Real and Virtual Classrooms Can Trigger the Same Levels of Stuttering Severity Ratings and Anxiety in School-Age Children and Adolescents who Stutter

Anne Moïse-Richard[1,2], Lucie Ménard[1,3], Stéphane Bouchard[4], & Anne-Lise Leclercq[5]

[1] Centre de Réadaptation Marie Enfant, Montreal, Canada

[2] Université de Montreal, Canada

[3] Laboratoire de Phonétique, Université du Québec à Montreal, Canada

[4] University du Québec en Outaouais et Centre Intégré de Santé et de Services Sociaux de l'Outaouais, Canada

[5] Research Unit on Childhood, Speech and Language Therapy Department, and Clinique Psychologique et Logopédique de l'Université de Liège, Belgium

Corresponding author:

Anne-Lise Leclercq, Department of Speech-Language Pathology, Liège University, 30 rue de l'Aunaie, B38, 4000 Liège, Belgium, al.leclercq@uliege.be

Abstract

Purpose: Many school-age children and adolescents who stutter experience the fear of public speaking. Treatment implications include the need to address this problem. However, it is not always possible to train repeatedly in front of a real audience. The present study aimed to assess the relevance of using a virtual classroom in clinical practice with school-age children and adolescents who stutter.

Methods: Ten children and adolescents who stutter (aged 9 to 17 years old) had to speak in three different situations: in front of a real audience, in front of a virtual class and in an empty virtual apartment using a head-mounted display. We aimed to assess whether the self-rated levels of anxiety while speaking in front of a virtual audience reflect the levels of anxiety reported while speaking in front of a live audience, and if the stuttering level while speaking to a virtual class reflects the stuttering level while speaking in real conditions.

Results: Results show that the real audience creates higher anticipatory anxiety than the virtual class. However, both the self-reported anxiety levels and the stuttering severity ratings when talking in front of a virtual class did not differ from those observed when talking to a real audience, and were significantly higher than when talking in an empty virtual apartment.

Conclusion: Our results support the feasibility and relevance of using a virtual classroom to expose school-age children and adolescents who stutter to a feared situation during cognitive behavioral therapy targeting the fear of public speaking.

Keywords

Virtual reality

Anxiety

School-age children

Stuttering

Public speaking

1. Introduction

Many people who stutter experience the fear of speaking in various situations, including the fear of public speaking (Craig, 2014; Craig & Tran, 2014; Davis et al. 2007; Vanryckeghem et al., 2017). Stuttering in adulthood is associated with an elevated rate of social anxiety disorder (Blumgart et al., 2010; Iverach et al., 2011; Iverach et al., 2009; Menzies et al., 2008). In their literature review, Iverach and Rapee (2014) underline that people who stutter frequently display greater fear of negative evaluation, negative thoughts, avoidance and safety seeking behaviors. These characteristics negatively impact quality of life and cause restrictions on social participation (Iverach et al., 2018; Mulcahy et al., 2008). Treatment implications include the need to address these thoughts and behaviors, given that targeting speech fluency only is not likely to improve the anxiety and psychological functioning (Iverach & Rapee, 2014; Menzies et al., 2008). Studies using cognitive behavioral therapy generally lead to positive outcomes in speech-related confidence, avoidance, self-efficacy belief, dysfunctional cognitions or communication attitudes (Amster & Klein, 2008; Langevin et al., 2010; Reddy et al., 2010). For example, cognitive behavioral therapy, including graded exposure to feared situations, has been shown to lead to improvements in psychological wellness in adults who stutter (Menzies et al., 2008).

Exposure-based intervention is the common approach for the treatment of anxiety disorders in school-age children and adolescents, including social anxiety disorder (Yang et al., 2019). It was inspired by fear extinction principles (Davis et al., 2006), an approach that has evolved into what is now referred to as inhibitory learning (Craske et al., 2014). Following the cognitive behavioral approach of exposure applied to children and adolescents (Bouchard et al., 2004), behavioral and cognitive avoidance, as well as the dysfunctional cognitions that are associated with feared situations, can be targeted by repeatedly confronting people with safe but feared situations in the

absence of the expected harm. In order to enable the emotional processing to occur, there should be an exposure to the feared stimulus during which the anxiety is activated to some extent, in the absence of the anticipated harm, in order to develop new associations with safety. Owing to logistical reasons and time constraints, it is not always possible to repeatedly confront people with some types of situations, such as speaking to an audience.

Over the past few decades, there has been an increasing interest in using virtual environments to help people in general (Wiederhold & Bouchard, 2014), and children specifically (Miller et al., 2012), overcome their anxiety. Virtual reality exposure-based therapy has shown efficacy in treating specific phobias in children and adolescents (e.g. Bouchard, 2011; Gutiérrez-Maldonado et al., 2009) and shows promise for social anxiety disorders (Parrish et al., 2016; Wong Sarver et al., 2014). However, less is known about its efficacy as an exposure tool in people who stutter.

1.1. Virtual Reality in Adults who Stutter

To date, only three studies have implemented the use of virtual reality with adults who stutter with encouraging results (Brundage et al., 2016; Brundage et al., 2006; Brundage & Hancock, 2015). Brundage and Hancock (2015) asked 10 adults who stutter to deliver a speech in front of a live audience, and two virtual audiences. They showed that the virtual audiences created similar anticipatory apprehension in adults who stutter as the live audience did. Moreover, the rates of speaking confidence prior to speaking in front of the virtual audiences predicted the rates of speaking confidence prior to speaking in front of the live audience. Finally, the percentage of syllables stuttered (%SS) during speeches in front of virtual audiences significantly correlated with %SS during speeches in front of live audiences. In another study, Brundage and colleagues (Brundage et al., 2006) exposed 23 adults who stutter to both a supportive and a challenging virtual job interview. The authors showed that people spoke less and stuttered more during the challenging job interview. Moreover, the %SS in both virtual conditions were positively correlated with the %SS in a

real interview. Finally, Brundage and colleagues (Brundage et al., 2016) asked 10 adults who stutter to give a talk in front of a virtual audience and in front of a virtual empty room. The participants reported higher subjective levels of anxiety when speaking to the virtual audience, compared to the empty room. These results provide evidence that virtual environments may be clinically useful tools to use in exposure therapy with adults who stutter. However, as far as we know, no study has yet assessed the feasibility of using virtual environments with school-age children and adolescents who stutter.

1.2. Speaking Anxiety in School-Age Children and Adolescents who Stutter

Youths who stutter are likely to encounter speaking anxiety. Iverach and colleagues (2016) have shown that a heightened rate of anxiety disorders is already present in children who stutter. More specifically, compared to the controls, the children who stuttered in their study were six times more likely to have a social anxiety disorder. In a study assessing communication apprehension and self-perceived communication capacities among 39 adolescents who stuttered and 39 non-stuttering controls, the adolescents who stuttered reported significantly higher levels of communication apprehension and poorer self-perceived communication capacities than the non-stuttering controls (Blood et al., 2001). In another study, 36 adolescents who stuttered also reported elevated communication apprehension and below average self-perceived communication competence (Erickson & Block, 2013). In the study of Mulcahy and colleagues (2008), 19 adolescents who stuttered reported significantly higher levels of state and trait anxiety, a greater fear of being negatively evaluated, and greater difficulty with functional communication compared with non-stuttering controls. Moreover, the measures of state and trait anxiety significantly correlated with the perceived difficulty of functional communication among the adolescents who stuttered. Iverach and colleagues (Iverach et al., 2017) showed that in 102 adolescents who stuttered, higher anxiety predicts a more negative impact of stuttering on quality of life. Middle childhood and adolescence

are crucial periods where the prevalence of anxiety and social anxiety increases in the general population (Beesdo et al., 2007; Kessler et al., 2005; Lawrence et al., 2015). During adolescence, speaking and social demands increase so that more pressure is put on communication. Adolescence may thus be a period where anxiety exceeds normal levels in people who stutter. It is therefore of primary importance that treatment programs address the speaking anxiety of school-age children and adolescents who stutter (Iverach & Rapee, 2014). More specifically, the need to perform oral presentations increases with age. Yet, talking in front of an audience is a situation frequently feared by people who stutter (Blumgart et al., 2010; Craig, 2014; Craig & Tran, 2014; Davis et al., 2007; Vanryckeghem et al., 2017). This is why our study aimed to simulate an oral presentation in front of a class.

1.3. Therapy for School-Age Children and Adolescents who Stutter

Some interventions have shown their efficacy in reducing stuttering in adolescents (e.g. Hearne, 2008; O'Brian et al., 2003), but the evidence is less convincing for school-age children. Even in adolescents, evidence about therapy is limited compared with the extent of available evidence about preschool children and adult therapy (for a review, see Baxter et al., 2016). Moreover, for both age groups, little is known about interventions targeting dysfunctional cognitions, avoidance and self-confidence about communication in school-age children and adolescents who stutter, even if the need to measure cognitive and affective parameters was identified years ago (Bothe et al., 2006). Hearne and colleagues (2008) also deplore the lack of interventions especially tailored for this age group, despite their specificities. When questioning 13 adolescents about their experience of therapy, participants mentioned that one of the main obstacles to long-term benefits of stuttering treatment is maintaining the progress made in the objective reality. They also outlined that transfer tasks (i.e. talking with different people and in various situations) were particularly useful.

1.4. Virtual Reality

Virtual environments offer multiple opportunities to practice in various situations, while respecting a gradual exposure to feared situations. Virtual reality environments are computer-generated 3-dimensional environments enabling the user to navigate and interact in real time with the environments so that their actions are experienced in the present moment, allowing the user to actually feel present in the virtual environment (Wiederhold & Wiederhold, 2014). Different technologies exist, from head-mounted displays to large immersive rooms with stereoscopic images projected onto walls. However, the most frequently used in the present literature are head-mounted displays connected to the computer. Among the advantages of virtual reality is the predictability of the situation: the clinician controls every element in the situation in order to respect the gradual exposure principle. Another advantage is the multiplicity of possible situations: for instance, training can be set in front of a virtual audience, in a restaurant or in a shopping center. Virtual environments provide multiple opportunities to expose school-age children and adolescents to environments that mimic real-world settings. The main aims could be to generalize new behaviors for increased spontaneity and naturalness across a range of situations, or to increase self-confidence about communication. Virtual environments could be particularly tailored to school-age children and adolescents given their interest in, and comfort with, technology. However, there are very few studies on virtual reality and anxiety in children and adolescents (see Bouchard, 2011, and Miller et al., 2012, for reviews). Parrish and colleagues studied the feasibility of using virtual reality exposure-based therapy with 20 adolescents suffering from social anxiety disorder (Parrish et al., 2016). Participants were exposed to two virtual social environments (a party and public speaking) as well as two virtual neutral environments. Compared with the control adolescents, those with social anxiety disorder reported higher self-rated anxiety levels in both social virtual environments, but not in the neutral environments. Turner (2013) used self-report measures to assess the acceptability and potential of inducing anxiety in 79 non-clinical adolescents between 14 and 15 years old using a virtual classroom. Participants were immersed and gave a speech in a counterbalanced order in a virtual empty classroom, or the same classroom with a virtual teacher and 7 virtual students

displaying a range of behaviors from attentive to sleepy, or even laughing at the participant when they were giving the speech. Turner's results support the idea that virtual environments can generate elevated anxiety levels in school-age children and adolescents, with the goal of modifying or reducing these levels during therapy until the participant gains enough confidence to speak in real feared situations. Indeed, it seems that changes in perceived self-efficacy and dysfunctional beliefs are the best predictors of change (Coté & Bouchard, 2009; Tardif et al., 2019). Finally, sense of presence and cybersickness are important characteristics of a virtual environment. A sufficient sense of presence, i.e. the psychological perception of being within the virtual environment (Heeter, 1992), is required to enable the users to actually feel, think and behave as if they were in the physical reality. Cybersickness, which may result from a conflict between sensory information, could cause symptoms of nausea, vertigo, headache or blurred vision. However, very few studies have documented sense of presence and cybersickness in children (Bouchard, 2011). These variables have thus to be explored further in order to assess the feasibility of using virtual reality in children.

1.5. Aims and research questions

The present study assesses the relevance of using a virtual environment in clinical practice with school-age children and adolescents who stutter. Our first aim was to assess whether the self-rated levels of anxiety while speaking in front of a virtual audience, reflect the levels of anxiety reported while speaking in front of a live audience. We expected these levels to be higher than those reported while speaking in a virtual empty apartment. Our second aim was to assess whether the stuttering level while speaking in a virtual classroom reflects the stuttering level while speaking in non-virtual conditions. Findings concerning an increase in stuttering in anxious situations are mixed. While some studies have observed an increase in stuttering when speaking under feared conditions (Brundage et al., 2006), others have not (Bauerly et al., 2019; Brundage et al., 2016). On the one hand, Brundage and colleagues (Brundage et al., 2006) have shown an increase in %SS in a challenging job interview

compared with a supportive job interview. On the other hand, Bauerly and colleagues observed no significant difference in the %SS when adults who stutter had to talk under social evaluation conditions compared with talking to an investigator, even if they showed an increase in autonomic arousal. In the same vein, Brundage and colleagues (2016) did not observe a significant difference in the percentage of stuttered words among adults who stutter when speaking to a virtual audience compared with an empty virtual room, even if higher subjective unit of distress (SUDS) ratings were reported among this group when speaking to a virtual audience, compared with an empty room. In line with the above-cited aims, the research questions that guided this study are the following: 1) Are self-rated levels of anxiety in school-age children and adolescents speaking in front of a virtual class different from those reported while speaking in a virtual apartment or in front of a live audience? 2) Is the stuttering level in school-age children and adolescents speaking in front of a virtual class different from that reported while speaking in a virtual apartment or in front of a live audience? Finally, the participants' sense of presence and their overall experience of immersion in the virtual classroom are explored.

2. Method

2.1. Participants

The participants were 10 school-age children and adolescents who stuttered (2 girls) between the ages of 9 and 17 (M = 12 years, SD = 2 years 2 months). They were recruited in the Marie Enfant Rehabilitation Centre (CHU Sainte-Justine) in Montreal, Quebec, Canada. All of the participants had received a stuttering diagnosis by a certified speech-language pathologist and were currently enrolled in treatment (see participants' description in Table 1). The study was approved by the CHU Sainte-Justine Institutional Review Board. All the parents gave informed written consent. The participant over 13 years old also gave his informed written consent.

<Insert Table 1 about here>

2.2. Material

2.2.1. Self-Report Scales

Participants completed two self-report scales aimed at assessing their initial levels of public speaking and social anxiety. The French version of the short form of the Personal Report of Confidence as a Speaker scale (PRCS, Heeren et al., 2013) consists of 12 true-false statements regarding participants' confidence in their public speaking abilities (e.g. 'I am fearful and tense all the time when I am speaking in front of a group of people'; 'I am terrified at the thought of speaking in front of a group of people'). Scores range from 0 to 12, with the higher scores indicating less confidence in one's public speaking abilities. The French version of the short form of the PRCS has very good internal reliability, good structural validity and good convergent validity with other scales measuring social anxiety (Heeren et al., 2013).

The French self-report version of the Liebowitz Social Anxiety Scale for Children and Adolescents (LSAS-CA, Schmits et al., 2014) contains 24 items measuring fear and avoidance in social (12 items) and performance (12 items) situations. For each of the 24 situations, the participants rate the intensity of fear they experience on a first 4-point Likert scale, and the frequency of avoidance of the situation on a second 4-point item scale. The French version of the LSAS-CA has good internal reliability and a previous study has confirmed its structural validity (Schmits et al., 2014).

Moreover, in order to respect a gradual increase in anxiety when the participants are immersed in the challenging virtual classroom, the participants are asked 4 questions about their judgement on the potential difficulty of talking in front of a class depending on the audience's behavior: 'How difficult is it for you to talk in front of a class?', 'How difficult is it for you to talk in front of a class when students are yawning?', 'How difficult is it for you to talk in front of a class when students are laughing?', 'How difficult is it for you to talk in front of a class if the teacher seems to be unhappy

with what you are saying?'. These 3 behaviors are the core of the challenging behaviors of the audience in the challenging classroom condition: students yawning, students laughing, and the teacher frowning unhappily at the participant. The participants answer each question on a 0-10 Likert scale. Based on their answers, the experimenter creates a hierarchy of feared reactions that is adapted to each participant during their immersion in the challenging virtual classroom (see below).

During the experiment, participants repeatedly provided a subjective unit of distress (SUDS) rating. The SUDS rating is a commonly used, reliable measure of self-reported anxiety (Benjamin et al., 2010). It typically ranges from 0 to 100 with higher ratings indicating greater anxiety. However, in the present study we decided to use an adapted SUDS ranging from 0 to 10, which has shown to be a useful and valid tool to measure anxiety in school-age children (Bringuier et al., 2009).

A 0 to 9 Likert stuttering severity rating (SR) scale was used to rate the stuttering severity after each speaking task. This rating was performed by the participants immediately after each speaking condition, and also by a research assistant, based on video recordings of the sessions (see below). This scale is a global measurement of stuttering severity that encompasses both the frequency and the severity of the stuttering events. This clinical rating has been shown to be a reliable measurement of stuttering (O'Brian, Packman & Onslow, 2004).

The participants filled in a French version (Baus & Bouchard, 2017) of the ITC-Sense of Presence Inventory (Lessiter et al., 2001) after their immersion in the virtual environments. The ITC-SOPI is a self-report questionnaire about the user's experience in the virtual environment. It has 44 items, scored on a Likert scale from 1 to 5 (1 = strongly disagree, 5 = strongly agree), and measures 4 dimensions: (a) Spatial Presence (sense of physical placement in the mediated environment, interaction, and control over different parts of the environment, e.g. 'I had a sense of being in the scenes displayed'); (b) Engagement (tendency to feel psychologically involved and to enjoy the content, e.g. 'My experience was intense'); (c) Ecological Validity/Naturalness (tendency to perceive the mediated environment as lifelike or real, e.g. 'The displayed environment seemed natural'); and

(d) Negative Effects (tendency to have adverse physiological reactions, e.g. 'I felt nauseous'). The authors of the inventory reported internal consistency coefficients ranging from .94 (Spatial Presence) to .76 (Naturalness). The participants completed the ITC-SOPI regarding their experience in the classroom environments.

2.2.2. Virtual Environments

During the virtual reality session, participants were successively immersed in four virtual environments: a virtual empty apartment, a 'neutral' virtual classroom, a 'challenging' virtual classroom. At the end, they were once more immersed in the virtual empty apartment they visited first.

The virtual apartment (VR training room; Loranger & Bouchard, 2017) was a control condition. It consisted of a virtual empty apartment that contained no anxious stimulus. This condition was included in order to introduce the participants to the experience of being in a virtual space and to act as a control for the anxiety induced by immersion in virtual reality.

The virtual classroom was developed by our research team. The classroom software has since been updated on Unity 3D to run on current virtual reality systems. It consisted of 7 students and a teacher sitting on chairs behind desks. The participant stood behind the virtual teacher's desk in front of the virtual class (see Figure 1). This environment was initially designed to treat social anxiety disorder. During the 'neutral' virtual classroom condition, the students looked mainly at the participant and were neither explicitly distractive nor supportive. The 'challenging' virtual classroom was the same, except that the researcher manipulated the reactions of the virtual students (yawning and falling asleep or laughing at the participant while they were giving the speech) and of the teacher (looking unhappy at the participant) by pressing a key on the computer keyboard so that a specific reaction was produced after 30 seconds, 2 minutes and 4 minutes. The order of presentation of the

virtual students' reactions was adapted to each participant and depended on their responses to the four questions about their judgement on the potential difficulty of talking in front of a class depending on the audience's behavior. The experimenter thus triggered the audience's reactions following an order specific to each participant, depending on their own hierarchy of feared situations, in order to enable a gradual increase in the anxiety that was adapted to each participant. Turner (2013) confirmed that our classroom depicts a challenging environment in non-clinical adolescents.

Insert Figure 1 about here

The virtual environment software was installed on an Intel I9-7900X PC with an ASUS STRIX-GTX graphics card. The PC was connected to an Oculus Rift head-mounted display (HMD). The HMD covered the upper half of the participant's face and contained a display screen for each eye, earphones to provide sounds (e.g. yawns, laughs) and a tracking device to calculate the orientation of the HMD. The participants saw the environments in the HMD and the researcher saw the participant's view on the computer monitor.

2.2.3. Speeches

There were three themes for the three speech conditions (the neutral virtual classroom, the challenging virtual classroom, and the real audience): the participants' favorite TV show, their ideal holiday and their favorite sports and hobbies. These three themes were counterbalanced between participants and conditions, in order to avoid an impact of the theme on the observed anxiety and disfluencies. The preparation was the same for each condition: the examiner gave the speech theme, and the participants had 3 minutes to prepare their speech just before talking. They were informed that they could not refer to any notes when talking.

2.3. Procedure

The study took place during two different sessions with a gap of 1 to 3 days. One of the two sessions was dedicated to the real audience condition, and the other one was dedicated to the immersions in the virtual environments. Half of the participants were exposed to the real audience first, while the other half were exposed to the virtual environments first. During their first session (either real or virtual), all participants completed the PRCS and LSAS-CA, as well as the four questions about their judgement on the potential difficulty of talking in front of a class depending on the audience's behavior (see Figure A1).

2.3.1. Virtual Reality Session

First, the participants rated their initial anxiety level with the SUDS (for half of the participants for whom it was their first session, this was done after the completion of the PRCS, the LSAS-CA and the questionnaire about the audience behavior). They were then asked to talk to the examiner for 4 minutes about their last holidays. During this speech, participants had to rate their anxiety level with the SUDS at the beginning of the speech, after 30 seconds and at the end of every minute. Upon completion of their speech, the participants were asked to rate their stuttering level on the 0 to 9 Likert stuttering severity rating (SR) scale.

The HMD was then placed on the participants' head and they were immersed in the virtual empty apartment for 4 minutes. The participants had to visit the apartment first without talking (for 1 minute). They were then asked to describe their exploration for 2 minutes and, finally, they were asked to stay silent during the last minute of immersion. During this immersion, the participants had to rate their anxiety level with the SUDS when entering the virtual apartment, after 30 seconds and at the end of every minute. After 4 minutes of immersion, the HMD was removed and the participants rated their stuttering severity on the SR scale for the description of their exploration.

The participants then rested for 3 minutes during which they had to read a text about relaxation and cross out every letter ‘e’ they found in the text. This task, generally described as a basic task that people can do easily and quickly (Baumeister et al., 1998; Xu et al., 2014), was used to enable the participants to avoid thinking about their experience in the virtual environment. During this resting period, the participants also rated their anxiety level with the SUDS at the beginning of the task and at the end of every minute.

The participants were informed that they would have to talk in front of a virtual class about a specific theme (randomly assigned) and that they could have 3 minutes to prepare this talk. The participants rated their anxiety level with the SUDS at the end of every minute during the preparation time. When the 3 minutes dedicated to preparing the speech were over, the investigator placed the HMD on the participants’ head and activated the software.

The participants gave their speech for 4 minutes in front of the neutral virtual class, where the students looked mainly at the participant and were neither explicitly distractive nor supportive. The participants rated their anxiety level with the SUDS when entering the virtual classroom, after 30 seconds and at the end of every minute. Upon completion of their speech, the HMD was removed and the participants rated their stuttering severity on the SR scale. They had a new 3-minute period of rest during which they read a text about relaxation while deleting the letter ‘e’ and rating their anxiety level every minute.

Next, they had to prepare a new speech for 3 minutes (while rating their anxiety level every minute) and were informed that this time, there could be some reactions from the audience. The HMD was then put back on their head and they gave a new 4-minute speech in front of the challenging virtual class, while rating their anxiety with the SUDS as previously done for the neutral virtual class. Upon completion of their speech, the HMD was removed and the participants rated their stuttering severity on the SR scale. Thereafter, the participants had the same 3-minute resting period as previously described and then completed the ITC-SOPI for the classroom environments.

In order to conclude with a more neutral experience of the virtual reality, they were once more immersed in the virtual apartment (with the HMD on their head) for 4 minutes, alternating the same periods of silence and talking as during their first immersion, and repeatedly rated their anxiety level. After this last immersion, the HMD was removed and each participant was debriefed. They were asked to rate the usefulness of the virtual classroom to help youths who stutter on a 0 to 10-point scale, to provide feedback regarding their experience in the virtual classroom and to provide suggestions for future developments.

2.3.2. The Live Audience Session

The live audience consisted of four other participants who stutter and two adults conducting the study. The participants rated their initial anxiety level with the SUDS (for half of the participants for whom it was their first session, this was done after the completion of the PRCS, the LSAS-CA and the questionnaire about the audience behavior). The participants were then informed that they would have to talk in front of the group about a specific theme and that they could have 3 minutes to prepare this talk. The participants rated their anxiety level with the SUDS at the beginning of the 3-minute period and at the end of every minute dedicated to the preparation of their speech. Next, they gave their 4-minute talk one by one in front of the other members of the group. The participants did not know each other and were not given specific instructions on how to respond to the speeches. The participants rated their anxiety level with the SUDS at the beginning of their speech, after 30 seconds and at the end of every minute. Upon completion of their speech, the participants rated their stuttering level on the SR scale.

2.4. Data Coding, Reliability and Statistical Analysis

All speeches were video-recorded for later analysis. Speech transcription and disfluency coding followed standard procedure. The research assistant, a specialized speech-language pathologist (SLP) who was blind to the objectives of the study, looked at the entire video recordings of each speech. She rated the stuttering severity on the SR scale for each speech sample and made sure stuttering severity seemed consistent throughout each recording. She then transcribed the 200 first syllables of each speech in order to calculate the %SS (repetitions of sound, syllables, sound prolongations and blocks) for each participant. If stuttering severity seemed to vary across the same recording, the entire video was analyzed to obtain the %SS (this only occurred for one condition in one participant). To determine inter-judge reliability, 20% of the speech samples were randomly selected and analyzed by another judge. Spearman correlation coefficients between the scores of both judges were very high (r_s = 0.98). Point-to-point percent reliability was 99.13%.

Concerning the self-rated anxiety levels, we calculated a mean with all the SUDS ratings in each condition. Initial SUDS levels were taken at the beginning of both the virtual and non-virtual sessions. In order to verify that the participants' initial SUDS levels did not significantly differ from one session to the next, we performed a Wilcoxon signed-rank test on the initial SUDS levels for each session. Results revealed that the initial SUDS ratings did not significantly differ between sessions (Z = 1.42, p = .16, r = .32). Moreover, in order to verify that completing the self-report scales about social anxiety did not significantly impact the SUDS ratings, we performed a Wilcoxon signed-rank test on the initial SUDS levels depending on whether the participant had just completed the self-report scales or not. Results revealed that the initial SUDS ratings did not significantly differ either (Z = 0.53, p = 0.59, r = .12).

For the control condition, the virtual empty apartment, only the moments when the participants were speaking were taken into account to compare the SUDS ratings in the three conditions. Only the data from the first immersion in the empty apartment were taken into account in the following analyses. However, we also performed the same statistical analyses when merging the data (the

SUDS ratings, the SRs and the %SS respectively) for both immersions in the empty apartment without any impact on the results significance. (Results from this second immersion in a control condition will not be discussed further in the article as they only revealed a reduction in the SUDS ratings, the SRs and the %SS, after the immersion in the virtual classroom. Results are available upon request.)

As for statistical analyses, since the data were not normally distributed (Shapiro-Wilk tests showing *p*-values < .01 for the SUDS ratings, the SRs and the %SS), non-parametric tests were used. To correct for multiple comparisons (virtual classroom vs. virtual empty apartment on the one hand, and virtual classroom vs. live audience on the other hand), the significance level was adjusted to $p = 0.025$ using the Bonferroni correction.

3. Results

3.1. Descriptive Statistics

Group means, standard deviations, and ranges for the PRCS and the LSAS-CA are listed in Table 2. In general, participants did not rate themselves as having high social anxiety or poor confidence as speakers. Group means, standard deviations, and range of SUDS ratings, SRs and %SS are listed in Table 3. The global anxiety scores were generally low. Contrary to our expectations, the Wilcoxon signed-rank tests revealed that the classroom condition (either neutral or challenging) did not impact the SUDS ratings ($Z = 0.72$, $p = 0.48$, $r = 0.16$), the %SS ($Z = 0.00$, $p = 1$, $r = 0.00$) or the SRs ($Z = 0.53$, $p = .59$, $r = 0.129$). Some possible explanations for this result are developed in the Discussion section. We thus decided, for each participant, to perform a mean of their scores in both virtual classroom conditions in order to consider three main exposure conditions: the empty virtual apartment, the virtual classroom, and the real audience.

<Insert Table 2 and Table 3 about here>

3.2. Statistical Analyses

3.2.1. Anxiety

For the preparatory phase, i.e. the 3 minutes during which the participants had to prepare their speech for the live and the virtual audiences, the Wilcoxon signed-rank test showed that the SUDS ratings when preparing the speech before speaking to the real audience (M = 2.7, SD =2.31, *Range* = 0.25 – 8.25) were significantly higher than when preparing the speech before talking in front of a virtual class (M = 1.59, SD = 1.81, *Range* = 0 – 5.75), (Z = 2.52, p = .01, r = 0.56). Concerning the SUDS ratings during the talks, a nonparametric Friedman test comparing the reported SUDS ratings in the virtual empty apartment, in both virtual classrooms and in front of the real audience, revealed that the SUDS ratings differed significantly depending on the situation (Chi^2 = 11.42, p = .003). The Wilcoxon signed-rank tests revealed that the SUDS ratings were significantly higher when talking in front of a virtual class than when talking in an empty virtual apartment (Z = 2.50, p = .013, r = 0.56). However, the SUDS ratings between the virtual classroom and the real audience did not differ significantly (Z = 0.18, p = 0.86, r = 0.04).

The SUDS ratings when talking in the virtual classrooms significantly correlated with the SUDS ratings when talking to the real audience (ρ = 0.92, p < .001), while they did not significantly correlate with the SUDS ratings when talking to the examiner (ρ = 0.49, p = .16).

3.2.2. Stuttering

In order to assess the impact of the speaking situation on stuttering severity, three main measures were considered: the %SS, the score on the SR that was given by the specialized SLP when looking at the video recordings, and the score on the SR that was given by the participants themselves after

each speech. The % SS and the SRs given by the SLP were significantly correlated in all speaking conditions: in the virtual empty apartment (ρ = .93, p < .001), in front of the real audience (ρ = .90, p < .001), and in front of the virtual class (ρ = .86, p = .001). Concerning the SRs given by the participants themselves, Participant 1, who only had two hours of speech therapy, was not familiar with the use of this scale and thus systematically gave SRs that were more than 2 points apart from the SRs given by the specialized SLP. We thus decided to exclude his SRs from the analyses. Once the SRs from Participant 1 had been removed from the analyses, the SRs given by the participants significantly correlated to the SRs given by the SLP and the %SS in the virtual empty apartment (ρ = .77, p = .016 and ρ = .79, p = .012, respectively), in the virtual class (ρ = .91, p < .001 and ρ = .78, p = .014 respectively), and in front of the real audience (ρ = .73, p = .04 and ρ = .76, p = .03 respectively).

A nonparametric Friedman test comparing the SRs given by the SLP in the virtual empty apartment, in both virtual classrooms and in front of the real audience, revealed that the difference was significant (Chi^2 = 6.74, p = .034). The Wilcoxon signed-rank tests revealed that the SRs given by the SLP were significantly higher when talking in front of a virtual class than when talking in an empty virtual apartment (Z = 2.37, p = .02, r = 0.53). The SRs between the virtual classrooms and the real audience did not differ significantly (Z = 0.68, p = .49, r = 0.15). The Wilcoxon signed-rank tests performed on the SRs rated by the participants themselves (excluding Participant 1) also revealed that the SRs were significantly higher when talking in front of a virtual class than when talking in an empty virtual apartment (Z = 2.02, p = .04, r = 0.53). The SRs between the virtual classrooms and the real audience did not differ significantly (Z = 1.18, p = .24, r = 0.29).

A nonparametric Friedman test comparing the %SS in the virtual empty apartment, in both virtual classrooms and in front of a real audience did not reach significance (Chi^2 = 2.46, p = .29).

3.3. Presence and Immersion in the Virtual Environments

After completing the speeches in the virtual environments, participants had to first complete the ITC-SOPI regarding their experience in the virtual classroom, after which they were debriefed and asked to provide feedback regarding their experience. The average scores were 3.22 (*SD* = 0.83) on the sense of physical space subscale, 3.21 (*SD* = 0.93) on the engagement subscale, and 3.63 (*SD* = 0.87) on the ecological validity subscale, all of which are above the mid-points of the subscales; and 2.03 (*SD* = 1.07) on the negative effects scale, which is below the mid-point of the subscale. The participants thus experienced acceptable levels of presence and immersion, suggesting that the virtual classroom was believable and engaging. They also experienced a low level of negative effects, suggesting that their immersion in this environment is acceptable. Moreover, various behavioral and affective reactions support the engagement of the participants in the task and suggest that they found the environment realistic (a sampling of the participants' responses is listed in Table 4).

Insert Table 4 about here.

Seventy percent of the participants found the virtual classroom very useful (rating 7 or more on the 0 to 10-point scale). Their comments addressed various topics such as anxiety, realism, motivation as well as statements about the usefulness of the virtual environments themselves. Participants also provided suggestions for future virtual environments and features that would be useful in stuttering treatment. The responses suggest that the participants found the virtual environments realistic and useful to address a variety of goals.

4. Discussion

4.1. Anxiety

Our results show that the self-rated levels of anxiety significantly increased when school-age children and adolescents who stutter had to talk in front of a virtual class compared with talking in an empty virtual apartment. Moreover, these anxiety levels were not significantly distinct from those they

reported when talking to a real audience, even if they were higher during the preparatory phase for the real audience compared with the virtual class. Finally, the anxiety levels experienced in the virtual classroom conditions seem to be specific to talking in front of a virtual audience, regardless of the audience's behavior, compared to talking to a single person, given that these anxiety levels did not significantly correlate with those experienced when talking to the examiner. These results suggest that exposure to the virtual classroom is able to generate levels of anxiety that cannot simply be attributed to the immersion in virtual reality, and are specific to the situation of talking to a virtual audience. Even if anticipatory apprehension seems to be lower for the virtual class than for the real audience, once immersed in the virtual or real situation, the self-reported anxiety levels are the same.

This difference in anticipatory apprehension was not observed by Brundage and Hancock (2015) in adults who stutter (even if their study did not aim at specifically assessing anticipatory apprehension). The authors found that the participants had similar apprehension before talking to the virtual and real audiences. However, their anxiety measures were not the same: the authors used two social anxiety scales (the PRCS and the Personal Report of Communication Apprehension-24). It is thus possible that items from these scales were less directly related to the current state-like feelings of anxiety than SUDS scores. The low anticipatory apprehension reported in the current study is consistent with impressions emerging from other studies, with children not being highly apprehensive toward virtual social stimuli, yet more apprehensive towards virtual phobogenic insect stimuli (e.g., Silva et al., submitted; Wong Sarver et al., 2014). Of particular interest is the fact that our study shows that, even if the participants are anticipatorily less anxious about speaking to a virtual than a real audience, the virtual classroom is able to induce anxiety that is not statistically different from what is observed in front of a real audience. This is of particular interest for future therapeutic use because using virtual reality may be more enticing for children (Silva et al., submitted), and hopefully increase motivation and adherence to treatments. Young people who stutter may more easily accept exposure to a virtual classroom than to a real audience, although our

data show that both environments generate the same anxiety levels and thus seem equally relevant to work on anxiety. Future studies should confirm this statement. Using virtual audiences could also be more practical for speech therapists: they do not need to gather a group of other children to act as an audience; they can easily control and gauge how challenging the audience is; and they do not have to worry about members of the audience fully respecting confidentiality.

The impact of the virtual classroom that we observed in the present study was found in the same virtual environment by Turner (2013), with a sample of non-clinical adolescents. The present study builds on the latter by showing that exposure to a virtual class with a teacher and other children is able to generate levels of anxiety in school-age children and adolescents who stutter, thus reflecting what is experienced in a real public speaking situation. These results are in accordance with what was previously observed in adults who stutter (Brundage et al., 2016; Brundage et al., 2006; Brundage & Hancock, 2015) and in adolescents with social anxiety disorder (Parrish et al., 2016). What is of particular interest is that our results show that the anxiety experienced when talking to a virtual audience specifically reflects the anxiety experienced when talking to a real class rather than the anxiety experienced when talking to the examiner. It thus seems that immersion in the virtual classroom is able to reflect what is experienced in a specific situation, rather than what is experienced in any speaking situation. Our results show that anxiety is effectively generated by the virtual classroom environment, as expected when conducting exposure (Bouchard et al., 2004; Craske et al., 2014). Our results extend previous data and support the feasibility and relevance of using virtual environments to expose school-age children and adolescents who stutter to feared situations during cognitive behavioral therapy targeting fear of speaking, confidence in communication and/or dysfunctional cognitions. Future studies, including clinical trials, should be able to prove their efficacy in therapy by including virtual environments as exposure tools in therapy with school-age children and adolescents who stutter.

4.2. Stuttering Severity

Concerning stuttering severity, our results show that the speaking situation has a significant impact on stuttering severity when analyzing the SRs, but not when analyzing the %SS. On the one hand, our data reveal that the SRs rated by the SLP or the participants themselves were higher when the school-age children and adolescents had to talk in front of a virtual class than when talking in a virtual apartment, and that these scores did not significantly differ from what is observed when talking to a real audience. This is in line with what was observed in Brundage and colleagues (Brundage et al., 2006), who observed an increase in stuttering when speaking under feared conditions, as measured by %SS. However, on the other hand, we found no significant difference in the stuttering severity when measured by %SS. This is in concordance with what was observed by Bauerly and colleagues (2019) when adults who stutter had to talk either to an investigator or under social evaluation conditions, even if they showed an increase in autonomic arousal. This is also concordant with the observations of Brundage and colleagues (2016), who did not observe a significant difference in the percentage of stuttered words among adults who stutter when speaking to a virtual audience compared with an empty virtual room, even if significant differences were reported in SUDS ratings. Our data reflect the mixed results previously found in the literature about the impact of the speaking situation on stuttering severity, as measured by the percentage of stuttered words or syllables. The present study is the first to use both the SR and the %SS to assess this impact. The SR scale not only encompasses the stuttering frequency, but also the severity of each stuttering event (including the length of blocks and the presence of concomitant behaviors, for example). Recent studies have shown the reliability and interest of using such severity scales as a clinical measurement procedure and recommend SR as a primary outcome in clinical trials (O'Brian et al., 2020; Onslow et al., 2018). It is possible that this more comprehensive stuttering severity scale is more appropriate than %SS to reflect the variations in stuttering severity depending on the impact of the speaking situations. Future studies should be able to determine whether it is better to use %SS or

the stuttering severity rating scale in studies exploring the beneficial impact of virtual exposure therapy on speech fluency.

4.3. Presence and Immersion in the Virtual Environments

Finally, our participants reported acceptable levels of presence and immersion, as well as various behavioral and affective reactions suggesting that the participants found the environment realistic and engaging. These results support the feasibility and relevance of using a virtual classroom with school-age children and adolescents who stutter.

4.4. Limitations and Future Directions

Contrary to our expectations, our results did not reveal significant differences between the neutral and challenging virtual classrooms. This is consistent with findings by Pertaub, Slater and Barker (2002), and by Corno, Hébert and Bouchard (2020), and could be explained by a combination of the following factors. First, as previously stated, the participants experienced low levels of anxiety overall when speaking in all situations. As observed in the standardized anxiety questionnaires, their level of social anxiety was not very high. It is possible that our results would have been different with a sample of more anxious participants. Second, there were only three reactions during the 4-minute talk, and the timing of the classroom reactions in the challenging classroom was preset so that the yawning, laughing and unhappy reactions of the audience would occur at the same time for all participants, instead of being realistically cued to what they were saying. It is thus possible that the negative reactions of the audience were not sufficiently frequent and/or that the participants did not interpret these reactions as being associated with their own behavior, and thus did not experience an increase in anxiety levels. Third, while the order of the real and virtual audience sessions were counterbalanced, the order of the virtual classroom conditions within the virtual classroom session

was fixed: the participants always had to talk in the neutral virtual classroom before talking in front of the challenging class. This fixed order was initially decided, following some pretests, to enable an increase in anxiety and avoid excessive emotional reactions in school-age children and adolescents who stutter. For a first study including children who stutter, we felt that beginning with a less threatening situation before facing a more challenging situation was more acceptable from both a clinical and an ethical point of view. However, it is possible that extinction of the fear response occurred so the level of anxiety experienced in a second challenging immersion was comparable to the level of anxiety experienced in a previously novel speaking situation (which is incidentally highly relevant to exposure therapy). Nevertheless, the effects of the virtual classroom cannot be attributable to being in virtual reality in itself, given that we did not observe the same effects in the virtual empty apartment: both the SUDS ratings and the severity ratings were significantly higher when talking in front of a virtual class than when talking in the empty virtual apartment.

Another limit is that the anxiety ratings were collected after 30 seconds and then every minute during the oral presentations. It is possible that repeatedly asking the participants about their anxiety level interfered with their immersion in the virtual environment. In a study on fear of public speaking in virtual reality, Pertaub and colleagues (2002) measured the satisfaction of university students regarding their performance. They also found that both a negative and a positive audience had a significant negative impact compared with the neutral audience, but no difference between the positive and the challenging audiences. It is possible that talking to an audience of virtual characters can, in itself, be an experience that is stressful and elicits self-focus attention and anxiety. In the Turner (2013) study, the comparison was with the same classroom, either empty or with a virtual audience. In our study, the use of a control condition that is not a classroom prevents us from isolating the effect of the classroom versus the behavior of the audience, and the absence of measures of self-focused attention or eye tracking does not allow us to confirm whether participants really pay strong attention to the ego-threatening nature of the behavior of the audience. These variables should be considered in further studies. However, a recent study by Corno, Hébert and

Bouchard (2020) conducted with adults suffering from music performance anxiety also found that the impact of exposure did not significantly differ when the audience had a positive or a negative attitude toward the performer. What was shown to be clinically important was the fact that performers made blunders and mistakes during the exposure. In sum, the impact and relevance of the attitude of the virtual audience might be more complex and nuanced than it seems a priori.

Even if the differences in SUDS and SRs are statistically significant between the VR apartment and the VR classroom, these differences are quite small, either due to the overall low level of the participants' anxiety profile, or to the specific characteristics of the environments. Future studies should include a larger sample size in order to confirm our results in a larger group of participants who stutter. Including physiological, objective measures of arousal may also be interesting to complete the self-rated subjective measures of anxiety used in the present study. These measures may include changes in skin conductance, heart rate, blood volume, respiratory measures or salivary cortisol. A previous study in adults who stutter did not show a significant increase in heart rate and skin conductance level when they had to talk in front of a virtual audience, compared with a virtual empty room (Brundage et al., 2016). More studies are needed to fully understand the complex relationships between physiological measures and subjective ratings of distress. Furthermore, since we merged the data from both classroom conditions, the exposure time varied from one condition to the other in the present study. Complementary analyses - not reported above - show that taking into account only one of the two classroom conditions (either the challenging or the neutral one) had no impact on the anxiety results significance. However, better control of the exposure time in all conditions is recommended for future studies. Finally, a control group with children who do not stutter may provide information on the specificity of the anxious reactions of the school-age children and adolescents who stutter.

5. Conclusions

Our results support the relevance of using virtual reality with school-age children and adolescents who stutter in order to generate public speaking anxiety that can be worked on. Our study shows that a virtual classroom is able to generate public speaking anxiety, even in school-age children and adolescents who do not show high social anxiety levels. Future therapy studies should establish the efficacy of virtual environments to overcome the fear of public speaking, to increase confidence in communication and to generalize fluency speaking abilities in various situations.

6. Acknowledgements

This research was supported in part by a clinical research grant from the multidisciplinary council of the CHU Sainte-Justine Hospital, awarded to the first author. It was also supported by the Canadian Foundation for Innovation grants, awarded to the second author, and funding from the Canada Research Chairs and the Commission Mixte Permanente Québec/Wallonie-Bruxelles awarded to the third author. We also thank Carolina Rossignuolo, program manager, for the human resources she devoted to this project. We thank Alexandra Seymour for her assistance with data analysis; Anne-Marie Etienne for her valuable enlightened view on virtual reality and anxiety; Lisandre Bergeron-Morin for her contribution to this project; Lydia Garneau and the speech therapist team for their assistance in recruitment; Isabelle Régnier and Chloé Dallaire-Dupont for their support during the experiment process; and the school-age children and adolescents who stutter and their families for their participation in this project. We also thank Camille Vidou for her assistance in data entry and Lambert Beaudry for his support in calibrating the virtual reality equipment. We thank Alice Cameron for her careful revision of the English text. Finally, we thank Josée Laganière, Patrick Dubé and his team as well as Hélène Bergeron for their work and suggestions on previous versions of this research.

7. References

Amster, B.J., & Klein, E. R. (2008). Perfectionism in people who stutter: Preliminary findings using a modified cognitive-behavioral treatment approach. *Behavioural and Cognitive Psychotherapy, 36,* 35-40.

Bauerly, K. R., Jones, R. M., & Miller, C. (2019). Effects of Social Stress on Autonomic, Behavioral, and Acoustic Parameters in Adults Who Stutter. *Journal of Speech, Language, and Hearing Research*, *62*(7), 2185-2202.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, *74*(5), 1252–1265. https://doi.org/10.1037/0022-3514.74.5.1252

Baus, O. & Bouchard, S. (2017). Exposure to an unpleasant odour increases the sense of presence in virtual reality. *Virtual Reality, 21*(2), 59-74. https://doi.org/10.1007/s10055-016-0299-3.

Baxter, S., Johnson, M., Blank, L., Cantrell, A., Brumfitt, S., Enderby, P., & Goyder, E. (2016). Non-pharmacological treatments for stuttering in children and adults: a systematic review and evaluation of clinical effectiveness, and exploration of barriers to successful outcomes. *Health Technology Assessment*, *20*(2), 1-302.

Benjamin, C., O'Neil, K., Crawley, S., Beidas, R., Coles, M., & Kendall, P. (2010). Patterns and predictors of subjective units of distress in anxious youth. *Behavioural and Cognitive Psychotherapy, 38*, 497–504.

Beesdo, K., Bittner, A., Pine, D. S., Stein, M. B., Höfler, M., Lieb, R., et al. (2007). Incidence of social anxiety disorder and the consistent risk for secondary depression in the first three decades of life. *Archives of General Psychiatry, 64*(8), 903–912.

Blood, G. W., Blood, I. M., Tellis, G., & Gabel, R. (2001). Communication apprehension and self-perceived communication competence in adolescents who stutter. *Journal of Fluency Disorders*, *26*(3), 161–178. https://doi.org/10.1016/S0094-730X(01)00097-3

Blumgart, E., Tran, Y., & Craig, A. (2010). Social anxiety disorder in adults who stutter. *Depression and Anxiety*, *27*(7), 687–692. https://doi.org/10.1002/da.20657

Bothe, A. K., Davidow, J. H., Bramlett, R. E., & Ingham, R. J. (2006). Stuttering treatment research 1970–2005: I. Systematic review incorporating trial quality assessment of behavioral, cognitive, and related approaches. *American Journal of Speech-Language Pathology, 15*(4), 321-341.

Bouchard, S. (2011). Could virtual reality be effective in treating children with phobias? *Expert Review of Neurotherapeutics, 11*(2), 207–213. https://doi.org/10.1586/ern.10.196

Bouchard, S., Mendowitz, S. L., Coles, M. E., & Franklin, M. (2004). Considerations in the use of exposure with children. *Cognitive and Behavioral Practice, 11*(2), 56-65.

Bringuier, S., Dadure, C., Raux, O., Dubois, A., Picot, M. C., & Capdevila, X. (2009). The perioperative validity of the visual analog anxiety scale in children: a discriminant and useful instrument in routine clinical practice to optimize postoperative pain management. *Anesthesia & Analgesia*, *109*(3), 737-744.

Brundage, S. B., Brinton, J. M., & Hancock, A. B. (2016). Utility of virtual reality environments to examine physiological reactivity and subjective distress in adults who stutter. *Journal of Fluency Disorders*, *50*, 85–95. https://doi.org/10.1016/j.jfludis.2016.10.001

Brundage, S. B., Graap, K., Gibbons, K. F., Ferrer, M., & Brooks, J. (2006). Frequency of stuttering during challenging and supportive virtual reality job interviews. *Journal of Fluency Disorders*, *31*(4), 325–339. https://doi.org/10.1016/j.jfludis.2006.08.003

Brundage, S. B., & Hancock, A. B. (2015). Real enough: Using virtual public speaking environments to evoke feelings and behaviors targeted in stuttering assessment and treatment. *American Journal of Speech-Language Pathology*, *24*, 139–149.

Corno, G., Hébert, V., & Bouchard, S. (2020). Exploring mechanisms underlying virtual reality exposure for music performance anxiety. *CYPSY23 Conference*, Milan, June 2020.

Côté, S., & Bouchard, S. (2009). Cognitive mechanisms underlying virtual reality exposure. *CyberPsychology & Behavior*, *12*(2), 121-129.

Craig, A. (2014). Major controversies in Fluency Disorders: Clarifying the relationship between anxiety and stuttering. *Journal of Fluency Disorders*, *40*, 1–3. https://doi.org/10.1016/j.jfludis.2014.05.001

Craig, A., & Tran, Y. (2014). Trait and social anxiety in adults with chronic stuttering: Conclusions following meta-analysis. *Journal of Fluency Disorders*, *40*, 35–43. https://doi.org/10.1016/j.jfludis.2014.01.001

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy, 58*, 10-23. https://doi.org/10.1016/j.brat.2014.04.006

Davis, M., Ressler, K., Rothbaum, B. O., & Richardson, R. (2006). Effects of D-cycloserine on extinction: translation from preclinical to clinical work. *Biological psychiatry*, *60*(4), 369-375.

Davis, S., Shisca, D., & Howell, P. (2007). Anxiety in speakers who persist and recover from stuttering. *Journal of Communication Disorders*, *40*(5), 398–417. https://doi.org/10.1016/j.jcomdis.2006.10.003

Erickson, S., & Block, S. (2013). The social and communication impact of stuttering on adolescents and their families. *Journal of fluency disorders*, *38*(4), 311-324.

Gutiérrez-Maldonado, J., Magallón-Neri, E., Rus-Calafell, M., & Peñaloza-Salazar, C. (2009). Virtual reality exposure therapy for school phobia. *Anuario de Psicología, 40*(2), 223-236.

Hearne, A., Packman, A., Onslow, M., & Quine, S. (2008). Stuttering and its treatment in adolescence: The perceptions of people who stutter. *Journal of Fluency Disorders*, *33*(2), 81–98. https://doi.org/10.1016/j.jfludis.2008.01.001

Heeren, A., Ceschi, G., Valentiner, D. P., Dethier, V., & Philippot, P. (2013). Assessing public speaking fear with the short form of the Personal Report of Confidence as a Speaker scale: Confirmatory factor analyses among a French-speaking community sample. *Neuropsychiatric Disease and Treatment*, *9*, 609–618. https://doi.org/10.2147/NDT.S43097

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators & Virtual Environments*, *1*(2), 262-271.

Iverach, L., Lowe, R., Jones, M., O'Brian, S., Menzies, R. G., Packman, A., & Onslow, M. (2017). A speech and psychological profile of treatment-seeking adolescents who stutter. *Journal of Fluency Disorders*, *51*, 24–38. https://doi.org/10.1016/j.jfludis.2016.11.001

Iverach, L., Jones, M., Lowe, R., O'Brian, S., Menzies, R. G., Packman, A., & Onslow, M. (2018). Comparison of adults who stutter with and without social anxiety disorder. *Journal of Fluency Disorders*, *56*(January), 55–68. https://doi.org/10.1016/j.jfludis.2018.03.001

Iverach, L., Jones, M., McLellan, L. F., Lyneham, H. J., Menzies, R. G., Onslow, M., & Rapee, R. M. (2016). Prevalence of anxiety disorders among children who stutter. *Journal of Fluency Disorders*, *49*, 13–28. https://doi.org/10.1016/j.jfludis.2016.07.002

Iverach, L., Jones, M., Menzies, R. G., O'Brian, S., Packman, A., & Onslow, M. (2011). Response to Walter Manning and J. Gayle Beck: Comments concerning Iverach, Jones et al. (2009a). *Journal of Fluency Disorders*, *36*(1), 66-71.

Iverach, L., O'Brian, S., Jones, M., Block, S., Lincoln, M., Harrison, E., ... & Onslow, M. (2009). Prevalence of anxiety disorders among adults seeking speech therapy for stuttering. *Journal of anxiety disorders*, *23*(7), 928-934.

Iverach, L., & Rapee, R. M. (2014). Social anxiety disorder and stuttering: Current status and future directions. *Journal of fluency disorders*, *40*, 69-82.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry, 62*(6), 593–602.

Langevin, M., Kully, D., Teshima, S., Hagler, P., & Narasimha Prasad, N. G. (2010). Five-year longitudinal treatment outcomes of the ISTAR Comprehensive Stuttering Program. *Journal of Fluency Disorders*, *35*(2), 123–140. https://doi.org/10.1016/j.jfludis.2010.04.002

Lawrence, D., Johnson, S., Hafekost, J., Boterhoven De Haan, K., Sawyer, M., Ainley, J., et al. (2015). *The mental health of children and adolescents. Report on the second Australian Child and Adolescent Survey of Mental Health and Wellbeing.* Canberra: Department of Health.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments*, *10*(3), 282-297.

Loranger, C., & Bouchard, S. (2017). Validating a virtual environment for sexual assault victims. *Journal of Traumatic Stress, 30*(2), 157-165.

Menzies, R. G., Brian, S. O., & Block, S. (2008). An experimental clinical trial of a Cognitive-Behavior Therapy Package for Chronic Stuttering, *51*, 1451–1464.

Miller, L., Silva, C., Bouchard, S., Bélanger, C., & Taucer-Samson, T. (2012). Using virtual reality and other computer technologies to implement cognitive-behavior therapy for the treatment of

anxiety disorders in youth. In T.E. Davis III, T.H. Ollendick, & L.-G. Ost (Eds.) *Intensive one-session treatment of specific phobias (pp. 227-251)*. Springer. https://doi.org/10.1007/978-1-4614-3253-1_12

Mulcahy, K., Hennessey, N., Beilby, J., & Byrnes, M. (2008). Social anxiety and the severity and typography of stuttering in adolescents. Journal of Fluency Disorders, 33(4), 306–319. https://doi.org/10.1016/j.jfludis.2008.12.002

O'Brian, S., Heard, R., Onslow, M., Packman, A., Lowe, R., & Menzies, R. G. (2020). Clinical trials of adult stuttering treatment: Comparison of percentage syllables stuttered with self-reported stuttering severity as primary outcomes. *Journal of Speech, Language, and Hearing Research*. Advance online publication. doi: https://doi.org/10.1044/2020_JSLHR-19-00142

O'Brian, S., Onslow, M., Cream, A., & Packman, A. (2003). The Camperdown Program: Outcomes of a new prolonged-speech treatment model. *Journal of Speech, Language, and Hearing Research*, *46*(4), 933–946. https://doi.org/10.1044/1092-4388(2003/073)

O'Brian, S., Packman, A., & Onslow, M. (2004). Self-rating of stuttering severity as a clinical tool. *American Journal of Speech-Language Pathology, 13,* 219-226.

Onslow, M. (2020, May). Stuttering and its treatment – Eleven lectures. Retrieved from: https://www.uts.edu.au/research-and-teaching/our-research/australian-stuttering-research-centre/asrc-resources/resources.

Onslow, M., Jones, M., O'Brian, S., Packman, A., Menzies, R., Lowe, R., ... & Franken, M. C. (2018). Comparison of percentage of syllables stuttered with parent-reported severity ratings as a primary outcome measure in clinical trials of early stuttering treatment. *Journal of Speech, Language, and Hearing Research, 61*(4), 811-819.

Parrish, D. E., Oxhandler, H. K., Duron, J. F., Swank, P., & Bordnick, P. (2016). Feasibility of Virtual Reality Environments for Adolescent Social Anxiety Disorder. *Research on Social Work Practice*, *26*(7), 825–835. https://doi.org/10.1177/1049731514568897

Pertaub, D.P., Slater, M., & Barker, C. (2002). An experiment on public speaking anxiety in response to three different types of virtual audiences. *Presence, 11*(1), 68-78.

Reddy, R. P., Sharma, M. P., & Shivashankar, N. (2010) Cognitive behavior therapy for stuttering: a case series. *Indian Journal of Psychological Medicine, 32*, 49-53.

Schmits, E., Heeren, A., & Quertemont, E. (2014). The self-report Version of the LSAS-CA: Psychometric Properties of the French Version in a non-clinical adolescent sample. *Psychologica Belgica*, *54*(2), 181–198. https://doi.org/10.5334/pb.al

Silva, C., Bouchard, S., & Bélanger, C. (2020). *Children's Perception of Phobogenic Stimuli in Virtual Reality* [Manuscript submitted for publication]. Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais.

Tardif, N., Therrien, C.-É., Bouchard, S. (2019). Re-examining psychological mechanisms underlying virtual reality-based exposure for spider phobia. *Cyberpsychology, Behavior, and Social Networking,* 22(1), 39-45. https://doi.org/10.1089/cyber.2017.0711

Turner, C. A. (2013). *Cyberpsychology and schools: A feasibility study using virtual reality with school children*. MA Thesis at the University of British Columbia.

Vanryckeghem, M., Matthews, M., & Xu, P. (2017). Speech Situation Checklist-Revised: Investigation With Adults Who Do Not Stutter and Treatment-Seeking Adults Who Stutter. *American Journal of Speech Language Pathology, 26*(4), 1129–1140. https://doi.org/10.1044/2017_AJSLP-16-0170

Wiederhold, B. & Bouchard, S. (2014). Advances in virtual reality and anxiety disorders. Springer.

Wiederhold, B. & Wiederhold, M. (2014). Introduction. In B. Wiederhold & S. Bouchard (Eds.) *Advances in virtual reality and anxiety disorders,* (pp. 3-8). Springer.

Wong Sarver, N., Beidel, D. C., & Spitalnick, J. S. (2014). The Feasibility and Acceptability of Virtual Environments in the Treatment of Childhood Social Anxiety Disorder. *Journal of Clinical Child and Adolescent Psychology, 43*(1), 63–73. https://doi.org/10.1080/15374416.2013.843461

Xu, X., Demos, K. E., Leahey, T. M., Hart, C. N., Trautvetter, J., Coward, P., … Wing, R. R. (2014). Failure to replicate depletion of self-control. PLoS ONE, 9(10), 1–5. https://doi.org/10.1371/journal.pone.0109950

Yang, L., Zhou, X., Pu, J., Liu, L., Cuijpers, P., Zhang, Y., … Xie, P. (2019). Efficacy and acceptability of psychological interventions for social anxiety disorder in children and adolescents: a meta-analysis of randomized controlled trials. *European Child and Adolescent Psychiatry, 28*(1), 79–89. https://doi.org/10.1007/s00787-018-1189-x

Table 1

Participants' Description: Age, Gender, Stuttering Frequency when Talking to the Examiner, Other Characteristics, Speech-Language Pathology (SLP) Treatment Length in hours, and Treatment Approaches.

Age	Gender	Stuttering Frequency	Other Characteristics	SLP Treatment length in hours	Treatment Approaches
12	M	4.0 %SS		2	FS + SM
17	M	5.3 %SS	Negative thoughts and emotions about his speech, weaknesses in oral language	19	FS
12	F	6.1 %SS	Negative attitudes and emotions about her speech	21	FS + SM Drama Gr
9	M	7.9 %SS	Negative emotions about his speech	39	LP + Exp Drama Gr
11	M	5.5 %SS	Reading and writing disorder	6 days intensive group	FS + Exp
12	M	4.0 %SS	Word-finding difficulties	6 days intensive group	FS + Exp
9	M	3.0 %SS	Weaknesses in reading abilities	40	LP
12	F	1.5 %SS		20	CBT + SFBT Drama Gr
10	M	1.0 %SS	Negative attitudes and emotions about his speech	14	LP + Exp CBT, ACT, SFBT
11	M	0.0 %SS		11	LP + FS

ACT: Acceptance and Commitment Therapy; CBT: Cognitive Behavioral Therapy; Drama Gr: Drama Group, an-11 hour activity designed to improve confidence during public speaking and acceptance of stuttering; Exp: Gradual Exposure; FS: Fluency Shaping; LP: Lidcombe Program adapted for school-age children; SFBT: Solution-Focused Brief Therapy; SM: Stuttering Modification.

Table 2

Means, Standard Deviations and Range of Personal Report of Confidence as a Speaker (PRCS), and Liebowitz Social Anxiety Scale of Children and Adolescents (LSAS-CA).

	PRCS (N=10)	LSAS-CA (N=9)				
		Total	Social	Performance	Fear	Avoidance
M	4.1	30.0	15.44	30.0	16.11	13.89
(SD)	(2.23)	(15.15)	(10.56)	(15.15)	(8.31)	(8.62)
Range	1-7	5-47	0-34	5-47	5-31	0-26
Max possible score	12	144	72	72	72	72

Note. PRCS scores range from 0 to 12, with higher scores indicating less confidence in one's public speaking abilities. LSAS-CA scores range from 0 to 144, with higher scores indicating increased social anxiety.

Table 3

Means, Standard Deviations and Range of the 0 – 10 Subjective Units of Distress Scale (SUDS), Stuttering Severity Rating (SR) and Percentage of Syllables Stuttered (%SS).

		Speaking conditions					
		With the examiner	Empty virtual apartment	Neutral virtual classroom	Challenging virtual classroom	Combined virtual classroom	Real audience
SUDS	*M*	1.35	1.33	2.30	2.30	2.30	2.42
	(SD)	1.38	1.45	2.63	2.04	2.27	2.83
	Range	0 – 4.67	0 – 4.67	0 – 9.17	0 – 7.17	0 – 8.17	0.17 – 10
SRs (SLP)	*M*	2.3	1.1	2.5	2.6	2.55	2.2
	(SD)	1.34	0.99	1.65	1.9	1.76	1.55
	Range	0 – 4	0 – 3	0 – 5	0 – 6	0 – 5.5	0 – 4
SRs (participants)	*M*	1.33	1.0	2.22	2.11	2.17	1.56
N=9	*(SD)*	1.66	1.94	2.14	2.15	2.08	1.05
	Range	0 – 5	0 – 6	0 – 7	0 –5	0 – 6	0 – 3.5
%SS	*M*	3.85	2.43	4.14	4.1	4.12	3.37
	(SD)	2.5	2	3.63	3.26	3.22	2.18
	Range	0 – 7.9	0 – 5.5	0 – 9.9	0 – 10.8	0 – 9.9	0 – 6.5

Note. SUDS scores range from 0 to 10, with higher scores indicating higher anxiety levels. SR scores range from 0 to 9, with higher scores indicating higher stuttering levels. Only the scores from the first immersion in the empty virtual apartment are reported.

Table 4

Participants' Comments regarding their Experience in the Virtual Classroom.

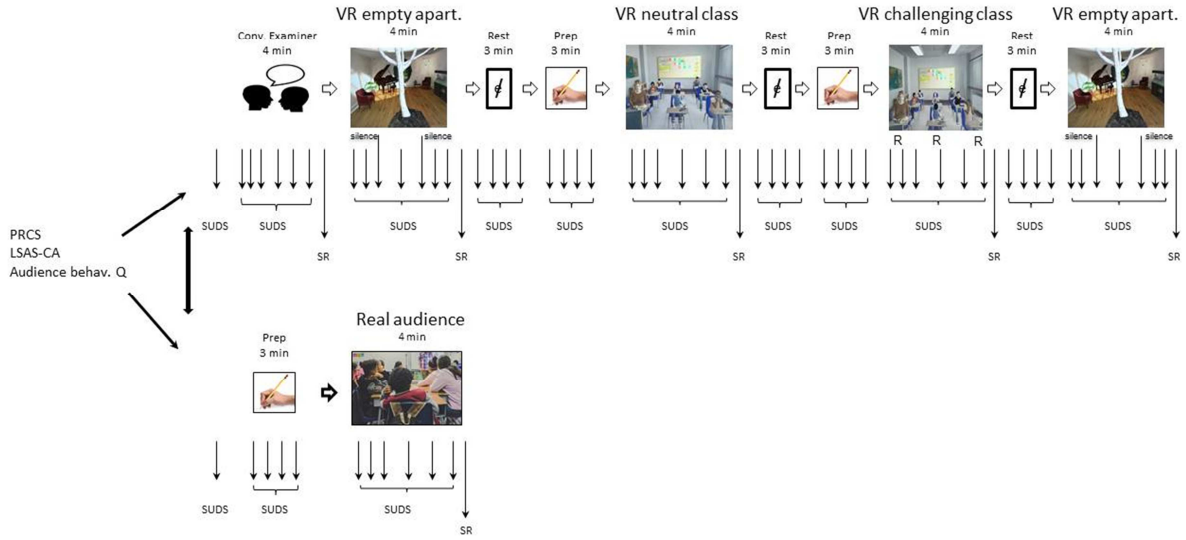
Topic of the comments	Comments
Usefulness	It is easier to do an oral presentation if we practice in the virtual environment before.
	[In the virtual environment], we can practice speech tools, speaking slowly and staying calm.
	We can practice in front of many people.
	It [the virtual environment] allows you to be prepared if the classmates yawn or laugh.
	It can help shy people.
	We can practice our speech, to be more fluent.
Anxiety	You know you are not in front of a real class so you are less stressed.
	I don't think anything serious would happen if I do it wrong.
Realism	When they started laughing, I froze for one second. I thought it was real.
	Students and the teacher act the same way they would in reality.
Motivation	Some kids like to play with technology so it can enhance interest in treatment.
Possible improvements of the virtual environment	Having more students in the class, having them talk, whisper, ask questions.
	Having more situations: teamwork, speaking with friends at lunchtime, ordering at the restaurant.

Figure 1.

Screenshot of the virtual classroom. Copyright 2018 InVirtuo, Inc. Published with permission.

Figure A1.

Procedure.



Note. PRCS: Personal Report of Confidence as a Speaker; LSAS-CA: Liebowitz Social Anxiety Scale of Children and Adolescents; Audience behav. Q: personal judgement on the potential difficulty of talking in front of a class depending on the audience's behavior; Rest: resting period during which they had to read a text about relaxation and cross out every letter 'e' they found in the text; Prep: Preparation time, i.e. time devoted to preparing the speech; SUDS: Subjective Units of Distress Scale; SR: Stuttering Severity Rating.