Anxiety Measures in Adults who do and do not Stutter During two Virtual Speaking Tasks

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Abstract of Thesis

Anxiety Measures in Adults who do and do not Stutter During two Virtual Speaking Tasks

Quantifying relationships between stuttering and anxiety typically occurs in experimental studies that are designed to systematically control variables thought to influence anxiety and stuttering. Virtual reality (VR) environments allow for immersion in speaking environments that mimic real-life interactions (Brundage, Hancock, Kiselewich, Graap, Brooks, & Ferrer, 2007). Our research question was: Is there a difference between adults who stutter (AWS) and adults who do not stutter (AWNS) in physiologic and verbal-cognitive/behavioral anxiety measures during speeches given in two settings? Ten AWS and 10 age and gender matched AWNS gave four-minute speeches to a virtual audience and to a virtual empty room. Statistical analysis revealed no significant differences in measures of galvanic skin response (GSR), heart rate (HR), and respiration rate (RESP) or *Subjective Units of Distress* (SUDS) between groups or within settings. There was a significant increase in SUDS ratings when giving a speech to the virtual audience for both groups.

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Chapter 1: Introduction and Literature Review

Defining Stuttering

Stuttering is a disorder that "countless writers have tried to capture the essence of…in a few sentences" (Guitar, 1998, p. 10). There has been much discussion and disagreement on how best to define this disorder that has a prevalence of approximately 1 % of the adult population (Guitar, 1998). Stuttering is a communication disorder often initially described by its core behaviors that are observable to listeners. In one of the most widely used and accepted definitions (Packman & Attanasio, 2004), Wingate (1964) defined stuttering as:

> **(a) Disruption in the fluency of verbal expression, which is (b) characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable. The disruptions (c) usually occur frequently or are marked in character, and (d) are not readily controllable. 2. Sometimes the disruptions are (e) accompanied by accessory activities involving the speech apparatus, related or unrelated body structures, or stereotyped speech utterances. These activities give the appearance of being speech-related struggle. 3. Also, there not infrequently are (f) indications or reports of the presence of an emotional state, ranging from a general condition of 'excitement' or 'tension' to more specific emotions of a negative nature such as fear, embarrassment, irritation, or the like. The immediate source of stuttering is some incoordination expressed in the peripheral speech mechanism; the ultimate cause is presently unknown and may be complex or compound. (p. 488)**

This definition distinguishes between primary behaviors and secondary behaviors. Primary behaviors may include sound and syllable repetitions, sound prolongations, interjections, broken words (pauses), blocks, and circumlocutions (American Psychiatric Association [*DSM-IV-TR*], 2000). Secondary behaviors include learned reactions to avoid dysfluency, and fall into two broad categories: escape behaviors and avoidance behaviors (Guitar, 1998). Wingate's definition also includes aspects of struggle, shame, fear, avoidance and anxiety, which are common themes in narratives of adults who stutter (AWS) (Conture & Curlee, 2007; Corcoran & Stewart, 1998; Plexico, Manning, & DiLollo, 2005). While some argue that this definition relies too heavily on the listener's perception of the acoustic speech signal (Smith & Kelly, 1997) researchers, for the most part, agree that these characteristics are most common to the disorder (Packman & Attanasio, 2004;Yairi, 1997).

In order to classify the disorder in terms more relevant to the lives of AWS, researchers have reframed Wingate's definition by emphasizing aspects of stuttering that impact the lives of AWS. These aspects, often referred to as "the ABC's of stuttering," include: *affective reactions* (feelings related to stuttering such as shame, fear, guilt, and anxiety), *behaviors*, (speech disruptions, avoidance, tension, and struggle) and *cognitive reactions* (negative self-evaluation or low self-esteem) (Yaruss & Quesal, 2004). In this way, researchers have attempted to assess and treat the disorder according to its defining characteristics. Stuttering can be a socially debilitating communication disorder that interferes with work, school and family life, causing AWS to often avoid speaking situations, feel embarrassed by how they talk, and anxious about communicating, (Conture, 1999; Craig, Hancock, Tran, & Craig, 2003; National Stuttering Association, 2009).

Theories of Stuttering

Understanding a basic framework of theories of stuttering may be valuable in considering appropriate integration of measures of stuttering and anxiety (Smith & Kelly, 1997). Theories can be separated into four generic types (Manning, 2010). *Psychological* approaches posit that stuttering behaviors are indicative of underlying psychological, emotional, or neurotic conflict. *Physiological* theories suggest a breakdown in producing fluent speech due to struggle in response to various internal and external stressors. *Learning* theories propose that the speaker learns that speaking is difficult, and learns to anticipate struggle and stuttering. Finally, *multifactorial models* consider stuttering in light of multiple factors that lead to the development and manifestation of the disorder (Manning, 2010). Most current research emphasizes the importance of viewing the disorder from a multifactorial perspective in assessment and treatment (Healey, Trautman, & Susca, 2004).

Measuring Stuttering

If stuttering is a multifactorial disorder, it stands to reason that many measures will need to be taken in order to characterize it accurately, the most obvious being the stuttering behavior itself. The behavioral symptoms of stuttering are measured by calculating the frequency of stuttered syllables in the acoustic speech signal, the duration of stuttering moments, and severity of observable escape and secondary behaviors such as loss of eye contact, eye blinks, head nods, and facial grimaces (Riley, 2009). Clinicians can administer subjective questionnaires regarding the affective aspect of stuttering to assess the AWS's feelings, attitudes, and behaviors associated with stuttering. Questionnaires commonly used include the *Modified Erickson Scale of Communication Attitudes* (S-24; Andrews & Cutler, 1974), and *Perceptions of Stuttering Inventory* (PSI; Woolf, 1967). Instruments developed in other academic fields, such as the *Fear of Negative Evaluation* scale (FNE; Watson & Friend, 1969) can also be used to quantify feelings and attitudes toward speaking. Likewise, cognitions relating to the individual's stutter can be monitored using scales such as the *Overall Assessment of the Speaker's Experience of Stuttering* (OASES; Yaruss & Quesal, 2006), *Locus of Control of Behavior* scale (LCB; Craig, Franklin, & Andrews, 1984), and the *Stuttering Problem Profile* (SPP; Silverman, 1980). Clinicians are also encouraged to assess speech in natural environments and functional tasks before, during, and after treatment (Manning, 2010). These questionnaires, combined with speech naturalness ratings allow clinicians to gain a more comprehensive view of the disorder (Ingham & Cordes, 1999; Riley, Riley,& Maguire, 2004; Riley, 2009).

Defining Anxiety

Marks (1987) defines *anxiety* by differentiating it from *fear*. While fear is an "unpleasant feeling that arises as a normal response to realistic danger," *anxiety* is a similar emotion that arises without any apparent, objective source of danger (Marks, 1987, p. 5). Additionally, *social anxiety* is a persistent fear of social or performance situations where an individual may be exposed to unfamiliar people or possible scrutiny from others (*DSM-IV-TR*, 2000). Anxiety is generally said to be a complex psychological construct that involves three components: verbal-cognitive (i.e., subjective reports of anxiety), behavioral (i.e., avoidance of situations), and physiological (i.e., objective measures of the body's reaction to situations; Marks, 1987). Individuals with social anxiety or social phobia may also experience extreme and intense anticipatory anxiety in social settings (Blumgart, Tran & Craig, 2010), as well as show a large discrepancy between the impression they want to create in social settings and their belief in their ability to make that impression (Rapee & Lim, 1992). It is believed that anxiety and fear are emotional experiences that serve a critical function in organizing survival responses within humans (Fendt & Fanselow, 1999). These survival responses to stress are regulated by the autonomic nervous system (ANS) and the hypothalamic pituitary adrenal cortex (HPA) axis (Martin, Ressler, Binder, & Nemeroff, 2009).

Measuring anxiety

The ANS is a part of the peripheral nervous system that controls vegetative functions of the body such as heart rate, constriction of the blood vessels, pupil dilation, blood pressure, sweat production, and digestion (Carlson, 1986). The ANS has two branches, the *sympathetic branch* and *parasympathetic branch*, each of which regulates bodily functions in aroused (sympathetic) or relaxed (parasympathetic) states. In many functions the sympathetic and parasympathetic branches of the ANS have opposite effects, such as increasing heart rate and decreasing heart rate in arousing situations (Alm, 2004). Monitoring levels of ANS responses to stressful stimuli have long been used in the field of psychology as a way to measure stress response in humans and these measurements are valuable because they do not reflect subjective opinion (Lazarus & Opton, 1966; Weber & Smith, 1990).

The HPA axis includes the hypothalamus, pituitary gland, and the adrenal glands. Working together these structures also control and regulate the body's reaction to stress (Ice & James, 2007). The hippocampus and amygdala are also important structures in the stress-response system. The hippocampus exhibits inhibitory control over the HPA axis, providing negative feedback for the HPA axis, while the amygdala processes external stimuli that lead to a behavioral and physiological responses. These responses include heart rate and blood pressure, cortisol release, respiratory changes, and the body's startle response (Martin et al., 2009). Hormonal variation to stressful events can be measured by monitoring levels of cortisol, a human stress hormone, in bodily fluids. While cortisol may be easy to collect, it is difficult to accurately interpret due to extraneous variables that affect cortisol production such as circadian rhythms, seasons of the year, menstrual cycle timing, gender, and eating habits (Ice & James, 2007).

Anxiety cannot be measured directly; only indirect objective and subjective measures can be taken. Objective measures of anxiety have been taken through monitoring changes in heart rate (HR), electrodermal measures on the skin (galvanic skin response; GSR), respiration rate (RESP) and cortisol levels (Bloodstein & Bernstein Ratner, 2008). These physiologic reactions may be taken through the use of belts placed around the body, electrodes attached to the skin, or sampling of salivary pH levels. Changes in these measures in different situations allow researchers to indirectly examine the stress response through physiological changes that occur during anxiety provoking situations (Ice & James, 2007).

Anxiety can also be measured subjectively, via the use of self-report measures of feelings, attitudes and anxiety. These can be termed as verbal-cognitive reports of anxiety. There are many different scales used to quantify perceived anxiety within individuals generally or in specific situations. In the field of fluency disorders, the most commonly used questionnaires/scales include: The *Subjective Units of Distress scale* (SUDS; Wolpe, 1958), the *Fear of Negative Evaluation Scale* (FNE; Watson & Friend, 1969), and the trait version of the *State-Trait Anxiety Inventory* (STAI-T; Speilberger, C. D, & Diaz-Guerrero, R., 1983). All of these measures require respondents to rate their subjective anxiety or fear using equal appearing interval scales. For the purposes of this study, physiological reactions to stress are considered *objective* measures of anxiety, and verbal-cognitive self-ratings of anxiety are considered *subjective* measures.

The relationship between stuttering and anxiety

Although the relationship between stuttering and anxiety is "distinct but inconsistent," (Bloodstein, 1995, p. 321), anxiety plays a role in many theories of stuttering and treatment types (Miller & Watson, 1992; Sheehan, 1970). Despite much research, the relationship between stuttering and anxiety remains complex and conflicting, and many researchers have typically rejected any systematic and clinically meaningful relationship between the two (Bloodstein & Bernstein Ratner, 2008; Menzies, Onslow, & Packman, 1999). Some studies have supported a positive relationship between the two, as measured by either physiologic or verbal-cognitive measures (Blood, Blood, Bennett, Simpson, & Susman, 1994; Blumgart et al., 2010; Craig et al., 2003; Iverach, O'Brian, Jones, Block, Lincoln, Harrison, Hewat, Menzies, Packman & Onslow, 2009; Kraaimaat, Vanryckeghem, & Van Dam-Baggen, 2002; Messenger, Onslow, Packman & Menzies, 2004). However, other studies have failed to find any significant relationship between stuttering and measures of anxiety in AWS as measured by verbal-cognitive reports or physiological measures of arousal (Caruso, Chodzko-Zajko, Bidinger, & Sommers, 1994; Dietrich & Roaman, 2001; Evans & Healey, 2010; Peters & Hulstijn, 1984; Weber & Smith, 1990). Still other studies examining the relationship between stuttering and anxiety find an increased probability of AWS meeting the criteria for a range of anxiety disorders (Iverach et al., 2009; Blumgart et al., 2010). Additional studies report that at least some AWS experience higher levels of anxiety in different types of tasks (Craig et al., 2003; Ezrati-Vinacour & Levin, 2003; Messenger et al., 2004), particularly tasks requiring self-reported, speaking-related social anxiety (Blumgart et al., 2010; Ezrati-Vinacour & Levin, 2004; Iverach et al., 2009; Menzies et al., 1999; Mahr & Torosian, 1999).

Conflicting findings in this area may arise from methodological inconsistencies across studies and shortcomings in experimental design in multiple areas: tasks used, participant selection, and measurement (Menzies et al.,1999). Studies range from measuring general anxiety without experimental speaking tasks (Craig et al., 2003; Iverach et al., 2009), to using relatively low-stress speaking tasks such as reading or speaking to a clinician (Ezrati-Vinacour & Levin, 2004; Ickes & Pierce, 1973; Peters & Hulstijn, 1984; Weber & Smith, 1990), or to combinations of low and high-stress speaking tasks with cognitive loads (Caruso et al, 1994; Dietrich & Roaman, 2001; Evans & Healey, 2010). These tasks can vary from responding to questions, sharing personal narratives, or to reading individual words or long passages (see table 1A). These types of studies have minimal ecological validity because the speaking tasks used are unlike everyday speaking tasks. Participant selection can also be problematic when examining anxiety related to a complex disorder such as stuttering. Multiple studies recruit from clinic waiting lists, which have been shown to include people who show higher levels of anxiety when compared to the overall population of people who stutter (Craig et al., 2003; Iverach et al., 2009). Furthermore, some studies attempt to monitor the presence of anxiety using only one measure of anxiety (Dietrich & Roaman, 2001), which can make interpretation of results difficult. Aside from design, another complicating factor is that studies measure different types of anxiety (e.g. social anxiety, state anxiety, trait anxiety), whereas others measure reactions that occur due to the *presence* of anxiety (e.g. physiologic reaction or cognitive/behavioral reactions). The variation in dependent variables can make it difficult to compare findings across studies (Menzies et al., 1999).

Smith & Kelly (1997) suggest that limitations such as these contribute to unclear findings by examining the disorder along linear models of stuttering. Linear models of stuttering are those that fail to recognize stuttering as a multifactorial disorder; one that requires definition and measurement on multiple levels (Smith & Kelly, 1997). Up to the present time, physiological measures of anxiety (e.g. GSR, HR, and RESP) have not been measured in ecologically valid speaking tasks, despite calls to do so (Weber & Smith, 1990). Investigations exploring the relationship between stuttering and anxiety are summarized in Table 1A and are organized according to variables measured (physiological or verbal-cognitive/behavioral), task, and findings.

Studies measuring anxiety using physiologic and verbal-cognitive/behavioral measures in AWS and AWNS have yielded inconsistent findings (see Table 2A), with some studies finding significant differences between AWS and AWNS (Caruso et al., 1994; Peters & Hulstijn, 1984) and others finding no differences between groups (Evans & Healey, 2010; Dietrich & Roaman, 2001; Peters & Hulstijn, 1984; Weber & Smith, 1990). Furthermore, for those studies that *do* find differences between groups the direction of the difference is not always in the direction of AWS exhibiting a greater stress response (Caruso et al., 1994; Ickes & Pierce, 1973; Peters & Hulstijn, 1984). This difference in direction may be due to coactivation of the sympathetic and parasympathetic branches of the ANS may have had on measures within these studies (Alm, 2004).

The tasks used to evoke a stress response likely influence findings in these studies as well. During *silence*, physiologic and verbal-cognitive measures of anxiety do not differ between AWS and AWNS (Bloodstein & Bernstein Ratner, 2008; Evans & Healey, 2010; Peters & Hulstijn, 1984; Weber & Smith, 1990). During low-stress speaking tasks, such as *reading a passage aloud*, no differences between these groups emerge in physiological measures (Weber & Smith, 1990), although there are conflicting findings for verbal-cognitive measures (Dietrich & Roaman, 2001; Peters & Hulstijn, 1984). Both AWS and AWNS exhibit higher levels of arousal during stressful speaking tasks, such as naming ink colors in Stroop color word tasks or other tasks that impose a linguistic, memory, or social load (Caruso et al., 1994; Evans & Healey, 2010). Therefore it appears to be important to measure physiologic reactions in a variety of tasks that span a low to high continuum of stress and during silence, in order to appropriately assess aspects of any relationship between stuttering and anxiety (Blood et al., 1994; Weber & Smith, 1990).

Although the task appears to influence findings, some researchers have elected to focus solely on verbal-cognitive self-reports to measure anxiety in AWS compared to AWNS without performance of an experimental speaking task (Blumgart et al., 2010; Craig et al., 2003; Iverach et al., 2009; Kraaimaat, et al., 2002; Messenger et al., 2004; Miller & Watson, 1992). In this body of literature we find conflicting findings with some studies finding greater self-reports of anxiety in AWS (Blumgart et al., 2003; Craig, 1990; Craig et al., 2003; Iverach et al., 2009; Kraaimaat et al., 2002; Messenger et al., 2004), whereas others find no differences between groups (Blood et al., 1994; Miller & Watson, 1992).

When examining levels of anxiety, additional factors to consider in experimental design include and age and gender of participants, as anxiety levels may change across the lifespan (Craig et al., 2003), and differ according to gender (Kajantie & Phillips, 2006). This supports the procedure of age and gender-matching control groups to those in experimental groups. The need for accurate collection and appropriate integration of multiple measurements, both subjective (verbal-cognitive) and objective (physiological), remains to strengthen and clarify relationships and differences between measures of stuttering and anxiety (Cordes & Ingham, 1994). This includes the integration of socially valid speaking tasks with behavioral aspects of stuttering and self-report measures of the experience of stuttering (Menzies et al., 1999; Iverach, Menzies, O'Brian, Packman, & Onslow, *in press*; Weber & Smith, 1990).

The use of virtual reality environments

Virtual reality (VR) has been used as a tool in treatment of feared situations in controlled, safe settings for a variety of disorders. These include eating disorders (Gorini, Griez, Petrova, & Riva, 2010), acrophobia and fear of flying (Strickland, Hodges, North, & Weghorst, 1997), fear of public speaking (Anderson, Zimand, Hodges & Rothbaum, 2005), generalized anxiety disorders (Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Powers & Emmelkamp, 2008), and social phobias (Riva, Botella, Legeron, & Optale, 2004). VR has also been validated for possible use in the assessment and treatment for stuttering (Brundage, Hancock, Kiselewich, Graap, Brooks, & Ferrer, 2007). Not only can VR settings emulate real world situations, but the use of VR allows the participant to experience exposure to feared objects with a degree of presence, making the exposure similar to a live experience (Krijn et al., 2004). Anderson and colleagues (2005) reported social phobic participants' decrease of anxiety, measured using self-rating anxiety scales, through repeated exposure to feared situations in VR. Brundage and colleagues (2007) suggest that VR speaking tasks engender similar affective, behavioral and cognitive reactions in both AWS and AWNS when compared to the same measures taken during live speaking situations.

Approaches that have been used to successfully address phobias include cognitive behavioral therapy and exposure therapy, with the introduction more recently of Virtual Reality exposure therapy (Krijn et al., 2004). Exposure therapy is a successful treatment for reducing social phobia; it works by activating the existing "fear structure" of an individual and then habituating them to the feared object or situation. In order for exposure therapy to be effective, tools must be used that realistically activate fear memories while introducing new (positive) experiences and information into the individuals existing fear structure, to make the experience less feared (Foa & Kozak, 1986). In the realm of stuttering, literature suggests increased fear of speaking in AWS (Manning, 2010), which can be addressed using VR technology.

The VR experience allows researchers to systematically manipulate tasks along a hierarchy of feared situations (Brundage & Graap, 2004; Brundage et al., 2006), which is common practice in many stuttering therapies (Culatta & Goldberg, 1995; Manning, 2010). Use of VR equipment allows researchers to control for factors such as location, time of day, speaking situation, and speaking task through immersion into new environments. Since stuttering typically worsens when an AWS enters stressful speaking tasks, such as addressing a large audience, (Mahr & Torosian, 1999; Porter, 1939; Siegel & Haugen, 1964) manipulation of audience size through the use of VR may represent an ideal procedure for the systematic evaluation of speaking related anxiety in AWS and AWNS. Through the use of VR, researchers can control variables that were not systematically controlled in studies up to the present time, and can emulate real world situations, therefore increasing the ecological validity of the findings.

In summary, there is a need for appropriate integration of behavioral aspects of stuttering with self-report measures of the stuttering experience (Menzies et al., 1999). Virtual reality is a tool that allows the researcher to systematically manipulate the speaking task across subjects. The purpose of this study is to evaluate verbal-cognitive and physiological measures of anxiety of AWS in speaking tasks in two different virtual environments. Outcomes resulting from manipulation of the virtual environment (e.g. audience vs. empty chairs) will be noted. Research questions include

1. Is there a difference between AWS and AWNS physiological measures (GSR, HR, RESP) when measured during silence tasks?
2. Is there a difference between AWS and AWNS in physiological measures (GSR, HR, RESP) during the two virtual speech tasks?
3. Is there a difference between AWS and AWNS in verbal-cognitive ratings of anxiety (SUDS) during the two virtual speaking tasks?
4. Is there a within group difference in verbal-cognitive ratings of anxiety (SUDS) between the two virtual speech tasks (VR empty chairs vs. VR Audience)?

Chapter 2: Methods

Participants

There were two groups of participants. The experimental group consisted of 10 adult males who stutter and the control group consisted of 10 non-stuttering males who were age-matched to the experimental group. A total of 11 AWS and 12 AWNS completed the study protocol. The GSR equipment (described below) failed to accurately record for one of the AWS and two of the AWNS subjects. These three subjects were replaced by three additional subjects (one AWS and two AWNS) in order to achieve groups of equal numbers of subjects.

The experimental group participants (mean= 30.8 years, SD= 12.4) were recruited from speech and hearing clinics and local National Stuttering Association support groups from the Metropolitan Washington, DC area. Six identified their ethnicity as Caucasian, two as African-American, one as Hispanic/Latino, and one as other. All AWS participants were self-identified as persons who stutter; this diagnosis was subsequently verified by a certified speech-language pathologist. Current levels of stuttering were determined using the *Stuttering Severity Instrument 4* (SSI-4; Riley, 2009) from information gathered in an opening interview with the researchers and passage reading. SSI-4 scores ranged from 10 to 35 (mean=20.9, SD=10.6), indicating very mild to severe stuttering. Participants were excluded if they reported any medical diagnosis of general anxiety disorders, speech or language disorders other than stuttering, motion sickness, epilepsy or seizure disorders, or a diagnosed psychiatric disorder with accompanying medication. Of the 10 AWS participants, eight had received previous speech therapy for their stuttering, with two receiving fluency shaping, none receiving only stuttering modification, six a combination of treatments, and two receiving no previous treatment. Two members of the AWS group were currently in treatment, both receiving avoidance reduction therapy. Of the AWS group, five were currently actively or semi-actively attending stuttering support groups.

All 10 AWS rated their speaking-related anxiety prior to the study, using a 5-point scale, with 1 being "I experience speaking related anxiety almost never" and 5 being "I experience speaking related anxiety almost all the time." The average rating for the AWS group on this scale was 2.6 (SD=.74). Participants in this group rated the impact stuttering had on their lives (as measured by the Overall Assessment of the Speaker's Experience of Stuttering scale), with the group of AWS ranging from mild-moderate impact to moderate impact. Other verbal-cognitive/behavioral measures of anxiety show that the experimental group of AWS, as a whole, scored closely to the AWNS control group on most measures, despite showing a wide range of stuttering severities (See table I).

The control group of 10 age and gender-matched AWNS were recruited by word of mouth, study pamphlets posted on campus, and snowball sampling of the AWS participants. The group consisted of individuals who did not report stuttering. Control group participants were excluded if they reported any medical diagnosis of general anxiety disorders, speech or language disorders, motion sickness, epilepsy or seizure disorders, or diagnosed psychiatric disorders with accompanying medication. Control group participants matched the experimental group on gender (all males) and were age matched within three years to the experimental group (see Table 3A). The 10 AWNS rated their speaking related anxiety prior to the study, using the same 5-point scale described above with an average rating of 1.6 (SD=.84).

Table I

Verbal-cognitive reports of anxiety for adults who stutter (AWS) and adults who do not stutter (AWNS)

Assessment	AWS	AWNS	Range of Possible Scores
5-point speaking-related anxiety scale	2.6 (SD=.74)	1.6 (SD=.84)	1-5
Erickson S-24	14.1 (SD=4.84)	5.8 (SD=3.55)	0-24
FNE	12.8 (SD=8.05)	11.2 (SD=10.91)	0-30
STAI-T	54.9 (SD=3.57)	53.3 (SD=3.53)	0-80
OASES	42.16 (SD=8)	—	20-100

Note. Assessments used were the Fear of Negative Evaluation scale (FNE), the trait version of the State-Trait Anxiety Inventory (STAI-T) and the Overall Assessment of the Speaker's Experience of Stuttering (OASES). Direction of all test scores are as was expected when comparing AWS vs. AWNS; higher S-24 indicating higher negative communicative attitudes, higher FNE indicating heightened fear of negative evaluation, and higher STAI-T indicating higher trait anxiety. The 1-5 anxiety scale measured frequency of speaking related anxiety where 1= "almost never" and 5= "almost all of the time."

Materials

Self-report Questionnaires

All participants filled out self-report questionnaires to measure levels of self-reported anxiety before beginning the experimental tasks. All self-report questionnaires were completed once. Each participant completed the trait version of the *State-Trait Anxiety Inventory* (STAI-T; Speilberger et al., 1983), the *Fear of Negative Evaluation Scale* (FNE; Watson & Friend, 1969), and *Modified Erickson Scale of Communication Attitudes* (S-24; Andrews & Cutler, 1974). The STAI-T is a standardized self-assessment of anxiety consisting of 20 descriptions of how people may generally feel and describe themselves. The FNE is a commonly used 30-item true/false questionnaire that measures a person's concern about perceptions by other people in social situations and has been shown to have empirical validity, excellent internal consistency, and test retest reliability (Musa, Kostogianni, & Lepine, 2004). The S-24 assesses the participant's feelings and attitudes regarding communication and stuttering through 24 true/false questions. Normative data are available for AWS and AWNS for the S-24. During the VR speaking tasks, participants rated their speaking related anxiety using the *Subjective Units of Distress Scale* (SUDS; Wolpe, 1958). This analog scale asks participants to rate their anxiety on a scale of 0-100, where 0 equals extremely calm and 100 equals an extreme amount of distress. Participants were told that they would be asked to provide this rating at the end of each minute of their speeches.

In addition to the above scales, AWS participants also completed the *Overall Assessment of the Speaker's Experience of Stuttering* (OASES; Yaruss & Quesal, 2006), an assessment of how the participant's stuttering affects their life in the following areas—general information, reactions to stuttering, daily communication, and quality of life. The OASES was completed at the beginning of the session.

Virtual reality software and hardware

Three virtual reality environments (VREs) were used in this study. These environments were developed by Virtually Better, Inc. (Decatur, GA). In the first VRE, participants sat in the driver's seat of a virtual car, which was parked in a virtual parking lot. This environment was accompanied by soft environmental sounds such as birds chirping and traffic passing by. Subjects entered this VRE to orient them to the experience of being in a virtual space. The second VRE was a virtual audience consisting of approximately 30 listeners (males and females of varied ethnicity) seated in a medium-sized room, with the participant standing behind a virtual desk (see figure B1). The chairs were arranged in five rows, with six chairs in each row. This condition was known as the VR audience condition. The researcher could control the reactions of virtual audience members; these reactions included whispering, yawning, puzzled facial expressions, falling asleep, and slight head nodding. The third VRE was the same room but without people in the chairs, hereafter known as the empty chairs condition (see figure B2).

The virtual reality software runs on a Dell Precision 390 desktop computer and interfaces with a head mounted display (HMD; eMagin model # Z800) and noise cancelling headphones. The HMD contains a tracking device that allows the participant to turn their heads and view different parts of the virtual space; headphones deliver environmental sounds. Both the HMD and the headphones are thought to contribute to the participants' sense of immersion or 'presence' in the virtual environment. During the virtual speaking tasks, the HMD and headphones were placed on the participant's head, and the participant was allowed to adjust the headset to a comfortable position prior to entering the VREs.

Biophysical Software and Hardware

Biophysical measurements were recorded using a BIOPAC MP150 system and associated peripheral acquisition units connected to a Dell Inspiron 1525 laptop programmed with AcqKnowledge 4.1 Software (Biopac, 2010). The MP150 system and associated peripheral acquisition units and amplifiers (STP 100C, UIM 100C, and TEL 100C with a TEL 100 M-C 4 CH amplifier) were used to record data. BIOPAC TEL 100M-C amplifier settings were as follows: Channel A (heart rate; HR) with filter set to .5Hz with gain at 1K, channel B (galvanic skin response; GSR) set at DC mode with gain at 1K, and channel C (respiration rate; RESP) set to .05 Hz with gain at 5K. EKG/ECHO electrodes from channel A were connected to the participants' right wrists and left ankles and measured HR. Electrodes from channel B were connected to the participants' middle and index fingers on the right hand and measured GSR. A respiration belt was plugged into channel C and placed around the participants' chests and measured RESP (see figure 3). A digital voice recorder with lapel microphone (Olympus WS-500M) was used to record speech and reading tasks for all participants.

Procedures

Each participant completed the informed consent process. Participants then completed a number of self-rating scales to measure anxiety (see materials). All participants were escorted into the testing room where they were asked a series of case history questions and where they read an SSI-4 passage aloud. The case history interview and reading passage were video recorded for later analysis of stuttering severity. Five to 10 minutes prior to beginning the experimental tasks, participants were instructed to wash their hands and wrists before electrode placement (Venables & Christie, 1980). A disposable electro Cardiogram lead electrode (EKG/ECHO) was attached to right wrist of each participant using electrode gel (Signa Gel, Biopac Systems, Inc.; GEL 100) and white surgical tape. Another EKG/ECHO electrode was placed, in similar fashion, on the left ankle as a way to ground the current. Galvanic skin response (GSR) EDA electrodes were applied using white electrode gel(Isotonic Recording Electrd Gel, Biopac Systems Inc.; GEL 101) to the middle and index fingers on the participant's right hand, then secured by white surgical tape. An elastic respiration belt was placed around the chest to measure breathing rate. Electrodes were attached to the BIOPAC equipment with wires. The grounding wire (GND) on channel A of the amplifier was connected to the participant's left ankle electrode. The white (VIN-) wire was connected to the participant's right wrist electrode. The right hand GSR electrode was connected to channel B via red and black wires. Once connected to the equipment, the participant stood for the remainder of the experiment, with his right hand placed palm side up on a podium in front of him, where it rested comfortably for all of the tasks. In order to insure that the equipment was working properly, the participant stood in silence for a few seconds breathing normally, while the experimenters viewed the EKG and respiratory tracings. Then the participant was asked to perform a valsalva maneuver (described below) to ascertain that the GSR was working correctly. Occasionally the GSR equipment did not appear to be recording properly; when this happened we unhooked the participant from the GSR electrodes and changed the electrodes. The valsalva maneuver was repeated until a sharp increase in the GSR tracing was noted during the task.

Following completion of the self rating scales, electrode placement, and VR silence condition, all participants received experimental speech and non-speech tasks in one of 10 counter-balanced orders. These tasks included high-stress and low-stress speaking tasks, as well as high-stress and low-stress non speaking tasks, as have been called for in previous literature (Weber & Smith, 1990). Our protocol included having the participants give two, 4-minute speeches in two VREs (high stress), reading aloud in a therapy room (low stress), valsalva maneuvers (high stress), and non-speech jaw movements (low stress). Physiologic measures of anxiety were also taken during periods of silence in a VRE and in a live silence condition. Research questions for the current project involve only the VR speaking tasks, and the periods of silence in a VRE and during the reading task. Tasks described below include those that were relevant to the research questions at hand.

Speaking task, high stress (Virtual speech tasks)

Participants were told that they would be giving two, four minute speeches while standing behind a podium and immersed in two different virtual environments. One of these environments was a virtual audience with approximately 30 audience members seated in a classroom-like setting; the other environment was a virtual classroom with empty seats arranged in rows. Prior to the speaking tasks (whether empty chairs first, or virtual audience first), each participant began their virtual exposure in the virtual car, in order to orient them to the virtual space. They stood in silence during this one minute task. The participants were instructed to stand quietly and attend to the image of an automobile interior presented by the VR head mounted display. Once one minute had elapsed, the subjects were asked to close their eyes while the experimenter changed the virtual environment. Upon opening their eyes subjects saw a white door in front of them. This door lead to the virtual speaking environments (empty chairs or virtual audience). At this point participants were given a topic for their first and instructed to speak on the topic once the door opened and they were 'moved' into the room beyond. They were instructed to speak for as long as they could on the same topic; they were given additional topics when necessary. Topics addressed everyday occurrences such as favorite restaurants, sports, hobbies, and books. The two VR speech tasks were performed one after the other, also in counterbalanced order (half of subjects completed empty chairs first, half completed virtual audience first). After each minute of the speech participants were asked to rate their anxiety level using the SUDS scale; these were recorded on a rating form. After completing the first virtual reality speaking task, participants were instructed to close their eyes while the experimenter changed the virtual environment. When they opened their eyes they were again in front of a white door, where the process began again, in the second virtual environment. The researcher began data collection by simultaneously ringing a small desktop bell to signal the participant to begin and pressing an event "hotkey" on the BIOPAC computer to synchronize the exact time of initiation of the task with the collection of GSR, HR and RESP rate. This system allowed audio data to be overlaid onto biophysical data for later data analysis.

Speaking task, low stress (Reading aloud)

Participants were instructed to begin reading the grandfather passage aloud when the researcher rang the bell. Following the reading, participants stood quietly with their eyes closed for 30 seconds. Each participant completed this task five times (per Weber and Smith, 1990). After each reading participants provided a SUDS rating which the researcher wrote down on a rating sheet. The researcher pressed an event "hotkey" on the BIOPAC computer to synchronize the exact time of initiation of the tasks with the collection of GSR, HR and RESP. All reading task occurred outside of a VRE.

Following all speech and non-speech tasks the participants were debriefed and thanked for their participation. Electrodes were removed and thrown away and gel was washed off their hands and ankles. Participants completed the Presence Questionnaire-Revised (PW; Witmer & Singer, 1998), a questionnaire used to rate their level of presence in the virtual environment. Each participant received $5 for participating in the study. A receipt was signed and collected before the participant was escorted out of the room.

Data Collection

Data collection required synchronization of audio data with biophysical data collected by the BIOPAC software during the speaking and reading tasks. After starting audio recording and biophysical data recording, the researchers began each task by ringing a bell while simultaneously pressing an event "hotkey" on the BIOPAC tracings for each task. These hotkeys appeared as small numeric signals on the timeline of data collection to signal when a task was initiated. The BIOPAC software included synchronization and playback functions that allowed coordination of audio data (bell ringing) to these hotkeys pressed when tasks began. Aligning these two data types allowed synchronization of audio playback with accompanying visual tracking of the collected biophysical data along three channels: GSR, HR, and RESP (See figure 4).

For the four minute speech tasks and the silence tasks, the researcher divided the biophysical data recorded by the BIOPAC into 10-second increments to find average GSR, HR and RESP for each 10-second increment. Using the cursors in the ACQ software, the researcher placed one cursor at the beginning of a ten second interval, and one at the end of the 10-second interval. The software then calculated the average GSR (in millimhos; mmhos), heart rate (in beats per minute; BPM) and respiratory rate (in breaths per minute; BPM) for each 10-second interval. The cursors were then moved to the next 10-second interval and the process repeated until reaching the end of the task. Each subject's mean GSR, HR, and RESP rates for each 10-second interval were entered into a Microsoft Excel spreadsheet to be transferred into an SPSS program for later data analysis.

Self-reported measures of anxiety before tasks (self-report questionnaires) and during/after tasks (SUDS ratings) were scored by a trained rater and then entered into a separate Microsoft Excel spreadsheet to be transferred into an SPSS program for later data analysis.

Reliability

SSI-4 scoring

A speech-language pathologist who was not associated with the study independently re-rated 20% of the SSI-4 samples. Point to point percent reliability was 90%.

Data entry

The research team of three lab assistants received specific training in proper methods for accurate data transfer from the BIOPAC tracings to the Excel spreadsheet. The first researcher independently re-rated 37% of the data set for intra-rater reliability. Each lab assistant was assigned to independently re-enter and compare data previously entered for inter-rater reliability. Point to point reliability scores were calculated for each individual biophysical measure (GSR, HR, and RESP). Intra-rater reliability was 465/470 GSR data points (98.9%), 460/470 HR data points (97.9%), and 443/470 RESP data points (94.3%).

Data analysis

Between group comparisons

Multivariate analyses of variance (MANOVA) were used to analyze biophysical and self reported SUDS data using *Statistical Package for the Social Sciences* (SPSS) version 15.0 (SPSS, Inc., 2006). The independent variables were setting (virtual audience vs. virtual empty chairs) and group (AWS vs. AWNS) and the dependent variables were GSR, HR, RESP, and SUDS ratings.

Chapter 3: Results

10 AWS and 10 AWNS participated in 3 tasks while measures of GSR, HR, and RESP were taken. Each participant remained silent for 60 seconds in a live setting (following reading a passage) and in a virtual environment (immersion in a virtual car). Each participant also gave two speeches, one to a virtual room of empty chairs and a room with a virtual audience. Verbal-cognitive measures of anxiety were also recorded before and during one minute intervals of the speech tasks.

Table II

Physiologic measures of anxiety for adults who stutter (AWS) and adults who do not stutter (AWNS)

Measure	Task	AWS	AWNS
GSR			
	READ Silence	6.2 (SD=3.83)	8.28 (SD=3.17)
	VR Silence	6.15 (SD=4.2)	8.2 (SD=3.51)
	VR Empty chairs	7.12 (SD=4.25)	8.8 (SD=3.71)
	VR Audience	7.57 (SD=4.06)	9.17 (SD=3.54)
HR			
	READ Silence	95.51 (SD=11.52)	84.68 (SD=8.11)
	VR Silence	89.76 (SD=13.07)	81.39 (SD=8.39)
	VR Empty chairs	98.21 (SD=14.82)	89.76 (SD=7.42)
	VR Audience	96.18 (SD=12.3)	91.28 (SD=8.79)
RESP			
	READ Silence	14.07 (SD=11.22)	11 (SD=2.02)
	VR Silence	9.82 (SD=2.22)	8.25 (SD=2.91)
	VR Empty chairs	10.4 (SD=1.12)	9.72 (SD=.81)

VR Audience	10.42 (SD=1.21)	10.05 (SD=2.03)

Note. GSR measured in millimhos (mmhos), HR in beats per minute (BPM), and RESP in breaths per minute (BPM)

Table III

Subjective Units of Distress measures taken during speaking tasks

Audience setting	AWS	AWNS
VR Empty chairs		
Post minute 1	20.5 (SD=16.06)*	22.20 (SD=16.72)
Post minute 2	24.17 (SD=12.75)	20 (SD=15.81)
Post minute 3	23.61 (SD=17.55)	16.8 (SD=13.510
Post minute 4	26.94 (SD=16.85)	15.5 (SD=13.63)
VR Audience		
Post minute 1	33.0 (SD=16.87)*	26.5 (SD=17.96)
Post minute 2	33.33 (SD=13.91)	24.50 (SD=19.5)
Post minute 3	30.56 (SD=12.1)	22.75 (SD=17.97)
Post minute 4	28.72 (SD=17.65)	21.0 (SD=13.9)

Note. *Post 1-minute SUDS for AWS based on n=10. Post 2-4 minute SUDS for AWS based on n=9. ALL AWNS SUDS ratings based on n=10.

Question 1: Is there a difference between AWS and AWNS Physiological measures (GSR, HR, RESP) when measured during silence tasks (VR silence vs. READ silence)?

Prior to answering question 1, we ran a repeated measures MANOVA to see if we could combine two, 30-second increments of silence that occurred between two readings of a passage in order to compare with one, 60-second increment of silence in the VR car setting. A significance level of .05 was used for all significance tests. A repeated measures MANOVA comparing silence after the first reading trial and the silence after the second reading trial revealed no significant differences within groups for GSR (F (1, 18) = .916, p = .351), HR (F (1, 18) = .959, p = .340) and RESP (F (1, 18) = .799, p = .383) within these 30-second READ silence increments. This allowed the researchers to combine the first and second 30-second silence periods obtained during the reading task. This 60-second silence during READING was then compared with the 60-second increment of silence in VR to answer research question #1.

Question 1: Is there a difference between AWS and AWNS physiological measures (GSR, HR, RESP) when measured during silence tasks?

A repeated measures MANOVA (between group) revealed no significant difference between AWS and AWNS in GSR (F(1,18)=1.69, p=.21), HR (F(1,18)=4.51, p=.05), or RESP (F(1,18)=1.83, p=.19) during silence tasks. A repeated measures MANOVA (within group) revealed that HR was significantly different (F(1,18)=13.077, p=.002) between read silence and VR silence settings, with HR being higher in the silence before and after the reading task. GSR (F(1,18)=.023, p=.88). and RESP (F(1,18)=2.88, p=.10) were not significantly different between read silence and VR silence settings. A repeated measures MANOVA revealed no significant interaction effects between independent variables of group (AWS vs. AWNS), and setting (VR silence vs. read silence) (F(3,16)=.318, p=.81).

Question 2: Is there a difference between AWS and AWNS physiological measures (GSR, HR, RESP) during the two virtual speaking tasks?

A repeated measures MANOVA revealed no significant main effects for settings (F(3,16)=2.924, p=.066) for any group, or for any measure [GSR (F(1,18)=.891, p=.358), HR (F(1,18)= 1.817, p=.194), or RESP (F(1,18)=1.135, p=.301)]. There was no significant interaction between independent variables (setting or group) (F(3,16)=1.755, p=.196).

Question 3: Is there a difference between AWS and AWNS in verbal-cognitive ratings of anxiety (SUDS) during the two virtual speaking tasks?

A repeated measures MANVOA revealed no significant differences between time (post 1, 2, 3, 4 min) and SUDS ratings ($F(3,51)=2.60$, $p=.062$). Therefore, the researchers used the SUDS rating taken post 1minute of the speaking in front of VR audience and VR empty chairs to answer question 3. A MANOVA (between group) revealed no significant differences between AWS and AWNS in SUDS.

Question4: Is there a within-group difference in verbal-cognitive ratings of anxiety (SUDS) between the two virtual speech tasks (VR empty chairs vs. VR audience)?

A repeated measures MANOVA (within group) revealed significant differences between settings (empty chairs vs. audience) in SUDS; SUDS levels were significantly higher in the audience speech task for both groups ($F(1,18)=11.2$, $p=.004$). This means that participants reported higher levels of speaking-related anxiety in front of a virtual audience compared to speaking-related anxiety while speaking to a virtual room of empty chairs.

Chapter 4: Discussion

The current study examined physiological and cognitive/behavioral measures of anxiety in AWS and AWNS in silence and in two speaking tasks: a virtual room of empty chairs and a virtual audience. Our findings suggest that AWS are not significantly different than AWNS in these measures during speaking tasks, but that both groups of participants self-reported higher anxiety (cognitive/ behavioral measures) when speaking in front of an audience.

Between group findings

The AWS and AWNS showed no significant differences in physiologic measures of anxiety (GSR, HR, RESP) during periods of silence. These findings are similar to other studies examining anxiety in AWS in silence tasks (Bloodstein & Bernstein Ratner, 2008; Evans & Healey, 2010; Peters & Hulstijn, 1984; Weber & Smith, 1990). Additionally, our findings revealed no significant differences in biophysical measures of anxiety between groups of AWS and AWNS in speaking tasks, similar to other studies (Dietrich & Roaman, 2001; Evans & Healey, 2010; Ickes & Pierce, 1973; Peters & Hulstijn, 1984; Weber & Smith, 1990). Our findings disagree with those of Caruso et al. (1994), whose findings indicated AWS showing significantly lower HR measures compared to those of AWNS. These differences may be due to the high premium placed on speed of response required in Caruso et al., study. Lastly, our findings showed no significant difference between AWS and AWNS in verbal-cognitive measures of anxiety (SUDS) during speaking tasks. These findings are similar to those of other studies (Dietrich & Roaman, 2001; Evans & Healey, 2010) and suggest that AWS are not significantly more anxious during speaking than non-stuttering speakers.

Our findings highlight the need for non-stuttering control groups in studies of anxiety and stuttering (Bloodstein & Bernstein Ratner, 2008). These findings also call into question theories that posit anxiety as an underlying cause of stuttering or a necessary precursor to its occurrence, given that AWNS and AWS in our study had similar physiological reactions to speaking tasks Bloodstein & Bernstein Ratner, 2008; Sheehan, 1970).

Within-group findings:

Our findings showed that among all three physiologic measures taken during silence, only HR was significantly different when compared in VR silence and silence in the READ task. This difference showed that both groups had elevated HR outside of the VRE when compared to silence in the VRE. This difference may be due to elevated physiologic arousal in the surrounding speaking task, as has been shown in other studies that recognize elevated levels according to task type, specifically in speaking tasks (Caruso et al., 1994;). In retrospect, it would have been ideal to include a 60-second non-VR silence task to directly compare to our 60-second VR silence task. However, measures of GSR and RESP were not significantly different between VR and live silence periods within groups. Furthermore, data revealed no significant differences in GSR, HR, and RESP between speech settings (VR empty chairs vs. VR audience). Our data suggest that levels of anxiety, as measured by biophysical arousal, within high stress and low stress speaking tasks were not significantly different within AWS or AWNS, similar to other findings in the literature (Evans & Healey, 2010; Peters & Hulstijn, 1984; Weber & Smith, 1990).

When looking at verbal-cognitive ratings of anxiety (SUDS) during speaking tasks, there was no significant within-group difference in SUDS scores from the beginning to end of the four minute speaking tasks. This suggests that within speaking tasks of this duration, verbal-cognitive ratings of anxiety for AWS did not significantly change over the four minutes of speaking time in either VR environment. Our experimental and control groups also did not significantly differ in measures of verbal-cognitive anxiety during/after speaking tasks, similar to findings in other studies of AWS and AWNS in VR environments (Brundage et al., 2007). The finding that AWS show no significant difference in verbal-cognitive reports of anxiety when compared to AWNS disagrees with findings of other studies (Blumgart et al., 2010; Craig, 1990; Craig et al., 2003; Iverach et al., 2009) which may be due to a number of reasons. As stated earlier, comparing findings across studies proves difficult when studies used varying speaking tasks and instruments to measure anxiety. In the case of Blumgart et al. (2010), and Iverach et al. (2009), measurements were taken via self-report surveys and not during speaking tasks, a methodology that tends to over-estimate the presence of psychological disorders (Manning & Beck, 2010). Craig (1990) also collected measures through self-report survey forms as well as state anxiety measures after AWS completed a five minute phone call to a stranger. While this task itself may hold ecological validity, participants selected for the study were all actively seeking treatment at the time, possibly influencing anxiety measures within the sample studied. Our findings agree with other studies using similar verbal-cognitive measurement scales and speaking tasks (Evans & Healey, 2010) that find no significant differences between groups in verbal-cognitive measures of anxiety. Our verbal-cognitive anxiety findings disagree with those of Peters & Hulstijn (1984) who found significantly greater subjective levels of anxiety in AWS. Again, different tasks performed and smaller sample size in the present study may have lead to these incongruent findings. Limitations of the present study include low statistical power possibly due to small sample size, low effect size, and large variance in measures of anxiety.

Our findings show significant differences in SUDS ratings between the two speaking tasks, VR empty chairs vs. VR audience. Self-reported levels of anxiety were higher in AWS and AWNS when they were required to speak in front of a virtual audience. This suggests that the virtual environments were able to induce anxiety, when that anxiety was measured subjectively. Our findings show that when monitoring levels of anxiety in AWS, task type can be a factor in these outcomes. As audience size is known to be an important factor in stuttering behavior (Siegel & Haugen, 1964; Von Krais Porter, 1939) the systematic manipulation of this variable may prove to have clinical value. Engaging the AWS in practice within VR environments may have clinical utility in stuttering treatment because of this element of control.

Weber & Smith (1990), in suggesting directions for future research, hypothesized that even if AWS were to speak in front of a live audience, clear group differences between AWS and AWNS would not emerge in measures of anxiety. Our findings support this hypothesis, since evidence suggests that affective, behavioral, and cognitive components of stuttering occur in similarly in virtual and real environments (Brundage, 2007). Additionally, studies examining the effects of VR manipulation of communication environments and communication partner style suggest not only can VR be used as a tool to engender similar emotions to those experienced in real-world situations, (Brundage et al., 2006), but can affect the amount of observable stuttering behavior itself (Brundage, 2006). Our findings suggest that manipulation of audience size within a realistic speaking task can affect subjective, verbal-cognitive measures of anxiety within AWS and AWNS. This controlled manipulation of anxiety through change in audience size supports the notion of allowing the use of VR as a potential tool in examining and treating speaking disorders that may have a component of anxiety. Future studies comparing multiple measures of objective physiological and subjective behavioral/cognitive anxiety in ecologically valid live and VR public speaking tasks will contribute to our understanding of anxiety in AWS.

In relation to previous studies investigating measures of anxiety in AWS during different tasks, it should be noted that ours is one of few that measures anxiety through multiple objective measures (GSR, HR, and RESP) as well as subjective measures before and during tasks. Our motive was to integrate physiological and verbal-cognitive measures of anxiety in a realistic public speaking task. When comparing studies that attempt to measure anxiety in AWS, it is clear that researchers have not always used speaking tasks (i.e. reading words or answering simple questions to one person) that are reflective of general communication environments of AWS. Per Weber & Smith (1990), we used a mix of low and high stress, speech, non-speech, and silence tasks. Furthermore, our speaking tasks hold an amount of ecological validity that previous studies lack. Our findings agree that AWS do not show significantly different levels of anxiety as measured by physiologic arousal compared to AWNS in an ecologically valid speaking task.

In conclusion, our research focused on examining anxiety in AWS in an ecologically valid speaking task within VR environments. Results suggest that AWS do not show significantly different levels of anxiety as measured by physiologic arousal or verbal-cognitive reports when compared to AWNS. Self-reported anxiety significantly increased when participants were required to speak in front of a virtual audience when compared to a virtual empty room. This suggests that the use of VR may be a potential tool in examining and treating speech disorders that may have a component of anxiety.

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Appendix A

Table A1

Previous studies examining Stuttering and Anxiety

Citation	Subjects	Variables measured	Tasks	Findings
1. Baumgartner & Brutten, 1983	3 male AWS age 18-21	**Physiological:** Average HR HR variance **Verbal-cognitive/ behavioral:** Stuttering expectancy as measured by Behavior Assessment Battery	Participants were asked to read aloud 40 "high risk" stuttering words and 40 "low risk" stuttering words.	Cognitive expectancy of stuttering was predictive of stuttering in 2/3 participants. 1/3 participants showed no relationship between expectancy and stuttering. 2/3 showed no relationship between physiologic measures and expectancy. Results indicate variability from person to person, suggesting pre-stuttering variables to be individualistic.
2. Blood, Blood, Bennett, Simpson& Sussman, 1994	11 male AWS 11AWNS , gender, age, education matched	**Physiological**: Salivary Cortisol levels **Verbal-cognitive/ behavioral:** Personal Report of Communication Apprehension	Questionnaires, videotaped interviews and saliva collection were conducted on 3 separate days: initial baseline day low stress day	No group differences in subjective measures of anxiety (questionnaires). AWS showed significantly higher Cortisol levels than AWNS control group on high-stress task/day.

			high stress day	
3. Blumgart, Tran & Craig, 2010	200 AWS 200 near age AWNS, not controlled for gender	**Physiological:** (none) **Verbal-cognitive/ behavioral:** State-Trait Anxiety Inventory Fear of Negative Evaluation—Long form The Social Phobia and Anxiety Inventory Psychiatric Diagnostic Screening Questionnaire	Participants completed questionnaires. 50 randomly selected participants from each group were screened for generalized anxiety disorders using the Psychiatric Diagnostic Screening Questionnaire	AWS were shown to be significantly more anxious than controls for all anxiety measures. Anxiety lessened with increasing age and no gender differences were shown. Stuttering severity was not found to be significantly associated with increased anxiety. The 50 randomly selected AWS showed significantly greater number of social phobia symptoms than controls.
4. Caruso, Chodzko-Zajko, Bidinger, & Sommers, 1994	9 AWS 9 AWNS	**Physiological:** HR Systolic blood pressure Diastolic blood pressure Stuttering **Verbal-cognitive/**	Stroop color word task Self-paced reading task	More stuttering was shown in tasks with high cognitive stress and speed when compared to self-paced reading tasks. Findings agree that AWS do not have abnormally high levels of autonomic activation. Activation varies according to

		behavioral: (none)		task difficulty (elevated levels for both groups in speaking tasks).
5. Craig, 1990	102 AWS seeking treatment, age & gender matched AWNS	**Physiological:** **Verbal-cognitive/ behavioral:** Speilberger State and Trait Questionnaire	Participants completed questionnaires pre and post therapy. State anxiety measure followed a 5-minute telephone conversation with a stranger.	Pre-treatment, AWS group showed significantly higher levels of state and trait anxiety than control group. AWS group continued to show higher state anxiety than control group post-treatment. Post treatment AWS did not significantly differ from AWNS in trait anxiety.
6. Craig, Hancock, Tran, Craig, 2003	63 AWS 102 AWNS age and gender matched	**Physiological:** (none) **Verbal-cognitive/ behavioral:** State-Trait Anxiety Inventory	Anxiety questionnaire over the telephone.	AWS who had previously sought speech therapy showed significant levels of elevated anxiety compared to controls. AWS who had not sought therapy did not show significant differences in anxiety levels.
7. Dietrich & Roaman, 2001	24 AWS	**Physiological:** GSR **Verbal-cognitive/ behavioral:** Speech-related anxiety	Questionnaire about speech-related anxiety in specific situations Selected tasks reenacted from	The purpose was to correlate individual's predictions of anxiety to physiologic measures. No correlation between predictions and biophysical measures was

		questionnaire (6-point scale)	anxiety survey: Reading aloud Monologue about a first date Speaking on the telephone Discussing personal information while being video taped	found.
8. Evans & Healey, 2010	9 AWS 9 AWNS	**Physiological:** Pulse volume HR **Verbal-cognitive/ behavioral:** Subjective Anxiety Scale after each task	Verbal completion of analogies given multiple choice answers Verbal completion of analogies in front of an audience of 3. letter recall before and after analogy task Completed analogies using single word in a sentence.	physiological and verbal-cognitive anxiety measures were similar for AWS and AWNS on tasks that imposed a linguistic, memory, or social load. As perceived, verbal-cognitive anxiety increased, heart rate decreased. This relationship was not observed for AWNS. AWS showed great variability in autonomic measures
9. Ickes & Pierce,	10 AWS 10	**Physiological:** Digital blood volume	Spoken word task preceded by a	The AWS group showed a significant decrease in blood

1973	matched controls	(vasoconstriction) **Verbal-cognitive/ behavioral:** (none)	30-second approach period and 30-second recovery period. (The word to be spoken was seen by the participant during the approach period)	volume prior to words that were disfluent. No significant difference to control group for words that were fluently spoken
10. Iverach, O'Brian, Jones, Block, Lincoln, Harrison, Hewat, Menzies, Packman & Onslow, 2009	92 AWS seeking treatment for stuttering 920 age gender matched controls from the Australian National Survey of Mental Health and Well-being	**Physiological:** (none) **Verbal-cognitive/ behavioral:** Composite International al Diagnostic Interview State-trait anxiety inventory The Social Evaluation scale New/Strange Situations Scale The Fear of Negative Evaluation Scale Anxiety Problems DSM-Oriented Scale of the ASEBA Adult	Anxiety questionnaires during assessment for stuttering treatment	Purpose: to determine rate of social phobia and other anxiety disorders for AWS seeking therapy. AWS had a 6 to 7-fold increased odds of meeting criteria for a DSM-IV or ICCD-10 anxiety disorder. Stuttering appeared to be associated with a dramatically heightened risk of a range of anxiety disorders.

		Self-Report		
11. Kraaimaat, Vanryckeghem, & Van Dam-Baggen, 2002	89 AWS 131 AWNS	**Physiological:** (none) **Verbal-cognitive/ behavioral:** Inventory of Interpersonal Situations	Participants completed questionnaires.	AWS showed significantly higher measures of emotional tension or discomfort (measures of anxiety in questionnaire). Not all AWS showed significantly higher measures, but results suggest there may be a subgroup of AWS who show elevated social anxiety
12. Messenger, Onslow, Packman & Menzies, 2004	34 AWS 34 AWNS	**Physiological:** (none) **Verbal-cognitive/ behavioral:** Fear of Negative Evaluation Endler Multidimensional Anxiety Scales-Trait	Participants completed questionnaires.	Purpose: to measure social anxiety. AWS had significantly higher anxiety that was restricted to the social domain. AWS showed greater expectation of negative social evaluation when compared to AWNS.
13. Miller & Watson, 1992	52 AWS 52 AWNS age, gender education, ethnicity	**Physiological:** (none) **Verbal-cognitive/ behavioral:** Beck Depression Inventory State-trait Anxiety Inventory	Participants completed questionnaires	No significant differences between groups for depression or anxiety. AWS showed higher scores on s-24 scale, suggesting higher negative attitudes toward communication.

	matched	Erickson Modified 24 Scale		
14. Peters & Hulstijn, 1984	24 AWS 24 AWNS	**Physiological:** GSR Pulse volume HR Stuttering **Verbal-cognitive/ behavioral:** Neuroticism Scale Neurotic Somatic Complaints Scale Amsterdam Biographical Questionnaire Debilitating anxiety scale Facilitating anxiety scale Achievement Motivation Test Subjective 5-point anxiety scale	Mirror writing (motor task) Intelligence test Reading aloud Spontaneous speech (2 minutes, topic chosen by subject)	No significant differences between groups for tasks. Higher arousal shown in speech tasks for both groups. Verbal-cognitive anxiety measures were higher during speech tasks for AWS. AWS did not show a higher trait anxiety than AWNS. AWS showed higher "failure anxiety" in stressful situations than AWNS.
15. Travis, Tuttle, & Cowan,	15 AWS 16 AWNS	**Physiological:** RESP HR	Silence Oral reading	Significantly higher HR during speech when compared to silence for both groups.

1936				Results suggest breathing abnormalities during stuttered speech.
16. Weber & Smith 1990	19 AWS 19 AWNS Age, sex, education matched	**Physiological:** GSR peripheral blood flow/volume HR stuttering **Verbal cognitive/ behavioral:** (none)	jaw movements up and down strenuous breath holding (valsalva) reading spontaneous speech (responses to questions)	No group differences in baseline (silence) condition. Considerable individual variability in both groups. Speech was associated with increase in sympathetic activity for both groups, but no significant group differences in activation. Higher autonomic arousal levels correlated with disfluencies. Occurrence and severity of stuttered utterances correlated with arousal.

Note. Measures above are as follows: Galvanic skin response (GSR), heart rate (HR), and respiration rate (RESP).

Table A2

A between-group view of results from previous research measuring stuttering and anxiety

AWS ≠ AWNS	Reference # on table A1	Task type	Dependent Variable	AWS=AWNS	Reference #
		silence	Subjective anxiety		
			scale	AWS=AWNS	8
			State-trait anxiety	AWS=AWNS	8, 14, 16
			HR	AWS=AWNS	8, 14
			Pulse volume	AWS=AWNS	13,16
			GSR	AWS=AWNS	14, 15
			RESP		
AWS>AWNS	14	Speaking	Subjective anxiety	AWS=AWNS	7, 8
		tasks	scales	AWS=AWNS	8, 14, 16
AWS<AWNS	4		HR	AWS=AWNS	8, 14
AWS>AWNS	15		Pulse volume	AWS=AWNS	14, 13
			GSR	AWS=AWNS	4
			Systolic blood	AWS=AWNS	4
AWS>AWNS	9		pressure		
			Diastolic blood		
			pressure		
AWS>AWNS	15		Digital blood		
			volume		
			RESP		
AWS>AWNS	3, 5	Not related	State anxiety scale	AWS=AWNS	2, 13
AWS>AWNS	3, 6	to speaking	Trait anxiety scale	AWS=AWNS	14, 13
AWS>AWNS	3		Erickson S-24	AWS=AWNS	13

		Beck Depression	AWS=AWNS	13
AWS>AWNS	3	Inventory		
AWS> AWNS	2	FNE		
(high stress)		Social phobia	AWS=AWNS	2
		anxiety scale		
		Salivary Cortisol	AWS=AWNS	2
		Personal Report of	AWS=AWNS	2
		Communication		
		Apprehension		

Note. Measures above are as follows: Galvanic skin response (GSR), heart rate (HR), respiration rate (RESP), and Fear of Negative Evaluation Scale (FNE).

Table A3

Participant characteristics summary

Subject ID	Gender	Age	Race/Ethnicity	Control	Age
AWS 01	M	23	Caucasian	AWNS 12	24
AWS 02	M	24	Caucasian	AWNS 03	24
AWS 03	M	32	Other (Italian/Indian)	AWNS 06	35
AWS 04	M	47	Caucasian	AWNS 08	46
AWS 05	M	28	Latino	AWNS 07	29
AWS 06	M	45	Caucasian	AWNS 09	43
AWS 07	M	51	Caucasian	AWNS 04	54
AWS 08	M	18	African American	AWNS 10	22
AWS 09	M	19	African American	AWNS 05	20
AWS 11	M	21	Caucasian	AWNS 11	24

Note. Abbreviations above as follows: Adults who stutter (AWS), adults who do not stutter (AWNS).

Appendix B

Figure B1

Setup of VR headpiece, electrodes, and respiration belt

Figure B2

Screen shot of BIOPAC graph showing GSR, HR, and RESP