it creates reactions similar to those created by a real audience. Therefore, ensuring that particular VREs elicit affective, behavioral, and cognitive reactions comparable to those in the real world for a person with a given disorder is a crucial precursor to implementing VREs in treatment protocols. Findings such as these could bridge the gap between clinic and real world.

What Are VREs?

VREs are computer-generated, three-dimensional worlds that allow users to interact with avatars in the virtual world. Active participation is thought to enhance the users' sense of presence or immersion in the VRE. Once immersed, the user can practice novel motor skills, revise negative affective reactions, and change his or her cognitive set. If a person is successfully immersed in the VRE, the VRE will cue one's memories and/or schema of common situations so that one can practice new reactions to those situations. VRE software and associated hardware are aimed at increasing immersion and presence. Visual stimuli and the ability to "look around" the VRE are presented via a head-mounted display (HMD) and tracking system that changes the visual display as if one is looking around in the real world. For example, if persons enter the VRE through a virtual door and then turn their heads to look back, they will see the door that they just passed through. Auditory stimuli, such as clapping in virtual audiences, or car engine noises in parking garages, can be added to increase presence. Olfactory stimuli can also increase immersion and presence; for example, the smell of alcoholic beverages has been shown to increase immersion in VREs aimed at reducing alcohol cue reactivity (Graap, Bordnick, Brooks, Ferrer, & Brundage, 2005). Finally, haptic gloves can be used to emulate tactile sensations such as those necessary for practicing surgery in VREs.

The Potential for VREs in Clinical Practice

Prior to using VREs in clinical practice, it is important to ascertain that VREs have criterion-related validity, in that performance in virtual space should correspond to performance in the real world (McCauley & Swisher, 1984). It is important to understand that criterion-related validity is measured by the strength of the correlation or relationship between two or more outcomes. Finding no statistical difference between two outcomes (i.e., failing to reject the null hypothesis that the outcomes are equal) is not a good test of validity because the probability of a Type II error cannot be controlled.

This type of validity has been established via correlational analyses for numerous types of VREs covering a wide range of behavioral assessments. Fiard et al. (2014) compared user accuracy in performing prostate biopsies in virtual versus real environments and found a significant Pearson correlation of .79 between the two environments, suggesting that performance in a VRE is a good indicator of accuracy in a real environment. Wald, Liu, and Reil (2000) compared the driving skills of survivors of traumatic brain injury in a virtual driving environment (*driVR*, a virtual reality assessment; Liu, Miyazaki, & Watson, 1999; Imago Systems, Vancouver, British Columbia, Canada) to on-road performance. Performance of multiple driving behaviors (e.g., following a car, parking) in *driVR* was significantly correlated with on-road performance, leading the authors to conclude that *driVR* was a useful tool for driving assessment in traumatic brain injury survivors. In addition to driving, other life skills such as preparing meals have been assessed by comparing VRE versus real-world environments; again, strong, significant correlations suggest that VRE-based performance is predictive of real-world performance (Zhang et al., 2003). In another study by Freeman et al. (2014), behavioral reactions in a VRE at initial assessment correlated with self-report measures and with initial interview findings; the behavioral reactions in the VRE also predicted the frequency of paranoid thinking 6 months after initial assessment. These findings led these researchers to conclude that "VR environments may be used in the clinic to complement standard self-report and clinical interview methods" (Freeman et al., 2014, p. 1). In addition to their established utility in assessment, VREs also have established effectiveness in augmenting treatment of various disorders such as those that involve (a) reducing negative emotional reactions to feared stimuli, (b) changing clients' cognitions about themselves, and (c) practicing various types of motor behaviors.

Effectiveness of VRE Practice in Affective, Behavioral, and Cognitive Disorders

Affective reactions. VREs are safe and relatively risk-free places to practice newly learned skills. This is particularly important in disorders involving a fear response, such as public speaking anxiety, because the basic human response to fearful situations is to avoid them. The use of VREs for fear-based disorders is based on emotional processing theory (Foa, Huppert, & Cahill, 2006; Foa & Kozak, 1986), which posits that fear responses can be mediated by "exposure to corrective information" when the fear response is elicited; this corrective information allows clients to form new memories of the situation in which the fear response is attenuated or absent. It is important to note that the conditions in which the client enters, either VRE or in vivo, must elicit the fear response in order for exposure therapy to be effective. The client must be in the feared environment before they can act to change their responses via corrective information provided by the clinician. If the fear response is not activated, then the corrective information is not necessary.

Exposure to fear typically increases anxiety, which in turn motivates the person to avoid the fear-inducing situation. In VREs, however, clinicians can systematically expose clients to feared stimuli in order to elicit the fear response. Once elicited, the client stays in the situation until the fear response habituates. Repeated exposures to the feared stimuli in this manner serve to decrease the fear response, thereby reducing anxiety. This process is referred to as *systematic desensitization.* Clients must be ready to encounter the feared situation. If they are not ready, the process is considered *flooding*. Flooding has questionable efficacy, and if flooding occurs before the client is ready for it, it can increase anxiety and result in other negative consequences, such as increased avoidance of the feared situation (Morganstern, 1973). The risk of increased avoidance can be seen in the high dropout rates associated with cognitive behavioral therapies (CBT) addressing the fear of public speaking (FOPS). Wallach, Safir, and Bar-Zvi (2009) carried out a randomized controlled trial (RCT) for FOPS comparing three groups: (a) in vivo CBT treatment group, (b) virtual reality–based (VR-based) CBT treatment group, and (c) a wait list control group. Both treatment groups had better outcomes than the wait list controls; however, more than twice as many people dropped out of the in vivo CBT group compared with the VR-based group. This finding suggests that clients are more willing to stay "in the moment" longer in VREs than in real-world scenarios, which would allow more practice in particularly stressful situations. VREs provide a unique opportunity to experience feared speaking situations without negative consequences (i.e., flooding); if clients become too fearful in the VRE, they simply exit it and begin again, without the accompanying affective and social consequences.

Exposure therapy via habituation and desensitization is one method of treating affective disorders involving fear, anxiety, and phobia. It entails exposing clients to the feared stimulus (e.g., an airplane if one fears flying, an open space for someone with agoraphobia) and continuing the exposure until the fear subsides. Once negative reactions such as fear, anxiety, and panic have been elicited by the VRE, VREs can be used as exposure tools to decrease the severity of these reactions and/or replace them with more appropriate reactions. VREs have proven useful in stimulating negative affective reactions, such as fear and anxiety in persons with various types of phobias including FOPS, fear of flying, agoraphobia, and social phobia (Anderson et al., 2013; Botella, Osma, Garcia-Palacios, Quero, & Baños, 2004; Klinger et al., 2005; Malbos, Rapee, & Kavakli, 2013; Meyerbröker & Emmelkamp, 2010; Rothbaum, Hodges, Anderson, Price, & Smith, 2002), and in anxiety disorders (Opris et al., 2013; Parsons & Rizzo, 2008).

Cognitive reorganization. Certain disorders require cognitive reorganization to replace older, more negative thoughts with newer thoughts that are more aligned with actual reality. Riva and colleagues have used VREs to assist persons with eating disorders to reorganize their cognitions about their own body image and to increase their motivation for change (Riva, Bacchetta, Baruffi, & Molinari, 2001; Riva, Bacchetta, Cesa, Conti, & Molinari, 2004). Riva and colleagues (2001, 2004) developed a series of VREs designed to calm the patients and allow them to focus on (a) identifying "distorted perceptions" of themselves, (b) relabeling these perceptions to be less negative, (c) exploring how negative beliefs can shape destructive behaviors, and (d) assisting the patients in reshaping negative beliefs about their behaviors and themselves. In an RCT comparing VR-based treatment versus standard CBT without VR, the VR-based treatment group had better body satisfaction, higher self-efficacy, and higher motivation for change than did the non-VR group (Riva et al., 2001). Cognitive reorganization was achieved best when treatment incorporated VREs.

Behavioral change. In addition to affective and cognitive changes, treatment with VREs can also address behavioral change. VREs have a long history of use to improve motoric deficits and to teach motor skills (Holden, 2005) due to the opportunities for repeated, systematic practice in VREs. For example, in survivors of stroke who have aphasia, virtual therapists have been used to practice verbal scripts (Cherney, Halper, Holland, & Cole, 2008; Holland, Halper, & Cherney, 2010). VREs have also been used to improve limb range of motion and speed of movement in survivors of stroke (Merians et al., 2002). Within the behavior realm, VREs have also been used in skills training and transfer in students learning various complex skills such as performing surgery (Gallagher et al., 2013) or flying a plane (Huet et al., 2009). Here, again, we see that practice in VREs can lead to better performance than practicing in vivo and that behaviors practiced in VREs transfer to the real world (Emmelcamp et al., 2002; Rose et al., 2000). An example is the work of Gallagher et al. (2013), who randomly assigned groups of novice and expert surgeons to receive either VR training or no VR training in laparoscopic surgery techniques. Each surgeon then completed a standardized laparoscopic assessment procedure wherein surgical cuts could be measured against a target for accuracy. The authors reported a correlation of $r = .96$ between real-world and VR-based performance. Furthermore, the novice and expert learners who trained in VREs made fewer errors (Gallagher et al., 2013). These findings led Gallagher et al. to summarize that "simulation models for skills training are effective because they provide a context, an organizational structure, and focus to apply information retrieved from long-term memory" (2013, p. 1030). These contextual, organizational, and focus characteristics of VREs may also influence affective and cognitive reactions, in addition to behavioral responses.

VREs With Persons Who Stutter

It is clear that VREs are useful for addressing affective, cognitive, and behavioral aspects of disorders. Stuttering involves all three of these aspects, and research has shown that these reactions can be manipulated in VREs (Brundage, 2007; Brundage, Graap, Gibbons, Ferrer, & Brooks, 2006). Behavioral aspects of stuttering include the observable stuttering itself, physiological conditions such as tension and struggle in the vocal tract, and avoidance of speaking situations that the speaker presumes will lead to stuttering (Manning, 2010). Accompanying affective reactions include feelings related to stuttering, such as anticipatory anxiety prior to feared speaking situations, fear, guilt, or shame (Murphy, 1999; Sheehan, 1953). Cognitive reactions include thought processes associated with stuttering, ideas about communication, and how stuttering influences quality of life. These negative reactions often lead adults who stutter to avoid social situations. Treatments for stuttering typically address one or all of these aspects (Bothe, Davidow, Bramlett, & Ingham, 2006). A VRE tool that could augment the treatment of all of the components of stuttering could be quite useful. Until now, there has not been a direct investigation of affective, behavioral, and cognitive stuttering reactions in VREs and the real world, although preliminary work has been done. Studies have addressed whether aspects of stuttering (e.g., behavior, affect) can be manipulated in VREs.

The nature of VREs can influence stuttering behavior (i.e., the frequency of stuttering observed) and affective reactions. Brundage et al. (2006) created and tested two VREs; the challenging VRE consisted of a job interview with the time-pressured chief executive officer (CEO) of a company in the CEO's office, whereas the supportive job interview occurred with human resources personnel in a small office. The frequency of stuttering, as measured by the percent syllables stuttered (%SS), increased during challenging virtual job interviews as compared with supportive virtual job interviews (Brundage et al., 2006). In a study examining affective reactions of people who stutter (PWS), Millar, Brundage, Lincoln, Onslow, and Menzies (2008) had 14 adult PWS give speeches to a virtual audience and to a virtual empty room. Each speech lasted 10 minutes, and participants provided a subjective units of distress (SUDS) rating at the end of each minute for each speech. The SUDS rating is a commonly used, reliable measure of self-reported anxiety (Benjamin et al., 2010) typically ranging from 0 to 100, with higher ratings indicating greater anxiety. SUDS ratings were significantly higher in the virtual audience condition than in the virtual empty room condition (Millar et al., 2008), a finding replicated by Brinton and Brundage (2011). These studies demonstrate that behavioral and affective aspects of stuttering can change as a result of manipulations available with VREs (Brundage, 2007).

The Current Study

What has not yet been reported is whether or not VREs can evoke affective, behavioral, and cognitive aspects of stuttering that are similar to those experienced in real environments. In order to address this, we chose speaking in front of an audience as the situation to evaluate in vivo and in virtual reality. We chose this situation because it is commonly reported to be a feared speaking situation for both those who stutter (Stein, Baird, & Walker, 1996) and those who do not (Pull, 2012; Stein, Walker, & Forde, 1996). In addition, VREs have been used successfully to minimize fears associated with public speaking in persons with social anxiety (Anderson et al., 2013; Anderson, Rothbaum, & Hodges, 2003; Anderson, Zimand, Hodges, & Rothbaum, 2005; Wallach et al., 2009).

The current study examined affective, behavioral, and cognitive reactions of PWS in the context of speeches delivered to real and virtual audiences. Our intent was to evaluate the potential of VREs for use in the assessment and treatment of stuttering by determining the extent to which measures prior to and during VRE-based speeches correlate with those same measures in a similar live environment.

Method

Participants

Ten adult PWS (seven males), ranging in age from 23 to 52 years (M = 35 years), participated. Seven participants were White, one was African American, one was Asian, and one identified himself as "Other." All participants reported stuttering onset in childhood. Stuttering severity was calculated using the Stuttering Severity Instrument for Children and Adults–3 (Riley, 1994), and severity scores ranged from 10 to 25 (M = 19, SD = 6). All participants completed the Modified Erickson Scale of Communication Attitudes (Andrews & Cutler, 1974); scores on this scale ranged from 7 to 24 (M = 15, SD = 5), with higher scores indicating more negative attitudes toward communication. Impact rating scores on the Overall Assessment of the Speaker's Experience of Stuttering (Yaruss & Quesal, 2006) ranged from 34 to 67 (M = 49, SD = 10; see Table 1). Participants reported having participated in a variety of durations and types of previous therapy, including fluency shaping and stuttering management programs. Five were currently in treatment (three in fluency shaping, one in stuttering modification, and one in a combined treatment program). Three participants were not currently receiving treatment for their stuttering, and two did not provide current treatment information. All participants reported stuttering as their only communication disorder, and no participants reported psychological or psychiatric diagnoses.

Materials

Self-report scales. Participants completed two self-report scales before the live audience (live) and virtual-reality audience (VR) conditions: the Personal Report of Confidence as a Speaker (PRCS; Paul, 1966) and the Personal Report of Communication Apprehension–24 (PRCA-24;

Table 1. Means, standard deviations, and impact ratings for Overall Assessment of the Speaker's Experience of Stuttering (OASES) scores (n = 9).

OASES section	M (SD)	Overall impact rating
1. General information	51.8 (12.3)	Moderate
2. Reactions to stuttering	57.7 (15.1)	Moderate
3. Communication situations	44.8 (8.6)	Mild to moderate
4. Quality of life	42.1 (13.8)	Mild to moderate
Total impact score	49.1 (10.0)	Moderate

McCroskey, 1997b). These scales served as measures of cognitive and affective state, respectively. Both measures are commonly used in studies of speaking fear and phobia. The PRCS consists of 30 true–false statements regarding participants' confidence in their public speaking abilities (e.g., "I face the prospect of making a speech with complete confidence" and "I look forward to an opportunity to speak in public"). Scores range from 0 to 30, with higher scores indicating less confidence in one's abilities in public speaking. The PRCS has high internal consistency, Cronbach's alpha (α) = .91 (Daly, 1978). Normative data for the PRCS suggest that average scores of nonclinical samples are in the 13–14 range, with no significant differences in scores across race or gender (Phillips, Jones, Rieger, & Snell, 1997).

The PRCA-24 consists of 24 statements that assess participants' feelings about communicating with others in four different communication settings: groups, meetings, interpersonal contact, and public speaking. Participants rank their responses on a scale of 1 to 5 (1 = *strong agreement with the statement,* 5 = *strong disagreement with the statement*). Sample statements from the PRCA-24 include "Engaging in group discussion with new people makes me tense and nervous" and "Usually I am calm and relaxed when participating in meetings." Scores on the PRCA-24 range from 24 to 120; scores above 80 indicate high communication apprehension, and scores below 51 indicate low communication apprehension (McCroskey, 1997a). Mean scores for large samples of nonclinical adults average 65.5 (McCroskey, 1997a). The PRCA-24 also has high internal consistency, $\alpha \geq .90$ (Daly, 1978; McCroskey, 1997a); content validity with other measures of anxiety and apprehension have been documented (McCroskey, Beatty, Kearney, & Plax, 1985).

VREs. Virtual audiences were created using a software program designed for treating the fear of public speaking (2013; Virtually Better, Decatur, GA). We created two virtual audiences in an attempt to extend prior findings (Brundage et al., 2006) that showed that %SS varied by type of virtual scenario. In the current study, one speech was delivered to a *challenging virtual audience (VA),* which consisted of approximately 20 listeners who did not pay attention, did not make eye contact, and made other nonverbal distracting behaviors (e.g., falling asleep). A second speech in VR was delivered to a *neutral virtual audience (VA)* of the same size; these audience members looked straight ahead and were neither distracting nor supportive. Figure 1 shows a screenshot of the virtual audience prior to introducing the challenging or neutral manipulations described above. Live audiences consisted of eight to 10 people; these people were told that they would be listening to speeches and evaluating each speech using a rating form. Audience members were not given specific instructions on how to respond to speeches because prior research suggests that significant amounts of training are necessary to achieve consistent, specific reactions (e.g., surprise, boredom, negative affect) across participants (Jönsson et al., 2010). Instead of receiving specific instructions, audience members were told to listen attentively in order to rate the speeches afterward. Audience members for the live condition were recruited via the participant pool in the psychology department, and audience members received course credit for participating.

Figure 1. Screenshot of the virtual audience. Copyright © 1996, Virtually Better, Inc. Published with permission.

Equipment. The VA software was installed on a Dell P-IV PC with an Nvidia Fx5200 graphics card. The PC was connected to a VFX-3D HMD and tracker combination computer (Interactive Imaging Systems, Rochester, NY). The HMD covered the upper half of the participant's face and contained display screens for each eye, earphones to provide sounds (e.g., audience clapping), and a tracking device to calculate pitch, yaw, and roll orientation of the HMD. The participants saw the VAs in the HMD, and the investigators viewed the same image on the computer monitor.

Procedure

Participants gave three 5-minute speeches over 2 days. Two of these speeches occurred in front of virtual audiences described above, and one occurred in front of a live audience. The order of speeches was counterbalanced to ensure that half of the participants gave speeches in VR prior to speaking in front of live audiences, and half the participants gave speeches to challenging VAs prior to neutral VAs. All speeches were audio-recorded for later analysis.

The VA speeches took place in a quiet, darkened room. Upon entering the room, the participants were informed that they would be giving two speeches in two different virtual audience environments, but they were not informed of the nature of these environments. They then filled out the PRCA-24 and the PRCS before entering the VRE, as measures of anticipatory apprehension and cognitive reaction, respectively. Participants did not complete the questionnaires again between the first and second VA speeches because of concerns that the result would not truly be a "pre" measure of confidence and apprehension. However, a second VA speech was still deemed valuable in order to explore whether the nature of a VRE would influence the strength of correlation between the VR and live conditions, as suggested by Brundage et al. (2006).

After completing the PRCA-24 and the PRCS, the participants were presented with a stack of cards that had speech topics written on them. The participants selected one card, and the topic on that card was what they talked about for their first speech. They were not given time to prepare a speech. Then the participant stood at a podium, and the investigator placed the HMD on the participant's head and activated the software. Once the software was activated, a virtual curtain appeared in front of the participant through the HMD. The investigator then pushed a controller button that opened the curtain and moved the participant to the front of the first VA. The participant then gave the first speech. Upon completion of the speech, the participant was instructed to close his or her eyes and remain standing in front of the podium. The investigator then changed the VA, and the process began again.

For the live condition, participants were told that they would be giving a speech in front of a live audience. They filled out the PRCA-24 and the PRCS in a quiet room and then were escorted into the room where the audience was seated. Participants stood at a podium and gave their speech to the audience.

Data Coding and Reliability

Speech transcription and disfluency coding followed standard procedures (Yaruss, 1997). An initial transcriber listened to the audiotape of each speech and transcribed each speech. The second transcriber then listened to the speech while viewing the transcript generated by the first transcriber. The second transcriber noted any discrepancies with the initial transcription. The two transcribers then reviewed these discrepancies and resolved them. On the rare occasions in which the two transcribers could not resolve the issue, a third transcriber listened to the audiotape and determined which transcription was correct; if the third transcriber did not agree with either transcriber, then the word was considered unintelligible.

We calculated the %SS in each speech given by each participant. Repetitions of sounds and syllables, sound prolongations, and blockages of air were considered stuttering events. We operationally defined *blockages* as periods of silence that lasted longer than 2 seconds. In addition, the word that followed the silence had to be produced with obvious tension or a perceptual "burst" of air. Our criteria for blocks were quite strict; we are aware of the challenges of identifying blocks from audiotape and therefore wanted to be conservative in our identification of this behavior. The %SS in each speech was calculated by dividing the total number of stuttered syllables by the total number of syllables in the speech and then multiplying that number by 100 to get a percentage. The 10 participants gave a total of 30 speeches. The authors independently coded disfluencies on seven (23%) of these 30 speeches. Point-to-point percent reliability was 98%.

Results

Descriptive Information

Group means and standard deviations for PRCA-24 and PRCS just prior to both the live-and VR-condition speeches are listed in Table 2. In general, the participants rated themselves as having very high apprehension and moderate confidence. The means and standard deviations for %SS were as follows: live (M = 2.73, SD = 1.9), neutral VA (M = 2.55, SD = 1.3), and challenging VA (M = 2.86, SD = 2.0). This frequency of stuttering behaviors is consistent with the classification of mild severity.

Statistical Analyses

Given the literature reviewed above, the working hypothesis was that apprehension, confidence, and stuttering frequency levels in VREs would correspond well to levels in real-world settings. Therefore, Spearman rank-order correlation coefficients were calculated to examine relationships between conditions for each measure (i.e., PRCA-24, PRCS, %SS).

Scores on the PRCA-24 prior to the live condition and prior to the VR condition were significantly correlated (ρ = .82, p < .004). Upon visual examination of the scatterplot, the correspondence was nearly 1:1, indicating that virtual audiences create similar anticipatory apprehension in PWS that live audiences do (see Figure 2). Figure 2 presents data for each of the 10 participants, comparing their PRCA-24 scores in live versus VR conditions.

Scores on the PRCS, a cognitive measure, prior to both the live and VR conditions were also significantly correlated (ρ = .88, p < .001). Figure 3 presents PRCS data for each of nine participants; one participant failed to complete the PRCS prior to the virtual condition and was therefore

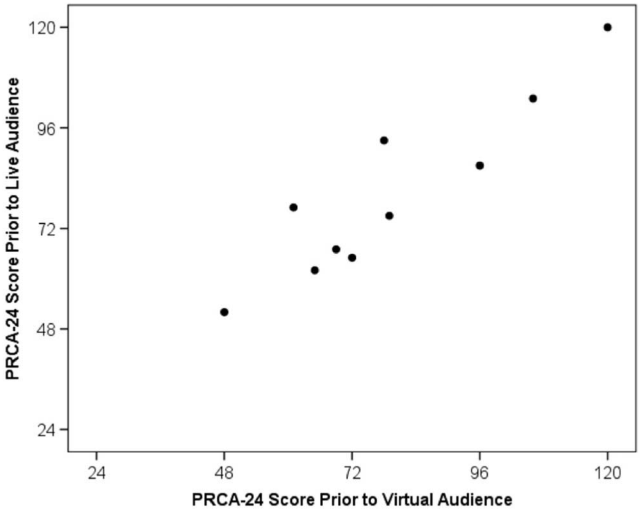
Table 2. Means and standard deviations of Personal Report of Communication Apprehension–24 (PRCA-24) and Personal Report of Confidence as a Speaker (PRCS) scores prior to speeches delivered to live and virtual audiences (n = 10).

Measure	Prior to live audience speech *M (SD)*	Prior to virtual audience speech *M (SD)*
PRCA-24	80.1 (20.8)	79.4 (21.9)
PRCS	12.7 (8.5)	14.4 (8.8)[a]

Note. PRCA-24 scores range from 24 to 120, with higher scores indicating higher apprehension. PRCS scores range from 0 to 30, with higher scores indicating lower confidence.

[a]n = 9.

Figure 2. Personal Report of Communication Apprehension–24 (PRCA-24) scores prior to speeches delivered to live and virtual audiences.



not included on this graph. This finding suggests that rates of speaking confidence prior to virtual conditions predict rates of speaking confidence prior to live conditions (see Figure 2).

Finally, the correspondence between %SS during speeches given to live, neutral VA, and challenging VA conditions was analyzed using Spearman correlations. The %SS during speeches to live conditions was significantly correlated with %SS in speeches given in neutral VA conditions (ρ = .82, p = .004) and challenging VA conditions (ρ = .99, p < .000; see Figure 4). Figure 4 presents data for each of the 10 participants, comparing their %SS scores in the live condition versus in the two virtual conditions.

Figure 3. Personal Report of Confidence as a Speaker (PRCS) scores prior to speeches delivered to live and virtual audiences.

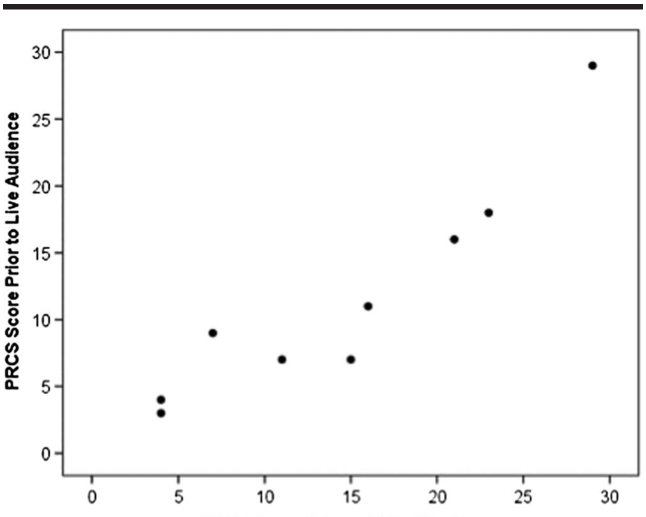
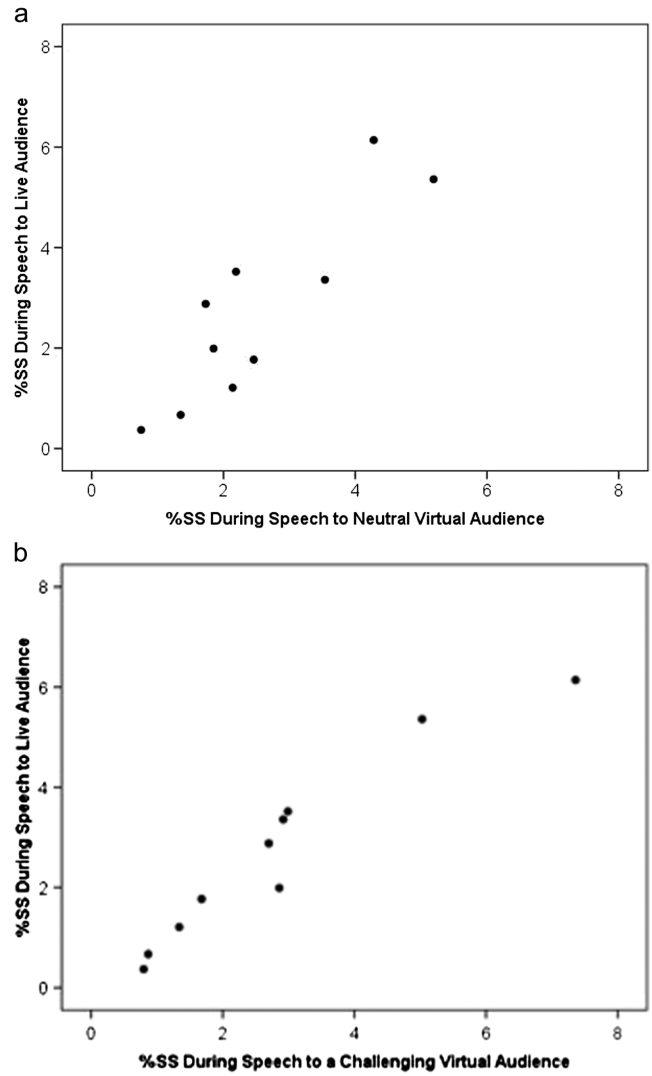


Figure 4. Percent syllables stuttered (%SS) during speeches delivered to live audiences and to (a) neutral virtual or (b) challenging virtual audiences.



These findings suggest that performance with a challenging VA condition is a stronger predictor of stuttering frequency in the real world than performance with a neutral VA condition, although both VA conditions are good predictors.

Qualitative Responses

After completing speeches in the VR conditions, each participant was debriefed and was asked to provide feedback regarding the experience. A sampling of their responses is listed in Table 3. The responses addressed affective and behavioral reactions as well as statements about the adequacy of the VREs themselves. Participants also provided suggestions for future VREs and tasks that would be useful in stuttering treatment. The responses suggest that the participants found the VREs realistic; many

Table 3. Qualitative responses about the virtual reality environment (VRE) experience.

Nature of the comment	Comment
Affective	I got clammy hands. *(possible indication of anxiety)*
Behavioral	As I was trying to come up with topic, my use of breathing and phrasing strategies decreased.
About the VRE itself	This was very real. I felt like I was there.
	I felt like they were hanging on my every word and I was talking about the cost of education, and I was like "oh no" but that's how immersed I was.
	With this, when I usually give a speech, that's how an audience is. Some are extremely attentive, and there are some nodding and then there are others that have got everything else in their life going on.
Other environments to model	Do a roundtable thing, presenting to a bunch of people in suits.
	Small group discussion to practice butting in.
	Social gatherings for initiating conversations.

reported that their behaviors in the VREs were similar to what they encounter in the real world.

Discussion

Our intent was to answer the following question: "In adults who stutter, do behavioral, affective, and cognitive reactions in two public speaking VREs correspond to those experienced with a live audience?" The answer to this question is clearly "yes." The affective, behavioral, and cognitive experiences characteristic of stuttering seen in real-world interactions can be predicted from experiences in VREs. These findings are consistent with findings from other disorders that are characterized by negative affective reactions (Botella et al., 2004; Klinger et al., 2005; Malbos et al., 2013; Meyerbröker & Emmelkamp, 2010; Opris et al., 2013; Parsons & Rizzo, 2008), cognitive reactions (Riva et al., 2001, 2004), and/or behavioral change (Cherney et al., 2008; Holden, 2005). Our findings indicate that public speaking VREs have great promise for use in stuttering assessment and treatment—at least, for persons with mild-to-moderate stuttering severity.

Stuttering treatment programs aim to reduce stuttering behaviors, change maladaptive affective responses, and reframe negative cognitive beliefs about stuttering (Yaruss, 1998). VREs show promise in allowing clinicians to systematically incorporate all of these processes into treatment. For example, VREs allow the client to enter the feared situation (affective), practice new responses to it (behavioral), and change their interpretations (cognitive) of the situation over time. Our findings suggest that stuttering reactions in VREs correspond to those seen in the real world, thereby giving clinicians confidence that VREs are an appropriate practice environment for adults who stutter.

The virtual audiences contained approximately twice as many "people" as did the live audiences. Although the larger VR audience is a potentially biasing factor leading one to expect more stuttering in the VRE, we did not find this to be the case. In fact, our results show that the challenging VA with multiple avatars was more highly correlated with the live condition than was the neutral VA. This finding suggests that it is the behaviors of the audience members, rather than just the size of the audience, that may increase stuttering frequency. These findings are consistent with those of Armson, Foote, Witt, Kalinowski, and Stuart (1997), who found no differences in stuttering frequency across audiences with two, four, and 15 people. Some qualitative participant comments about the neutral VA condition also support this conclusion. It could be that the neutral VA was not as neutral as intended. We programmed the neutral avatars to stare straight ahead and not look away from the speaker. Some of our participants thought that the neutral audience was "creepy" and "they kept staring at me without blinking."

Limitations and Future Directions

Correspondence between experience in live and virtual settings may vary with PWS of different severity or age. The PWS in this study exhibited stuttering severity in the mild-to-moderate range and overall moderate impact ratings. It is possible that PWS exhibiting different combinations of overt behaviors and impact ratings may react differently to VREs. We did not test adolescents and, thus, cannot fully generalize findings to this population. However, this is a next logical step, given adolescents' affinity for gaming technology, particularly in male participants (Willoughby, 2008). In fact, practice in VREs might represent a positive new line of treatment for adolescents who stutter—a notoriously difficult population to keep in treatment (Manning, 2010).

Measuring additional dependent variables in a variety of VREs would be worthwhile in order to evaluate VREs for use in assessment and in treatment generalization activities. For example, speech rate and speech naturalness could be measured in VREs. Our study addressed two levels of a VRE. However, a variety of VREs—such as the virtual party, developed to investigate the effects of cue exposure on nicotine and alcohol craving—could be used to practice introducing oneself or telling jokes to groups of strangers (Traylor, Parrish, Copp, & Bordnick, 2011). Speaking to persons in authority has been modeled in the virtual job interview (Brundage et al., 2006). Finally, the virtual convenience store could be used to practice giving specific answers such as asking for directions to specific locations or ordering fast food (Paris et al., 2011). Additional studies of what environments may be most useful and/or challenging, as well as factors influencing ecological validity of each environment, are encouraged.

Comparing the effects of VRE practice versus traditional practice in an RCT of stuttering treatment is another future direction. This would best be done in conjunction with treatments with proven effectiveness (Bothe et al., 2006). Comparing the extent and rate of change after using traditional versus VRE practice would inform treatment efficacy.

Conclusion

The ability to observe and evaluate speech patterns in real-world settings is critical to the documentation of individual treatment outcomes and to the evaluation of therapy programs. Our findings suggest that affective, behavioral, and cognitive experiences of PWS in public speaking VREs are correlated to those seen in the real world, and, therefore, the authentic and controlled environments provided by VREs have utility in stuttering assessment and treatment.

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