Vocal Responses in Heighted States of Arousal

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Summary: Objectives. The purpose of this study was to investigate electroglottography (EGG) contact quotient modulation with emotional state in the presence of increased arousal.

Study Design. A within-subject reversal paradigm using multiple experimental conditions.

Methods. A total of 11 healthy undergraduate students underwent emotion induction with intermittent startles to increase physiologic arousal. During emotion induction, they vocalized on the vowel /u/ while EGG was recorded.

Results. EGG contact quotient was significantly greater for negative emotions compared with positive emotions with increased arousal commensurate with past research. In addition, overall EGG contact quotient was greater with elevated arousal. However, the effect sizes were small.

Conclusions. EGG contact quotient appears to increase with elevated arousal and be greater for negative mood states than positive mood states confirming that emotion states directly influence vocal functioning.

Key Words: Voice–Arousal–Emotion–Electroglottography–Voice Disorders.

INTRODUCTION

Investigations into the nature of certain voice disorders, specifically those with a behavioral etiology, have included the study of personality, particularly temperament (an individual's propensity to respond in a specific manner to emotional stimuli).[1–4] The Trait Theory of Voice Disorders put forth by Roy and Bless[1,2] posits that those with behaviorally acquired voice disorders (eg, vocal fold nodules and functional dysphonia) differ in temperamental traits compared with those with medically acquired voice disorders (eg, unilateral vocal fold paralysis and spasmodic dysphonia) and that these traits may predispose or contribute to the development of their voice disorder.

Numerous follow-up studies have begun experimentally investigating the nature of voice,[3–6] as it relates to temperament, emotion, and stress, and have found promising, albeit tenuous, links between voice use and personal experience/reactions to emotional states. van Mersbergen et al[4] found that those with functional dysphonia presented with less emotionally expressive muscular activity in the muscles of the face, which appeared to reflect previous research that noted that those with functional dysphonia scored high in temperamental constructs of behavioral constraint and negative emotionality/neuroticism. This finding established a link between communicative expressions of emotion via muscles of facial expression and temperament. Unfortunately, in this study, no voice measures could confirm a direct relation between temperament and vocal output.

Dietrich and Verdolini Abbot[5] investigated healthy controls and found a temperamental difference in voicing-related measures of extrinsic laryngeal muscular activity. Those who scored highly in the construct of introversion demonstrated greater infrahyoid muscle activity during a perceived stress inducer, suggesting that temperament may influence vocal expression. However, the link between vocal fold activity and temperament was tacitly measured through extrinsic laryngeal activity. Nonetheless, these findings suggest that temperament is related to vocally expressive behaviors.

To establish a more immediate link between temperament and vocal output, van Mersbergen and Delaney[6] found that in healthy controls, electroglottography (EGG) contact quotient modulated up for negative mood states compared to those in neutral or positive mood states. Establishing a vocal response in emotional states proved a promising tool to begin to study the link between voice and temperament. However, effect sizes were small, which lead to the question whether the mood induction employed was strong enough. Although not entirely necessary, having a measure with greater effect sizes between conditions may facilitate greater success in this line of research. Elevating the arousal level of the stimuli may create a greater distinction in EGG contact quotient between moods, particularly for negative moods.

One way to increase the arousal level during a task is to introduce a noxious distractor, such as an acoustic startle. Noise is well known to influence arousal levels in individuals and affect performance,[7] potentially elevating the base level of arousal during a task. Acoustic startles have been used extensively in emotion research[7–10] and have been thought to underlie a negative, avoidance neural system.[11] Although noise (that is, acoustic startles) is considered negative, it does not dominate current mood states such that neutral or positive states are overshadowed.[11] An introduction of an acoustic startle may prove an expeditious method to increase arousal without erasing the relationships between negative, neutral, and positive emotions.

Purpose and hypothesis

The purpose of this study was to investigate EGG contact quotient modulation with emotional state in the presence of increased arousal. Mood induction via picture viewing of scenes with emotional content served as the trigger for emotional modulation. An acoustic startle (white noise presentation of 50 milliseconds at 102 dB with an instantaneous rise time) was randomly presented during 37% of trials to elevate the participant's arousal state. Based on past research, negative mood states should have elevated EGG contact quotient compared with neutral states and positive states. Increased arousal should influence the degree and

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separation of EGG contact quotient in negative mood states compared with other conditions.

METHODS

Experimental design

The experimental design was within-subject reversal paradigm using multiple experimental conditions (negative, neutral, and positive mood induction with and without startle) where experimental stimuli were counterbalanced within and between subjects to avoid order effects. All participants were exposed to all stimuli. The study was approved by the Internal Review Board at Northern Illinois University.

Participants

Participants included eight female and three male students of Northern Illinois University ranging in age from 18 to 26 years with an average age of 23.4 years. Recruitment for this population came from class announcements where they received course credit for participation. The inclusion criteria for this group were the absence of any current chronic vocal difficulties or a history of a chronic voice disorder such as vocal fold nodules, unilateral vocal fold paralysis, or functional dysphonia as determined through a nonidentifying score on the Voice Handicap Questionnaire,[12] an informal self-report questionnaire, and an auditory perceptual rating by the primary author who is a certified speech language pathologist specializing in voice disorders. In addition, they did not currently experience upper respiratory infections or psychological ailments such as depression, generalized anxiety disorder, or any other personality disorder as determined through an informal self-report questionnaire.

Measures

Independent measures

Stimuli. Mood induction through picture viewing from the International Affective Pictures System[13] included 60 different slides of negative, neutral, and positive content or valence (20 each). Picture stimuli were matched on ratings of valence (pleasantness vs. unpleasantness) and arousal (calm vs. exciting). Negative, neutral, and positive pictures were significantly different from one another in valence ratings (t tests; positive vs. negative, $P < 0.001$; positive vs. neutral, $P < 0.001$; negative vs. neutral, $P < 0.001$). The neutral pictures differed in arousal compared with those in two other picture conditions (t test, $P < 0.001$), but there were no arousal differences between the positive and negative pictures. There was a total of 8 blocks of pictures with 24 pictures per block. Each block contained 8 negative, 8 neutral, and 8 positive pictures in a quasirandomized order such that no block contains more than 3 of the same valence in a row to avoid habituation effects. The pictures were presented multiple times. In addition, 37% of the trials included an acoustic startle (50 milliseconds at 102 dB white noise instantaneous rise time)[8] occurring at either 1000 milliseconds , 1500 milliseconds, or 2500 milliseconds postpicture presentation. The varying time points were designed to avoid habituation effects.[11,14] Each valence type had an equal number of acoustic startles in each block and at each time point. Startles were quasirandomized within each block and trial run. The presence and timing of these startle trials were meant to increase overall arousal during the experiment. Because startle trials provided a means to increase arousal during the entire experimental run, vocal data from the startle trials were not independently analyzed.

Dependent measures

Manipulation variables

Self-report measures verified mood induction during the experimental procedures and included the Self-Assessment Manikin (SAM) rating protocol of affective valence (pleasantness vs. unpleasantness) and arousal (calm vs. exciting) along a 9-point Likert-type scale.[15] Perceived vocal effort, using a modified Borg CR-10 (Borg) scale[16] provided subjective experience of vocal effort, which was an anchor for the other voice measure.

Voicing-related variables

EGG, which measures vocal fold contact area,[17,18] was the primary measure of interest. Previous research found that EGG contact quotient varies with emotional valence via mood induction[6] and therefore is thought to also vary in the presence of increased arousal.

Procedures

After the participants consented to the procedures, EGG electrodes (Glottal Enterprises) were placed on the laminar edges of their thyroid cartilages and in-the-ear headphones (Sony MDR-EX57LP) were placed binaurally. Next, they underwent instructions in experimental procedures where they were instructed to look at a fixation point on the computer screen (ApexX233H) to prepare for an upcoming picture (500 milliseconds before presentation). They were instructed to say the vowel /u/ for 3–4 seconds once the picture appeared, which was the duration of the picture presentation. They were informed that some of the pictures would have a loud noise and that they are to ignore this noise as it is not important. After the picture disappeared, they were instructed to fill out a brief mood inventory to verify their perceived vocal effort and current mood and arousal; the Borg, SAM-V, and SAM-A, respectively. Following completion of the self-report measures, the next trial began with the fixation point. Stimuli were delivered via *E-Prime software* (v. 2.0, Psychology Software Tools, Inc.) running on a Dell (Optiplex 755). Self-report ratings were also generated and recorded through *E-Prime*. Participants viewed 8 blocks of 24 pictures for a total of 192 picture presentations. After all pictures were presented, EGG electrodes and headphones were removed, and the participants were thanked for participating. The total experiment took approximately 60 minutes, 30 minutes of which was the experimental paradigm.

Instrumentation and data reduction

EGG data were acquired using dual-channel electrodes, digitized with an EG2-PCX2 (Glottal Enterprises) and recorded onto *Audacity* (1.3 beta). EGG signals were analyzed by *EggWorks*

(UCLA Phonetics Lab Software) using the Closed Quotient cutoff percentages put forth by Baken and Orlikoff.[17,18]

Analysis

Hypotheses were tested using repeated-measures analysis of variance (ANOVA) (*SPSS*, IBM v21) with condition assignment (mood: negative, neutral, and positive) as the independent variable. Variables for SAM-V, SAM-A, Borg with and without startle, and EGG without startle were included in the analysis. Additional analysis included a two-way repeated-measures ANOVA with condition assignment (mood: negative, neutral, and positive) X trial type (startle: without startle and with startle) for the SAM-v, SAM-A, and Borg to compare subjective differences between the startle and no startle trials for the self-report measures. Because of the anticipated disruption to the respiratory and phonatory system as a result of the acoustic startle (eg, breath-holding and sudden jumps in fundamental frequency during startle responses),[14] EGG for startle trials were not included in the analysis as the data would be uninterpretable. As is typical in this line of research, *post hoc* testing was performed using pairwise comparisons between conditions and *t* tests to further clarify the relationship between individual valences. All *post hoc* tests were corrected to guard against α-error.

RESULTS

Manipulation variables

To confirm appropriate mood induction for all *non-startle* trials, a one-way ANOVA verified the valence (SAM-V) and arousal (SAM-A) evoked by negative, neutral, and positive moods. A one-way ANOVA confirmed subjective vocal effort/experience (Borg) during mood induction for all *non-startle* trials. In addition to the trials without startle, a one-way repeated ANOVA with condition assignment (mood: negative, neutral, and positive) was done on SAM-V, SAM-A, and Borg measures for all the conditions that included an acoustic startle to assess if the acoustic startle significantly changed the nature of the self-report responses. If self-report for trials *with* acoustic startle did not follow expected modulation, then there would be no indication that the acoustic startle was indeed producing an arousal effect for participants. Further, to verify that the acoustic startle did not significantly affect the overall direction or shape of the responses, a two-way repeated-measures ANOVA with condition assignment (mood: negative, neutral, and positive) X trial type (startle: no startle, startle) for the SAM-V, SAM-A, and Borg was completed. Finally, to confirm that startle trials were indeed more arousing and affected participants in the expected direction (reduced overall pleasantness ratings, increased arousal, and increased perceived vocal effort), *post hoc t* tests were completed between startle and nonstartle trials for each condition.

For valence ratings (SAM-V) in *non-startle* conditions, results show significant differences in valence ratings (SAM-V) between images, $F(2, 861) = 1182.49$, $P < 0.001$. Pairwise comparisons revealed that the positive images (3.26, SD 0.99) were rated more positively than the neutral images (4.57, SD 0.89), which were rated more pleasant than the negative images (7.49, SD 1.11), $P < 0.01$. The main effect for valence ratings *with* startle revealed significant differences between conditions $F(2, 1090) = 12.820$, $P = 0.002$. Pairwise comparisons revealed that the positive images (3.41, SD 0.99) were rated more positively than the neutral images (4.68, SD 0.96), which were rated more pleasant than the negative images (9.23, SD 1.17), $P < 0.01$. The interaction between valence and startle, as expected, was not significant $F(2, 160) = 0.483$, $P = 0.634$. *Post hoc t* tests revealed that participants rated all conditions as less pleasant (SAM-V) for the startle condition compared to the non-startle condition; *t* tests: aversive $P < 0.001$, neutral $P < 0.001$, and positive $P < 0.001$ (Figure 1).

For arousal ratings (SAM-A) for *non-startle* conditions, negative, neutral, and positive images were significantly different from one another in arousal ratings, $F(2, 1371) = 250.71$, $P < 0.01$. Pairwise comparisons showed that negative images (4.46, SD 1.57) and positive images (3.24, SD 1.48) were significantly more arousing than neutral images (2.96, SD 1.39), $P = 0.045$. The main effects for arousal ratings (SAM-A) *with*

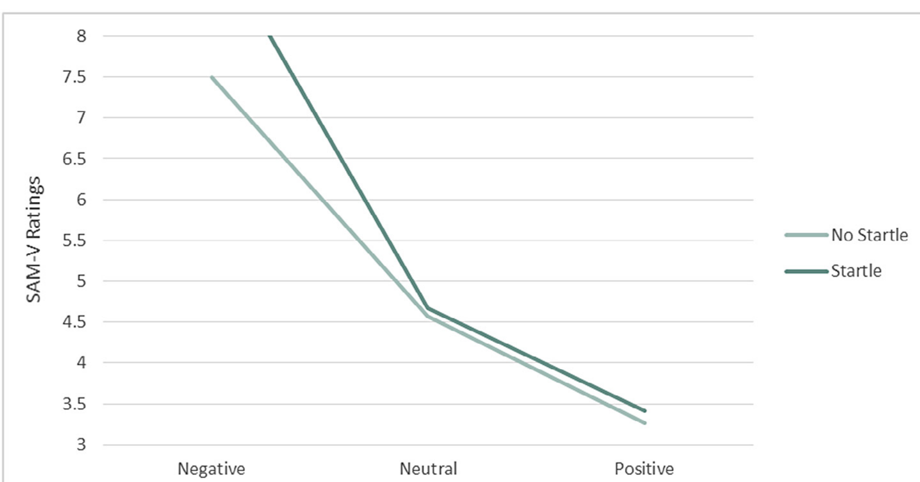

FIGURE 1. Positive images were rated significantly more positively than the neutral images, which were rated significantly more pleasant than the negative images for both trials with and without acoustic startles. Although overall, trials with acoustic startles were rated significantly less positive for all conditions.

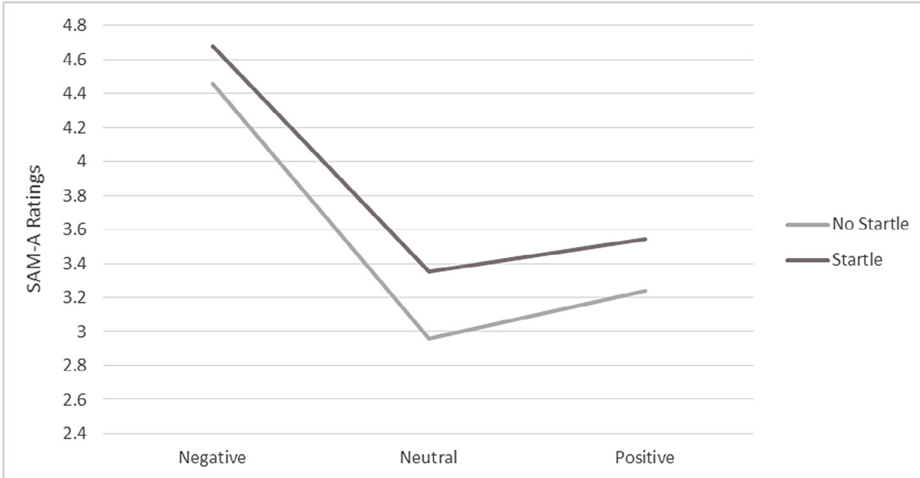

FIGURE 2. Negative and positive images were rated as significantly more arousing than neutral images for both trials with and without acoustic startles. Acoustic startle trials were rated significantly more arousing for all conditions.

startle revealed no significant differences between conditions $F(2, 1482) = 0.616$, $P = 0.562$. However, pairwise comparisons showed that negative images (4.67, SD 1.59) and positive images (3.54, SD 1.42) were significantly more arousing than neutral images (3.35, SD 1.58), $P = 0.045$. The interaction between arousal and startle, as expected, was not significant $F(2, 160) = 1.350$, $P = 0.313$. Participants rated all conditions as more arousing (SAM-A) for the startle condition compared to the non-startle condition; *t* tests: aversive $P = 0.004$, neutral $P < 0.001$, and positive $P < 0.001$ (Figure 2).

A one-way ANOVA confirmed subjective vocal effort/experience (Borg) during mood induction for all *non-startle* trials. Results revealed significant differences in perceived vocal effort during mood induction, $F(2, 59.014) = 15.15$, $P = 0.004$. Pairwise comparisons showed that perceived vocal effort during negative images (1.712, SD 0.416) was greater than during neutral images (1.165, SD 0.331) and positive images (1.153, SD 0.336) $P = 0.04$. Positive and neutral images did not differ, $P = 0.216$. The main effect for perceived vocal effort *with* startle revealed significant differences between conditions $F(2, 104) = 7.394$, $P = 0.013$. Pairwise comparisons showed that perceived vocal effort during negative mood (2.46, SD 1.52) was greater than during neutral images (1.41, SD 1.07) and positive images (1.47, SD 1.093) $P = 0.04$. Neutral and positive images did not differ $P = 0.314$. The interaction between perceived vocal effort and startle, as expected, was not significant $F(2, 160) = 1.928$, $P = 0.201$. Participants perceived increased perceived vocal effort (Borg) during the startle condition compared with the non-startle condition; *t* tests: aversive $P = 0.002$, neutral $P = 0.007$, and positive $P = 0.006$ (Figure 3).

Variable of interest

To test the main question of whether vocal fold contact modulates in the expected direction (negative > neutral > positive) under conditions of increased arousal, vocal fold contact quotient during phonation while under mood induction for *non-startle* trials, a

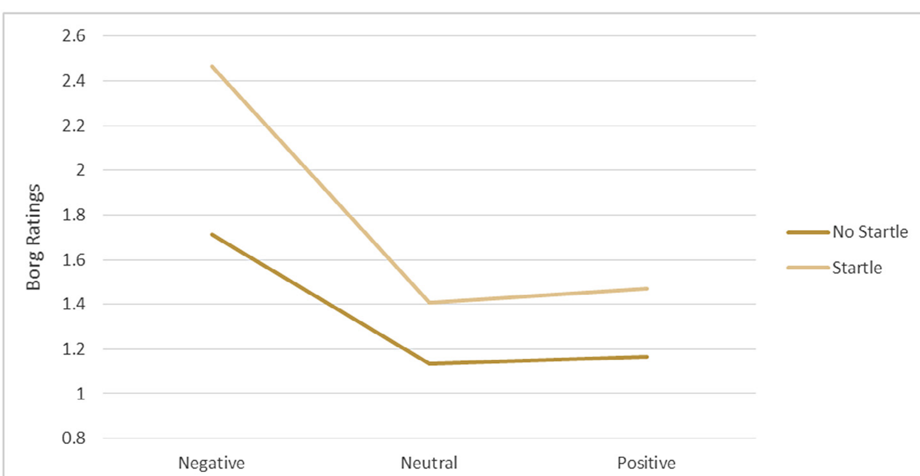

FIGURE 3. Negative images were rated as having significantly greater vocal effort than the neutral images, which were rated more effortful than the positive images for both trials with and without acoustic startles. Although overall, trials with acoustic startles were rated as having significantly more effort for all conditions.

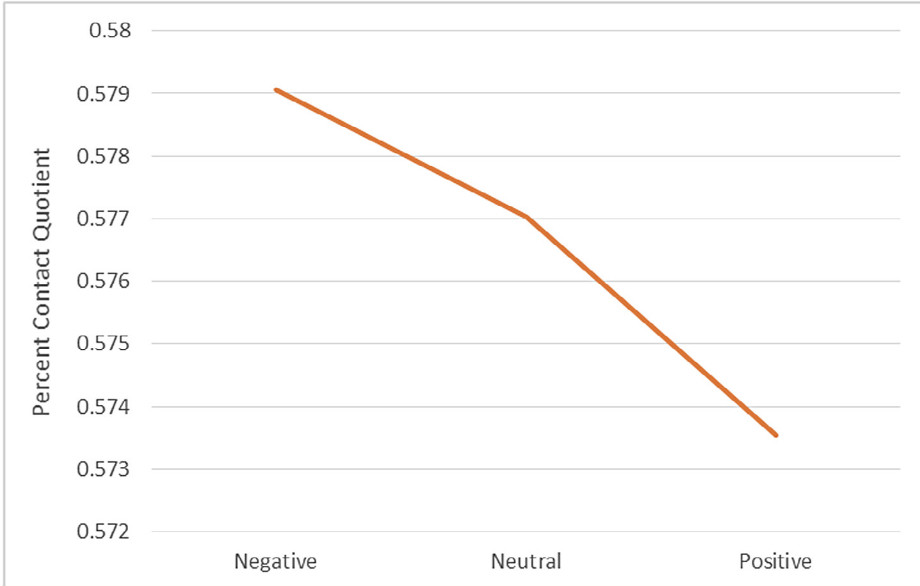

FIGURE 4. Vocal fold contact is significantly greater when individuals are in a negative emotional state compared with that when they are in a neutral or positive emotional state.

one-way ANOVA was performed. Results showed that vocal fold contact quotient significantly differed during mood induction $F(2, 10.969) = 854$, $P < 0.001$. Pairwise comparisons showed that vocal fold contact quotient during negative mood (0.579, SD 0.019) was greater than during neutral moods (0.577, SD 0.021) although not significantly, $P = 0.549$. Positive moods (0.574, SD 0.020) were significantly less than negative moods, $P = 0.006$, but not neutral, $P = 0.268$ (Figure 4).

DISCUSSION

The purpose of this study was to determine whether EGG contact quotient modulated with emotional state in the presence of increased arousal. To this end, individuals underwent mood induction via picture viewing with 37% of trials including a noxious acoustic startle designed to elevate the participant's arousal state. For trials without startles, self-report and EGG contact quotient modulated in the expected direction, based on past research;[6] that is, EGG contact quotient was greater in negative conditions. The ratings for valence confirmed that negative, neutral, and positive pictures were indeed rated as such. In addition, ratings for arousal were increased for emotional pictures (negative and positive) but not for neutral pictures. Finally, perception of vocal effort was increased for negative conditions and reduced for neutral pictures as observed in past research.[4,6] The results from the self-report data verified that the acoustic startle did indeed increase arousal states in participants. Based on the assurance that the emotional and arousal manipulations were present, it appears that the EGG contact quotient continues to modulate in emotion states. EGG contact quotient is significantly greater in negative emotion states than positive. EGG contact quotient was greater in negative states than in neutral states, but not significantly.

Furthermore, compared with past research,[6] elevated arousal appears to increase overall EGG contact quotient. van Mersbergen and Delaney[6] found that EGG contact quotient modulated between 0.505% and 0.515% (0.505% for neutral, 0.506% for positive, and 0.515% for negative), whereas in this study, the modulation was between 0.574% and 0.579% (0.574% for positive, 0.577% for neutral, and 0.579% for negative). In addition, elevated arousal changed the statistical separation of each condition. In the previous study, there was statistical separation between the negative compared with the neutral and positive, but no difference between neutral and positive. This study found that elevated arousal lowered positive ratings significantly but only compared with the negative condition. So, elevated arousal appears to increase overall EGG contact quotients and to separate the positive condition (less contact), whereas baseline arousal appears to have overall lower EGG contact quotients and to separate the negative condition (greater contact).

This difference could indicate that increased arousal, which can be experienced as more negative (as indicated by the self-report measures), might increase EGG contact quotient overall, leading to a relative change in the relationship between negative, neutral, and positive moods. This change might be due to a ceiling affect where all conditions are increased, but the positive condition, because it is lower, remains significantly different. The evidence for this can be found in the smaller range between conditions for the arousal study (0.005%) compared with the previous study (0.01%).

The largest concern in this line of research is the minute changes in EGG contact quotient observed. A change of 0.005% contact quotient can hardly be considered clinically meaningful. Indeed, it might be difficult to infer the physiological underpinnings for a change, given the miniscule nature of this modulation. However, there are a few comments about these small changes. First, emotional influences on voice production are significant and detectible, even if they are small. This could suggest that either emotional states have minor effects on voice output or that other motor systems responsible for vocal output might interfere with emotional effects to mitigate any perturbations in voice output.[17,18] Auditory and other sensory feedback mechanisms might override initial phonatory changes to maintain steadier, more predictable phonation.[19]

Second, despite the small changes observed laryngeally, acoustic output as a result of these small changes can be larger, resulting in an overall greater influence on phonation. This study did not include acoustic output measures and, therefore, future research should incorporate such measures to verify the magnitude of acoustic changes during emotional states. In fact, much of the research investigating emotional influences on voice production use acoustic measures.[20] Auditory perceptual judgments might also amplify the small physiological effects observed in this study. The large body of literature on auditory perceptual ratings and effort might complement this line of research.[21] So, combining acoustic measures and auditory perceptual ratings with the cadre of measures that track physiological changes in voice production appears necessary for the continued validation of this line of research.

Third, slight changes in EGG vocal fold contact area might be meaningful when factoring overall vocal load. For individuals who might have large vocal loads,[22] this could indicate that increased arousal or negative emotion states could tip the scales from a recoverable vocal load to one that is not recoverable. So, sustained negative emotions or increased arousal during vocal communication might increase the risk for individuals with high vocal demands or increased communication drives.

Finally, as in other lines of psychophysiological research, where clinically oriented physiological measures are usurped by psychologists to link the body with the brain, these modest changes in EEG contact quotient appear reasonable and even promising. For example, the measure of heart rate is used to assess cardiac functioning such that increased heart rate can identify cardiac malfunction.[23] However, in psychophysiology, increased heart rate can represent orienting responses to stimuli, *albeit* orienting increases in heart rate are quantifiably far less than what would be meaningful in cardiac function.[14] Although the measure is the same, the values and implications for this measure have different meanings depending on the intended use. Nonetheless, because of its dual use, we have developed a strong appreciation for the link between our cardiac fitness and our psychological activities. In the same way, employing EGG contact quotient as a psychophysiological measure, instead of a clinical voice measure, can allow us to link our psychological states with our vocal output and serve to bridge the gap in understanding between our emotions and our voices.

Future directions

This investigation revealed that EGG contact quotient modulates not only under conditions of emotional valence but also under conditions of increased arousal. Because increased arousal can be observed in conditions of increased stress, illness, and physiological demands, it is important to appreciate these factors and how they affect vocal output. Future research in this area should include acoustic measures, other physiological measures of phonation, and more ecologically valid emotion induction paradigms to fully understand how emotion and arousal influence our communication. In addition, assessing vocal patterns across the span of the research, comparing initial vocalizations in the study to final vocalizations, might elucidate additional questions about emotional influence in voicing. Finally, measures of brain activity, electroencephalography, or magnetoencephalography could be useful in determining the relative influence of emotion on overall motor vocal output to begin addressing if there are individual differences in emotional/vocal processing that could predispose individuals to voice disorders or interfere with vocal recovery.

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