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Heart Rate Variability as a Predictor of Speaking Anxiety

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This study examines the relations among the perception of speaking anxiety and difficulties in emotion regulation with 2 measures of physiological activity: heart rate (HR) and heart rate variability (HRV). Results show significant changes in HR and state anxiety, but not HRV, among the 6 experimental conditions: quiet, reading in both sitting and standing positions, and speaking in both sitting and standing positions. HRV significantly and negatively correlated with difficulties in emotion regulation and HR, but not with public speaking apprehension (PSA) scores or state anxiety ratings. PSA scores, however, were significantly and positively correlated with state anxiety ratings. Results are interpreted in terms of the simultaneous, coordinated operation of physical reactions and emotional coping strategies.

Keywords: Emotion Regulation; Heart Rate; Heart Rate Variability; Public Self-Consciousness; Speaking Anxiety; State Anxiety

Many individuals react to the prospect of communication, such as public speaking or reading aloud, with varying degrees of anxiety and apprehension (collectively, we refer to anxiety in those situations as ‘‘speaking anxiety’’). It is somewhat ironic that

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speakers' own internal physiology can work against their wishes, as they struggle to keep surging emotion under control. Variations in the intensity of the anxiety reaction are at least partially a function of the continuous interaction between internal physiological processes and the speaker's ability to regulate emotion. In this study, we examine the relations among the perception of speaking anxiety and difficulties in emotion regulation with two measures of physiological activity: heart rate (HR) and heart rate variability (HRV).

Emotion regulation can be defined as the cognitive and behavioral processes that influence the occurrence, intensity, duration, and expression of emotion (Campbell-Sills & Barlow, 2007). The ability to regulate emotions is derived from the use of adaptive strategies (Gross & Thompson, 2007) that may decrease the negative cognitive and physiological effects of anxiety (Campbell-Sills & Barlow, 2007). Researchers demonstrated that people attempt to reduce anxiety during a speaking task by using different types of emotion regulation strategies (Egloff, Schmukle, Burns, & Schwerdtfeger, 2006). For example, the ability to interpret and reinterpret cues both internal and external to the body is an adaptive emotion regulation strategy (Egloff et al., 2006). Public speakers can be advised to use this strategy to interpret physiological arousal as facilitating energy driving a good speech rather than a potentially debilitating, fearful reaction to the audience (Rolls, 2007).

In addition to conscious efforts, emotion regulation also occurs at a physiological level with the function of the autonomic nervous system (ANS; Austin, Riniolo, & Porges, 2007). The physical symptoms of speaking anxiety include sweaty palms, gastrointestinal discomfort, trembling, and increases in HR (Witt et al., 2006), all of which are indicative of ANS activation (Croft, Gonsalvez, Gander, Lechem, & Barry, 2004; Friedman & Thayer, 1998). The ANS is comprised of the sympathetic nervous system, which activates the physical anxiety reaction, and the parasympathetic nervous system, which calms the body down. For example, a speaker's HR will tend to accelerate during a speech and return to normal (baseline) as a function of the coordinated effects of both the sympathetic and parasympathetic branches of the ANS (Croft et al., 2004).

Whereas heartbeats might be thought of as quite regular, there actually is a surprising amount of variability between beats. These variations are captured by an index of HRV, which can be differentiated from the more familiar measure of HR. If HR is defined as the number of heartbeats per minute, HRV is the variation in time between heartbeats (Achten & Jeukendrup, 2003). It might be useful to think of HR as an average or mean number of beats over a given time period for an individual person, and HRV the standard deviation around that mean (Berntson et al., 1997). HRV has received increasing attention in recent years as it relates to a growing number of affective reactions, including stress (Li et al., 2009; Utsey & Hook, 2007), depression (Catipovic-Veselica et al., 2007; Udupa et al., 2007), and posttraumatic stress disorder (Blechert, Michael, Grossman, Lajtman, & Wilhelm, 2007; Keary, Hughes, & Palmieri, 2009).

The connection between the brain and the heart is a complex one, as each will influence activity in the other. The two-way communication between the heart and the brain suggests that not only does the heart react to cortical activity, the heart itself may influence the processing of emotion by the brain (Lane et al., 2009). A highly variable heartbeat can adjust to situational changes more readily and, therefore, is considered more adaptive than a less variable heartbeat (Thayer & Lane, 2000).

It is important to note that HRV is based on the hardwiring of the nervous system and is consistent from one situation to another (Berntson et al., 1997). Physiological factors that influence HRV include ANS innervations of the heart's pacemaker—the sinoatrial node (Hainsworth, 1995), as well as changes in respiration (Song & Lehrer, 2003). There tends to be a quickening of HR during inhalation and a slowing during exhalation (Song & Lehrer, 2003), with optimal estimates of HRV obtained under controlled breathing conditions (Pinna et al., 2007). Therefore, if HRV is stable across speaking contexts, the interpretation of HRV as an individual difference measure of ANS activity can supplement other physiological measures of this dynamic system (Thayer & Lane, 2000).

Although HRV may be relatively stable across situations, both HR and the subjective experience of anxiety are responsive to the stressfulness of a given context, and will change with activity (Smith, Sawyer, & Behnke, 2005). For example, when a person sitting as an audience member stands up to give a speech, the maximum HR is likely to be achieved approximately four seconds after moving from a sitting to standing position (Appelhans & Luecken, 2006). In classroom-based public speaking contexts, it would seem that students are likely arriving at the podium at approximately the same time as their HR peaks (Witt et al., 2006). Self-reports indicate that anxious speakers often become aware of their heart "racing" (Rolls, 2007). The enhanced perception of visceral cues may be the result of an increase in self-focused attention, and can be quite distracting to the person (Scheier, Carver, & Gibbons, 1979).

Previous studies have shown that high HRV is related to emotion regulation ability (Appelhans & Luecken, 2006), and that emotion regulation ability is related to lower public speaking anxiety (Egloff et al., 2006). This leads to our first hypothesis:

> *H1: If higher HRV indicates a greater capacity to regulate the emotions experienced during communication, then we would expect it to be negatively correlated with difficulties in emotion regulation, HR, and self-reported anxiety.*

To investigate HRV, HR, and speaking anxiety, we used six laboratory conditions: three tasks (silence, reading aloud, and speaking) in both sitting and standing positions. The three types of communication tasks produce different patterns of respiration, and vocal and mental activity. Silence can be considered a baseline condition. Reading aloud involves a respiration pattern associated with talking, but differs from the speaking condition because the participant is not choosing her or his own words, thereby separating the processes of talking and thinking on one's feet (referred to as message assembly by Greene & Graves, 2007). Each of these activities was performed in the sitting and standing position because moving from sitting to standing is associated with increased muscle tension and increased HR (Witt et al., 2006). Finally, to simulate a public speaking situation, without the experimental complications and unpredictable moment-to-moment reactions of a live audience, speaking aloud was performed in front of a mirror. Both mirrors and audiences are experiences that promote self-focus (Morin, 1997), and previous research has used mirrors to increase anxiety and self-focused attention (Carver & Scheier, 1978). We propose three additional hypotheses:

H2: HR will show a significant increase between sitting and standing, and will be highest in the standing and speaking condition.

H3: Although differences are not expected, HRV will be examined for significant changes across the six speaking contexts as a test of the effect of uncontrolled patterns of respiration on HRV.

H4: State anxiety will increase from sitting to standing, and will be highest in the standing and speaking situation.

Method

Participants

Thirty-three university students were recruited from various courses by making a presentation to the class and asking for volunteers. Seven students received course credits for participation based on the professor's marking scheme, and the rest were volunteers. All participants were informed about the experimental procedures in advance—specifically, that they would be asked to give a speech. Three participants were eliminated from analysis as their speech times ran under two minutes, leaving unreliable HRV data. The remaining sample consisted of 30 participants (13 men and 17 women); all were Caucasian, with a mean age of 22.7 years ($SD = 3.69$) and no self-reported cardiovascular health issues.

Materials

Difficulties in emotion regulation was measured using the Gratz and Roemer (2004) Difficulty in Emotion Regulation Scale ($\alpha = .90$). This 36–item, self-report scale assessed difficulties in the successful regulation of emotion ($M = 139.40$, $SD = 15.90$).

Public speaking apprehension (PSA; $\alpha = .82$) was measured using the six-item subscale from McCroskey's (1982) Personal Report of Communication Apprehension. There were three positive items (e.g., "I have no fear of giving a speech") and three negative items (e.g., "While giving a speech, I get so nervous I forget facts I really know"). High scores indicate high levels of apprehension about public speaking ($M = 22.50$, $SD = 8.40$).

State anxiety ($\alpha = .88$) was assessed using a visual analog scale (MacIntyre & Gardner, 1991) called the Anxometer. Six thermometer-shaped figures were presented on a single page and used to rate state anxiety after each of the six tasks. Anxiety was rated from 0 (*no anxiety*) to 10 (*the most anxiety*) by drawing a line across the thermometer (overall $M = 2.90$, $SD = 1.50$).

On the demographics section of the questionnaire, participants were asked to indicate their age, gender, ethnicity, and approximate height and weight. Participants also were asked to indicate whether their HR may be affected by poor cardiovascular health or any medications they may be taking.

The Polar S810i (Polar Electro Inc., Lake Success, NY) heart rate monitor (HRM) was used to measure individual HR. The HRM is placed around the torso and must be in contact with the skin. The transmitter on the strap detects HR and transmits information to a receiver worn on the wrist. The receiver displays HR and time interval data. All data are transferred from the receiver to the Polar S-series Toolkit software via the Polar Infrared Interface. Errors or anomalies in HR were corrected using the Polar S-series software.

HRV was calculated using statistical time series analysis. The standard deviation of inter-beat (RR) intervals was individually calculated for each task (each a minimum three-minute sample) and as an overall estimate of HRV, which included all six tasks. As a measure of the reliability of HRV that is not confounded with respiration differences during the speaking tasks, the nonparametric Spearman rank order correlation between the sitting and standing in silence conditions was computed ($r = .68$, $p < .001$). The reliability of HRV data tends to improve when the experiment can control for or pace the person's breathing. Although day-to-day intra-individual variation can be high, especially when respiration cannot be controlled (as in our study), "...observed differences between individuals mostly reflect differences in the subjects' true [HRV] value rather than random error" (Pinna et al., 2007, p. 138).

In terms of the *speaking task*, two documents were given to participants to read during the study, and were chosen based on salience to university students. "Increasing Tuition Subsidies is a Regressive Policy" (Gordon, 2007) was an article containing arguments for raising tuition fees in Canada, and "University Tuition Fees" (Statistics Canada, 2006) argued against raising tuition fees.

A *speech template* was given to participants to facilitate speech writing in the brief experimental time frame. The template included six possible arguments for and six against raising tuition fees.

Procedure

All participants were individually tested in a session lasting approximately 45 minutes in total. Participants received instructions on how to wear the HRM, and were sent to a nearby washroom to put it on under their shirts. Instructions were taken from the Polar S810i user's manual (p. A9).

Condition 1 (sitting in silence). Participants returned to the lab and completed the Difficulty in Emotion Regulation Scale, the PSA measure, and the demographic information sheet. HR was recorded during this period to establish a baseline. When the questionnaire was complete, the participant was asked to indicate on the first Anxometer his or her level of state anxiety for sitting in silence experienced during the task. The HRM was then turned off until the beginning of the next condition.

Condition 2 (reading while seated). Participants were asked to remain seated and read aloud the tuition fee article of their choosing for three minutes. After three minutes, the HRM was turned off, and participants were asked to record their level of anxiety on the second Anxometer.

Condition 3 (speaking while seated). When the participant indicated they had completed preparing their notes for the speech, they were instructed to remain seated and deliver their speech to a mirror. The HRM was turned on to record their HR during the speech and was turned off upon completion. At this time, participants recorded their level of anxiety while giving the speech on the third Anxometer.

Condition 4 (standing in silence). A baseline level of HR for standing was taken while the participant stood silently for three minutes. When time had expired, the HRM was turned off, and the person was asked to record their level of anxiety for standing in silence on the fourth Anxometer.

Condition 5 (reading while standing). Participants next were asked to read one of the tuition fee articles out loud, for a second time, for three minutes while standing. During this time, HR was measured. When time expired, the HRM was turned off, and participants were asked to record their level of anxiety for the fifth Anxometer.

Condition 6 (speaking while standing). For the final task, participants were instructed to remain standing and deliver their speech to the mirror. They were able to watch themselves giving the speech. HR was recorded during the speech and, upon its conclusion, the HRM was turned off. Participants then rated their anxiety on the sixth Anxometer.

Debriefing. The HRM was removed, and the participants were thanked for taking part in the study. Each person was provided with an opportunity to ask questions about the study and about their own physiological reactions.

Results

To investigate the relationships among HRV, HR, difficulties in emotion regulation, and anxiety scores, correlations were computed (see *H1*) and evaluated with a two-tailed test of significance ($p < .05$) and 28 *df.* Consistent with *H1*, total HRV significantly and negatively correlated with scores for difficulties in emotion regulation ($r = -.43$) and HR ($r = -.65$). Contrary to *H1*, however, total HRV did not correlate with PSA scores ($r = -.09$) or state anxiety ratings ($r = .13$). It can be noted that PSA scores were significantly and positively correlated with state anxiety ratings ($r = .48$).

To assess the effect of the experimental conditions on physiological reactions, two 2×3 within-subjects analyses of variance (ANOVAs) were conducted separately on the dependent variables HR and HRV data (see *H3*). The independent variables were body position (sitting and standing) and task (silence, reading aloud, and speech). With respect to HR, we predicted a significant increase between sitting and standing, with the highest HR expected in the standing and speaking condition (*H2*). Mauchly's test indicated that sphericity in HR data could be assumed for task (Mauchly's $W = .75$), $\chi^2(2, N = 30) = 7.94$, $p > .01$; and the interaction (Mauchly's

Table 1 Significant Main Effect Means for Body Position

	Heart rate		Heart rate variability	
Variable	*M*	*SD*	*M*	*SD*
Sit	86.29	11.45	0.09	0.03
Stand	93.30	15.39	0.08	0.02
Overall	90.13	13.11	0.10	0.03

$W = .89$), $\chi^2(2, N = 30) = 3.27$, $p > .01$. Body position had a significant main effect on HR, $F(1, 29) = 30.20$, $p < .05$ (partial $\eta^2 = .51$); as did task, $F(2, 58) = 30.60$, $p < .05$ (partial $\eta^2 = .51$). However, no interaction was observed, $F(2, 28) = 0.98$, $p > .05$ (partial $\eta^2 = .03$). Mean HR increased by over 8% (the means and standard deviations are shown in Table 1) from sitting to standing positions. A post hoc analysis was conducted on the main effect of task. Means and standard deviations for task are summarized in Table 2. Post hoc pairwise comparisons of the means of the three tasks were conducted using Tukey's honestly significant difference (HSD) test. Silence produced significantly lower mean HRs than the reading, $q(3, 58) = 6.97$, $p < .05$, and speaking, $q(3, 58) = 6.63$, $p < .05$ tasks, which did not differ between themselves, $q(3, 58) = 0.29$, $p > .05$.

We performed an analysis of HRV data similar to the analysis of HR data. Although no changes across conditions were expected, a 2×3 repeated-measures ANOVA was conducted to test for significant differences (*H3*). With respect to HRV data, Mauchly's test indicated that sphericity could be assumed for task (Mauchly's $W = .90$), $\chi^2(2, N = 30) = 2.81$, $p > .01$, and the interaction (Mauchly's $W = .99$), $\chi^2(2, N = 30) = 0.16$, $p > .01$. As expected, this analysis yielded no significant main effects for task, $F(2, 58) = 0.61$, $p > .05$ (partial $\eta^2 = .02$); nor an interaction, $F(2, 58) = 0.02$, $p > .05$ (partial $\eta^2 = .001$), although it is interesting that the main effect for body position approached significance, $F(1, 29) = 3.49$, $p = .072$ (partial $\eta^2 = .11$). Means and standard deviations are summarized in Table 1.

Self-reported anxiety was expected to increase from sitting to standing and be highest in the standing and speaking situation (*H4*). State anxiety ratings were examined using a 2×3 repeated-measures ANOVA procedure, with the same independent variables as the preceding analysis. No significant main effects were found for body

Table 2 Significant Main Effect Means for Task

	Heart rate		State anxiety ratings	
Variable	*M*	*SD*	*M*	*SD*
Silence	85.46	14.43	2.08	1.22
Reading	91.64	13.33	2.79	1.75
Speech	92.27	12.59	4.09	1.97

position, $F(1, 29) = 1.90$, $p > .05$ (partial $\eta^2 = .031$), or the interaction, $F(2, 58) = 0.56$, $p > .05$ (partial $\eta^2 = .02$). There was, however, a significant main effect for task, $F(2, 58) = 34.07$, $p < .05$ (partial $\eta^2 = .54$). Tukey's HSD test of pairwise comparisons revealed significant increases in mean state anxiety ratings from silence to both reading, $q(3, 58) = 3.99$, $p < .05$, and speech, $q(3, 58) = 11.28$, $p < .05$; and also from reading to speech tasks, $q(3, 58) = 7.23$, $p < .05$. Means and standard deviations are shown in Table 2.

Discussion

We found that HRV was significantly and negatively correlated with difficulties in emotion regulation and HR—that is, as HRV increased, so did the perceived ability to regulate emotion, accompanied by a lower HR during the experimental tasks (see *H1*). This result is consistent with previous research (Appelhans & Luecken, 2006) and suggests that HRV may be a physiologically based facilitator of coping with the potential to affect the emotions people experience. Given that this suggestion is based on correlation, we must allow for the possibility that emotion regulation strategies might affect HRV (see Campbell-Sills & Barlow, 2007). Egloff et al. (2006) showed that cognitive reappraisal strategies can influence the physiological reactions in public speaking anxiety. The significant correlation between HRV and difficulties in emotion regulation also supports the possibility of HRV and emotion regulation being influenced by shared underlying physiological processes.

The difference between the ANOVAs for HRV and HR data is interesting (see *H2* and *H3*). Although HRV was not significantly affected by experimental condition, HR increased from sitting to standing, and from silence to both reading aloud and speaking tasks. When a person begins to speak, airflow through the nose and mouth must change to produce sound (Siegler & Alibali, 2005). Respiration is related to HR and is very sensitive to changes in situations (Song & Lehrer, 2003). Our data suggest that talking, whether it be reading aloud or delivering one's own speech, increases HR to a similar extent. Increased respiration may also explain why there is a difference between HR in silence and the two talking conditions, but not between speaking and reading aloud. This does not, however, account for increased self-reported state anxiety across conditions.

Public speaking anxiety has both physiological and cognitive components (Egloff, Wilhelm, Neubauer, Mauss, & Gross, 2002). We found that people report feeling more anxiety when giving a speech than when reading aloud (see *H4*). This difference does not appear in HRV or in HR measurements. Therefore, there appears to be an effect of the cognitive component of the process that heightens the perception of anxiety above the benchmark set physiologically. Given that HR reaches its peak as speakers stand and walk to the podium, it would be reasonable for a speaker to interpret increased HR as a sign of anxiety arousal, rather than simply a change in body position and muscle tone. If we add the notion of a cognitive script that suggests public speaking is an especially anxiety-provoking event (MacInnis, Mackinnon, & MacIntyre, 2010), we can see a synergy of physiological and cognitive processes

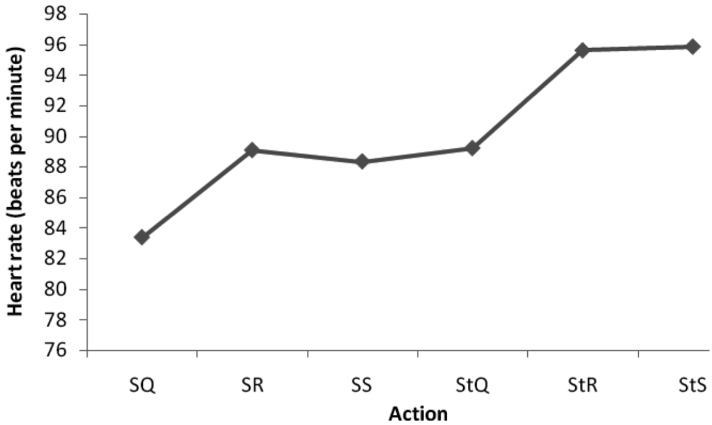

Figure 1 Heart Rate Across Six Experimental Conditions. *Note.* SQ = Sitting Quietly; SR = Reading While Sitting; SS = Speaking While Sitting; StQ = Standing Quietly; StR = Reading While Standing; StS = Speaking While Standing.

that exacerbates speaking anxiety. When a person stands to speak, her or his physiological arousal increases due to muscular activity. However, the feedback from the visceral cues is integrated with a cognitive script, suggesting speaking is a potentially embarrassing situation, heightening the anxiety experience. In future research, it would be interesting to consider the processes associated with perception of audience reactions (e.g., facial expressions) and training in the reappraisal of HR cues that we did not include in this study.

Our results suggest that HR varies across conditions, but we found no clear evidence that HRV differs across the tasks.[1] As shown in Figures 1–3, the HRV pattern did not mirror the HR or state anxiety pattern across conditions. Prior research has considered HRV to be a trait-like facilitator of emotion regulation (Thayer &

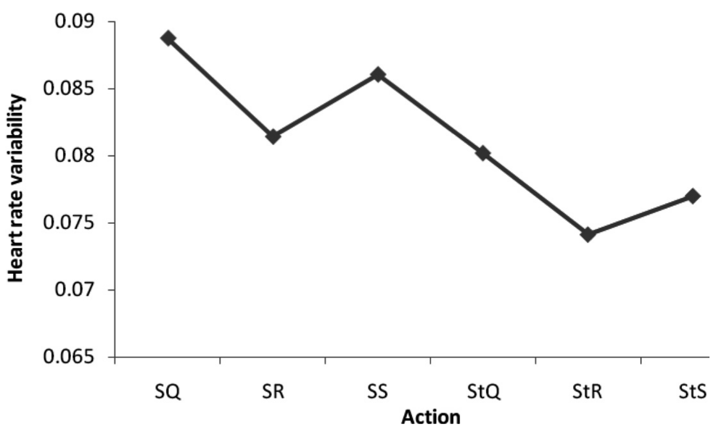

Figure 2 Heart Rate Variability (HRV) Across Six Experimental Conditions. *Note.* SQ = Sitting Quietly; SR = Reading While Sitting; SS = Speaking While Sitting; StQ = Standing Quietly; StR = Reading While Standing; StS = Speaking While Standing.

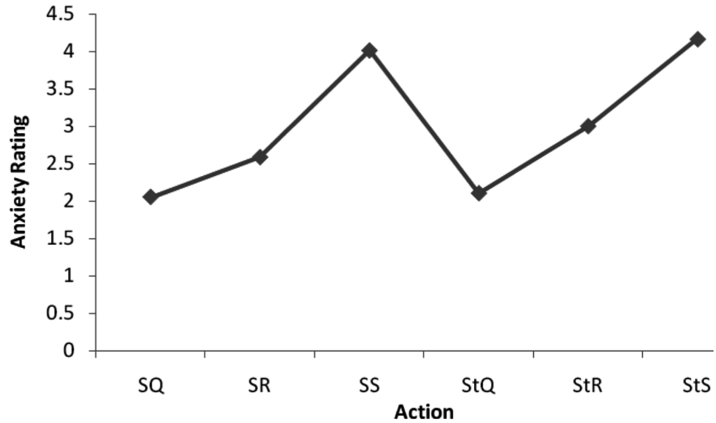

Figure 3 State Anxiety Rating Across Six Experimental Conditions. *Note.* SQ = Sitting Quietly; SR = Reading While Sitting; SS = Speaking While Sitting; StQ = Standing Quietly; StR = Reading While Standing; StS = Speaking While Standing.

Lane, 2000). An individual's capacity for success in emotion regulation may be determined, in part, by the ability of his or her heart to quickly adjust to stressful situations; but, in our data, HRV does not appear to be correlated with either PSA or state anxiety. Future research might be undertaken with spectral analysis of the subcomponents of HRV (see Pinna et al., 2007) to tease apart their relationship to speaking anxiety. Our approach to computing HRV estimates, calculating the standard deviation of the RR interval, is one of several methods for estimating HRV. Pinna et al. noted that the rapidly increasing interest in HRV requires greater attention to the reliability of its measurement.

The limitations of the study include a lack of counterbalancing across conditions; therefore, we cannot rule out the possibility of order effects. If a between-subject design is used in future studies where conditions are ordered differently for groups of participants, the effect of frequent change in body position on respiration and HR data should be taken into account. Future research also might employ experimental contexts that produce higher levels of anxiety and, therefore, require more use of emotion regulation strategies, such as public speaking to a live audience.

In conclusion, the pattern of results obtained in this research is consistent with the notion that hardwired physiological processes, combined with the ability to regulate emotions, shape the experience of public speaking anxiety. If HRV is related to difficulties in emotion regulation, future research also may be able to sort out more specifically how the sympathetic and parasympathetic components of the ANS interact with cognition to affect emotional experience during a variety of speaking tasks.

Note

[1] The main effect of body position approached significance, and it would seem advisable for future research to continue to test for changes in heart rate variability across experimental conditions.

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