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Unresolved Anger and Sadness: Identifying Vocal Acoustical Correlates

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The authors conducted 2 studies to identify the vocal acoustical correlates of unresolved anger and sadness among women reporting unresolved anger toward an attachment figure. In Study 1, participants ($N = 17$) were induced to experience and express anger then sadness or sadness then anger. In Study 2, a 2nd group of participants ($N = 22$) underwent a relationship-oriented, emotion-focused analogue therapy session. Results from both studies showed that, relative to emotionally neutral speech, anger evoked an increase in articulation rate and in mean fundamental frequency (F0) and F0-range, whereas sadness evoked an increase in F0-perturbation. Both F0 and F0-range were larger for anger than for sadness. In addition, results from the mood-induction-procedure study revealed 2 Emotion × Order interactions. Whereas variations in amplitude range suggested that anger evoked less physiological activation when induced after sadness, variations in F0-perturbation suggested that sadness evoked more physiological activation when induced after anger. These findings illustrate the feasibility of using acoustical measures to identify clients' personally and clinically meaningful emotional experiences, and shifts between such emotional experiences, in the context of psychotherapy.

Keywords: anger, sadness, acoustical analysis, psychotherapy, attachment

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Clients often present for therapy with lingering anger toward a significant other (e.g., parent, former romantic partner, or close friend). Such anger typically forms when one feels as though one's self and/or dignity has been intentionally undermined (Lazarus, 1991). For example, unresolved anger may develop when individuals feel as if a significant other has consciously betrayed, rejected, or disregarded them. The angry person blames the perceived perpetrator for causing her/his distress and seeks retribution and/or avoids contact with the offender (Del Barrio, Aluja, & Spielberger, 2004; Lazarus, 1991). Unresolved anger can persist for months or even years and destroy the fabric of one's most prized relationships.

One way to understand unresolved anger is as a defensive response. Criticism, rejection, or betrayal at the hands of a significant other (i.e., attachment figure) leads to feelings of loss, sadness, shame, and worthlessness. When such feelings become intolerable, one coping strategy is to shift attention away from the self and onto the other. By focusing on the perpetrator's deficits (e.g., selfishness, insensitivity), the narcissistically injured individual diminishes the importance and, therefore, the negative impact of the perpetrator's actions. In addition, criticizing, attacking, or otherwise punishing the offender are all assertive behaviors that can restore a sense of control and self-esteem (Greenberg, 2002; Greenberg & Safran, 1987, 1989). Because it can be effective in any or all of these ways, defensive anger is, in the short term, functional and reinforced.

Ironically, although defensive anger serves a protective function in the short term, in the long term, it potentially leads to further rejection and/or emotional distancing. When people feel constantly criticized or blamed, they tend to withdraw, leaving the angry person with reduced social support (Coyne, 1976). Also, when people avoid accessing and fully experiencing the primary vulnerable emotions thought to fuel their anger, they are deprived of essential information required to accurately adapt their representations of themselves and others and identify and act upon unmet attachment needs, leaving themselves psychologically, emotionally, and interpersonally stuck (Greenberg & Malcolm, 2002; Paivio & Greenberg, 1995). For example, identifying that one is sad or hurt can serve as an important signal that it is time to reach out for support, comfort, or protection. Furthermore, displaying sadness or vulnerability increases the likelihood that friends, partners, or family members will become more empathic and supportive (Diamond & Stern, 2003; Johnson, 1996; Johnson & Greenberg, 1992). In some instances, the explicit expression of hurt can even lead the perceived offender to acknowledge their hurtful behavior and ask for forgiveness and/or make amends.

It is worth noting that in the same way that anger can represent a secondary, defensive response to sadness, so can sadness serve as a secondary, defensive response to anger. For some individuals, anger is a particularly threatening emotion. They may have been raised in homes in which they were taught that expressing anger is hurtful and destructive. As a result, they may attempt to suppress

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or avoid expressing their anger, particularly toward significant others, even in situations in which anger would be the natural, appropriate response. In some instances, these individuals may redirect their anger toward themselves in an attempt to preserve the integrity of the relationship. Unfortunately, suppressing one's experience and expression of anger, or directing it inward, can lead to self-criticism, self-denial, and a sense of helplessness and loss. In fact, some have suggested that this very mechanism lies at the heart of depression (Alexander & French, 1948; Freud, 1917). Indeed, findings show that depressed people have higher rates of suppressed anger (i.e., anger-in) and lower rates of anger expression (i.e., anger-out) than do nondepressed people (Brody, Haaga, Kirk, & Solomon, 1999). For such individuals, sadness may take the place of, or mask, underlying primary anger. Avoiding anger diminishes the likelihood that individuals will exhibit assertive, self-protective behaviors (i.e., set interpersonal limits) when appropriate.

A number of emotion-focused, experiential, and attachment-based therapies emphasize accessing and processing interrupted or avoided primary emotions (Diamond, Reis, Diamond, Siqueland, & Isaacs, 2002; Elliott, Watson, Goldman, & Greenberg, 2004; Johnson & Greenberg, 1992). For example, in attachment-based family therapy (Diamond et al., 2002) for depressed and suicidal adolescents—many of whom bear unresolved anger associated with past trauma and family conflict—the therapist systematically works to help adolescents not only express their anger in a regulated manner but also access and express previously suppressed or unarticulated fear and feelings of loss and sadness associated with ruptures in the adolescent–parent relationship. Likewise, in emotion-focused therapy, therapists help clients who are organized by or "stuck in" secondary, reactive anger to access and express primary, adaptive, attachment-related vulnerable emotions, such as fear of rejection and need for love and care (Greenberg, 2002; Greenberg & Johnson, 1988). Indeed, research on process-experiential therapy has shown that clients who displayed more intense emotions and explicitly expressed need (e.g., attachment-related feelings of sadness and loss) during therapy were more successful in resolving lingering negative feelings toward a significant other (Greenberg & Foerster, 1996; Greenberg & Malcolm, 2002). However, more research is required to better understand the role of clients' in-session experience of unresolved anger and sadness, and shifts between these emotions, in the change process.

Measuring in-session emotions presents a number of methodological challenges. Repeatedly stopping a therapy session to have clients report on their emotional experience would interfere with the therapy process. Although it is possible to ask clients at the end of a given session how they felt during the session, such responses reflect a global, average estimate across the session and are prone to memory biases. Some researchers have used videotaped aided procedures whereby clients watch their own session after its completion and retrospectively report on their emotional experience during the session (Elliott, 1986; Kagan, 1980). Others have used independent, objective coders to rate clients' affective states (Gottman, 2001). However, the observation and coding of videotaped sessions is labor intensive and costly. Furthermore, it is unclear how accurately observers, even if the observer is the client her/himself, can retrospectively identify the moment of onset, intensity, or subtle transformation of emotional experiences over the course of a therapy session.

In a previous study, Rochman and Diamond (2008) examined the feasibility of using continuous measures of physiological functioning (e.g., finger temperature, skin conductance, heart-rate variability) to unobtrusively and objectively quantify unresolved anger and sadness. Using a mood-induction procedure similar to the process of psychotherapy, the authors found that sympathetic activation, as reflected by finger temperature, increased significantly from anger to sadness, suggesting that unresolved anger may be a response to, and prime individuals to experience, associated vulnerable emotions. However, none of the measures examined differentiated between anger and sadness. The ability to distinguish between clients' experience of sadness versus anger is necessary to explore which therapist interventions or in-session processes are associated with the elicitation and eventual working through of each of these emotions.

One potentially useful yet unexplored method for measuring clients' in-session experience of unresolved anger and sadness entails examining their vocal acoustical characteristics. The possibility of examining the patient's voice during therapy has been entertained in a series of previous studies (e.g., Mohr, Shoham-Salomon, Engle, & Beutler, 1991; Wiseman & Rice, 1989). However, these studies examined *perceptual* attributes of the patient's voice based on listeners' judgment. In contrast, more recent research on emotions and voice has focused on the *acoustical* properties of the voice signal, in an attempt to identify more accurate and objective measures (Scherer, Johnstone, & Klasmeyer, 2003). Acoustic parameters commonly studied include (a) mean fundamental frequency (mF0), which represents the rate of vibration of the vocal folds during phonation and speech and is subjectively perceived as the speaker's *pitch*; (b) F0-range, which represents the dynamic range of the fundamental frequency within a speech segment and is perceived as the patient's *pitch range*; and (c) amplitude-range, which represents the range of intensity levels within the speech segment and is perceived as *loudness variability*.

Relative to emotionally neutral speech, expressions of anger have been associated with increased values of mF0 (subjectively perceived as pitch), F0-range (subjectively perceived as pitch range) and amplitude-range (subjectively perceived as loudness variability), whereas sadness has been associated with decreases in those same parameters (Scherer et al., 2003). Other acoustic parameters have also been shown to be sensitive to the vocal expressions of anger and/or sadness. For instance, measures of amplitude-perturbation and F0-perturbation (which may be represented by shimmer and jitter, respectively, or by amplitude-perturbation quotient [APQ] and pitch-perturbation quotient [PPQ], respectively) have both been reported to increase during the vocal expression of anger (Scherer et al., 2003). F0-perturbation has also been found to increase during expressions of sadness (Juslin & Laukka, 2001). In addition, measures of speaking/articulation rate have been found to decrease for sadness and to increase for anger, relative to emotionally neutral speech (Scherer & Banse, 1991), although such findings have not been consistent (see Whiteside, 1999). These results are most likely attributable to the fact that anger increases tension or neurological control over the muscles affecting the lungs and vocal folds, whereas sadness decreases tension or neurological control over the same muscles, muscles responsible for producing voice signals (Titze, 2000). For a more detailed description of these acoustical measures, as well as an introductory explanation of how they are obtained, please see the Supplemental Materials.

Although prior studies have shown that anger can be distinguished from sadness on a number of acoustical parameters, it remains unclear to what degree these findings can be generalized to the psychotherapy process. Past research has used methods to elicit anger and sadness that, on one hand, were highly standardized but that, on the other hand, had questionable ecological validity. For example, much of the research to date has been based on actors voicing prescripted, generic sentences meant to mimic the expression of specific emotions. However, personally meaningful events, of the type typically addressed in therapy sessions, may evoke higher levels of sympathetic activation (Rimm-Kaufman & Kagan, 1996), potentially leading to relatively higher values of mF0, F0-range, and amplitude-range. Furthermore, in response to potentially higher levels of sympathetic activation during therapy sessions, clients may try harder to regulate their emotional experiences (Butler et al., 2003; Butler & Gross, 2004). Such regulatory attempts may actually *reduce* between-emotion differences in parameters such as mF0, F0-range, and amplitude-range (i.e., voice dynamic parameters, typically regarded as prosody), which are most noticeable to the human ear, and *increase* between-emotion differences in control-sensitive parameters, such as F0-perturbation (i.e., voice quality parameters), which are less noticeable to the human ear. In sum, research is needed to explore the acoustic profiles of anger and sadness as they manifest in a context more similar to psychotherapy.

The two studies presented below employed two different yet complementary methodological approaches to examine the association between voice quality and production and emotions in a context similar to psychotherapy. In Study 1, participants suffering from unresolved anger toward an attachment figure underwent a mood-induction procedure to elicit their unresolved anger and associated sadness. In Study 2, a second, independent sample of participants suffering from unresolved anger toward an attachment figure participated in a relationship-oriented, emotion-focused analogue therapy session designed to alleviate such anger. Moments of anger and sadness expression were identified, and voice quality and production measures were analyzed.

Study 1

Participants suffering from unresolved anger toward a significant other (i.e., attachment figure) underwent a mood-induction procedure with features similar to those characterizing the process and content of psychotherapy. More specifically, participants were induced to experience and talk to an interviewer about their painful, personally meaningful emotions (i.e., their unresolved anger and associated sadness) regarding a significant other. Independent coders then identified those segments of the mood-induction procedure evidencing the most intense expressions of unresolved anger and sadness. We then analyzed these segments to quantify their acoustical properties. On the basis of previous findings, we expected mF0, F0-range, amplitude-range, and articulation rate to increase for anger and decrease for sadness, relative to baseline, emotionally neutral speech. We also expected F0-perturbation levels to increase for both anger and sadness and amplitude-perturbation levels to increase for only anger, relative to baseline, emotionally neutral speech. Along the same lines, we expected articulation rate, amplitude-range, F0-range, mF0, and APQ to be larger for anger than for sadness.

Methods

Participants

The final sample included 17 female university students who participated in the study in return for research credit. All participants reported persistent feelings of unresolved anger (i.e., duration of at least 6 months) toward a significant other (e.g., parent, sibling, past or present romantic partner, or close friend). Participants were included only if they reported that such feelings of unresolved anger were intense enough to interfere with their daily lives and were readily aroused whenever they talked or thought about the significant other. They ranged in age from 22 to 24 years ($M = 22.82$, $SD = 0.88$).

Procedure

Recruitment. Signs were posted in a university and two surrounding colleges in the southern region of Israel. The signs read, “We are looking for people with persistent feelings of anger toward a significant person in their lives. In order to participate, your anger must be intense, aroused when you think or talk about the other person, and be bothersome to you.”

When potential participants called, we used a short phone screen to ensure that they met all inclusion criteria. Two respondents were excluded because their anger was not directed toward a significant other.

Twenty-six eligible participants were invited to the laboratory and asked to sign a consent form explaining the study’s procedures. As part of the consent procedure, participants were told that they would be asked to think and talk about their unresolved anger and sadness and that their voice would be recorded.

Mood-induction procedure. Each individual participant was led into a 2.5-m × 2.5-m room, seated, and fitted with a headset attached to a fixed microphone. Following the activation of the digital recording software, the investigator (Daniel Rochman), who was seated across from the participant throughout the session, initiated the mood-induction procedure.

The mood-induction procedure consisted of four stages and was similar to that used in a previous study examining physiological functioning and emotions (Rochman & Diamond, 2008). Stage 1 (baseline) was designed to help participants overcome their natural anxiety associated with the experimental environment. The investigator engaged the participant in a conversation about ordinary, day-to-day topics (e.g., preferred activities, family, school curriculum). This part of the procedure was designed to obtain a recording of participants’ baseline vocal characteristics (i.e., vocal acoustical properties of emotionally neutral speech). The baseline stage was approximately 4 min in duration.

Stage 2 (anger-inducing procedure) began with the investigator saying, “I would like you to recall an interpersonal, anger-evoking experience that occurred with respect to the person with whom you are angry. This could be a single event, or a string of events, which made you angry. As you remember this event or series of events, allow yourself to feel similarly to how you felt in those moments.”

Participants were allotted approximately 5 min to talk about their angry feelings. During this time, the investigator used prompts such as "tell me how you felt" to help the participant focus on the anger-inducing aspects of the experience. At the end of the mood induction, the participant was asked to rate the intensity of her anger on a scale of 1 to 10, with 1 = *the lowest intensity* and 10 = *the highest intensity*.

Stage 3 (baseline) was designed to help participants disengage from their angry mood state and return to their baseline functioning. To this end, the investigator asked the participant to "Think about something else that does *not* make you feel angry." The investigator then waited for 1 or 2 min before asking questions about ordinary, day-to-day topics similar to those discussed during Stage 1. Once the investigator judged, on the basis of the participant's speech, facial expression, behavior, and body posture, that she had stopped experiencing anger, he asked her directly whether she was no longer feeling angry. Extra time was provided, if necessary, for the participant to disengage from her anger. This stage ended when the participant reported that the anger had subsided.

Stage 4 (sadness-inducing stage) began with the investigator saying,

> I would like you now to recall an interpersonal experience, with *the same significant person you talked about before* (i.e., during the anger-inducing stage), that made you feel sad. This could be a single event, or a string of events, that made you feel sad, lonely or hurt. As you remember this event or events, allow yourself to feel similarly to the way you felt in those moments. I want you to take your time, and nod your head when you feel you have connected emotionally to the sadness.

Once the participant indicated that she was experiencing sadness, the investigator asked her to talk about the sad experience. More specifically, the investigator said, "Please tell me what happened, and try to remain connected to your sadness." Participants were allotted approximately 5 min to describe the event(s). During this time, the investigator used prompts, such as "Tell me how you felt," to help the participant focus on the sad aspects of the experience. At the end of the mood induction, the participant was asked to rate the intensity of her sadness on a scale of 1 to 10, with 1 = *the lowest intensity* and 10 = *the highest intensity*.

At the end of the procedure, the investigator initiated a conversation about emotionally neutral, ordinary, day-to-day subject matter to help the participant disengage from her sadness. The order of the mood inductions was counterbalanced, such that half of the participants were randomly assigned to a condition in which anger was induced first and the other half to a condition in which they were induced to experience sadness first.

Recording voice signals and acoustical analysis. Participants' voice signals were recorded using a Sennheiser PC150 headset microphone (High Wycombe, United Kingdom). The fixed microphone was positioned approximately 5 cm from the corner of the participant's mouth and connected directly to a portable IBM computer. To record speech samples, we used the GoldWave program (Version 5.12, GoldWave, Inc., 2005) set at a sampling rate of 48 kHz (16 bit), mono channel. Acoustical analyses were performed using Praat software (Version 4.1.2, Boersma & Weenink, 2003) and the Multidimensional Voice Program (Model 5105, Version 2.1, KayPENTAX, 2007). Additional information regarding the measurement procedures can be found in the Supplemental Materials.

Identifying valid cases. During the mood-induction procedure, the investigator noted which participants appeared to engage in the task and which ones did not. His observations were based on participants' general demeanor, body posture, and facial and vocal cues. Eight participants were excluded from further analyses because they were judged as not having sufficiently engaged in at least one of the two emotion inductions, leaving a total of 18 valid participants.

Locating voice segments reflecting anger and sadness. Two independent coders listened to the recorded files from the 18 remaining participants to identify the exact location of segments reflecting anger and sadness. The coders were bachelor's-level psychology students. Their task was to listen to the entire mood-induction procedure and identify a 30-s segment reflecting unresolved anger and a separate 30-s segment reflecting sadness. The 30-s criterion was necessary to ensure that each segment chosen contained at least five valid utterances for analysis (for further details, see the *Determining the unit of analysis* section below). One of the coders, the primary coder, was familiar with the concept of unresolved anger and sadness and had, in the past, been shown videotaped exemplars of the expression of both emotions. The second coder had no previous exposure to the concept of unresolved anger, nor had she previously seen videotaped examples of such anger and sadness. However, prior research has shown that naïve raters can reliably and validly code emotion expressions from videotaped interactions (Waldinger, Shultz, Hauser, & Allen, 2004) and from voice recordings (Banse & Scherer, 1996).

One additional participant was excluded from the final sample because neither coder could identify a sufficiently long segment of anger expression. Therefore, the final sample included 17 participants, 9 of whom had been assigned to the anger-first condition and 8 of whom had been assigned to the sadness-first condition of the mood-induction procedure.

The primary coder also extracted a 30-s segment from the last 2 min of the initial baseline condition (i.e., Stage 1) for each participant. This segment was chosen to reflect emotionally neutral speech. The segment was chosen from the last 2 min of the initial baseline stage because, by the end of the initial baseline stage, participants had assumedly become more familiar and comfortable with the experimental setting and procedure and therefore would be experiencing less anxiety.

Results

Preliminary Analyses

Coder agreement. Between-coder agreement was calculated as the percentage of time upon which both coders agreed regarding the location of anger or sadness. For example, if the primary coder chose a 30-s segment deemed to reflect anger and the second coder chose a segment that overlapped with the first coder's segment for a duration of 15 s, then the rate of agreement would be 50%. Using this procedure, the two raters evidenced absolute agreement 70% of the time regarding when anger was expressed and 60% of the time regarding when sadness was expressed. When coders disagreed, the primary coder's ratings were considered valid.

Self-reported intensity of emotions. On average, participants reported experiencing both anger and sadness at relatively high levels of intensity during the mood-induction procedure. The mean score for anger was 7.44 (SD = 1.47) and for sadness was 7.65 (SD = 1.66). To examine whether there were differences in subjectively reported intensity according to type of emotion (i.e., sadness and anger) or order of induction (i.e., either sadness-first or anger-first), we conducted a two-way mixed model analysis of variance (ANOVA), using order of induction as a between-subjects independent variable and type of emotion as a within-subjects variable. Participants' ratings of their emotional intensity for each emotion during the anger and sadness mood inductions served as the dependent variable. No main effects for emotion or for order were found. Likewise, the Emotion × Order interaction was not significant.

Determining the unit of analysis and data reduction. Prior to performing the acoustical analyses, we divided the 30-s segments identified by the coders into utterances. For this purpose, an utterance was defined as a string of words that (a) communicates an idea, (b) is bounded by a simple intonation contour, (c) is grammatically acceptable, (d) contains at least three consecutive words or five syllables, and (e) includes no dysfluency or pauses longer than 250 ms (Hall, Amir, & Yairi, 1999). The first five utterances that adhered to these criteria within each 30-s segment (i.e., baseline, anger, and sadness) were selected for the computerized acoustical analysis. Thus, a total of 255 utterances were submitted for analysis (17 participants × 3 segments [i.e., baseline, anger, sadness] × 5 utterances).

Acoustical parameters related to prosody were measured using Praat software. Articulation rate was calculated by dividing the number of words contained in the utterance by its temporal duration. The number of words was determined by auditory inspection. Duration was determined by locating the beginning and the end of the utterance, which required visual and auditory inspection of its spectrogram and time-wave display. Articulation rates were expressed in words per minute (WPM). To calculate F0-range (i.e., highest minus lowest F0 value in the voice signal) and amplitude-range (highest minus lowest amplitude value in the voice signal), we used Praat software to locate the highest and lowest F0 and amplitude values within the utterance. We used the Multidimensional Voice Program to measure two acoustical properties associated with the perception of voice quality: F0-perturbation and amplitude-perturbation. More specifically, we measured (a) PPQ (i.e., F0-perturbation calculated as the amount of cycle-to-cycle F0 instability with a smoothing factor of five vocal cycles) and (b) APQ (i.e., amplitude-perturbation calculated as the amount of cycle-to-cycle amplitude instability with a smoothing factor of 11 vocal cycles). These two measures were selected for this study because their smoothing factor better suits the examination of perturbation in continuous speech, as opposed to jitter and shimmer, which are more appropriate for the study of perturbation in sustained phonation of isolated vowels. Further explanation regarding these acoustic measures and how they are calculated appear in the Supplemental Materials. Data reduction was performed by calculating the mean value for each acoustic measure on the basis of the five utterances produced by an individual participant within each specific condition.

Main Analyses

Table 1 presents mean values and standard deviations obtained for each measure according to emotion. Table 2 presents the intercorrelations among the six dependent measures. MF0 was positively correlated with F0-range and amplitude-range, and negatively correlated with PPQ and APQ. APQ and PPQ were positively correlated, as were PPQ and amplitude-range. None of the acoustical parameters were significantly correlated with self-report of emotional intensity.

To examine whether any of the dependent measures (i.e., WPM, mF0, F0-range and amplitude-range, PPQ and APQ) varied according to type of emotion (i.e., baseline, anger, and sadness), order of induction (anger-first, sadness-first), or the interaction between these two variables, we conducted six mixed-model 2 × 3 repeated-measures ANOVAs. For each ANOVA, type of emotion served as the repeated-measure independent variable, order of emotion served as a second independent variable, and one of the voice parameters served as the dependent measure. It is worth mentioning that we did not conduct an omnibus multivariate ANOVA for two reasons. First, the number of dependent variables (six) almost equaled the number of participants in the smallest cell (8). Second, although no two dependent variables were linearly dependent, mF0, F0-range, and PPQ were not completely independent.

All six ANOVAs yielded a significant main effect of emotion. To probe the source of these effects, we conducted post hoc Tukey's honestly significant difference (HSD) tests, with p = .05, comparing the mean scores for baseline, anger, and sadness. We conducted post hoc Tukey's HSD tests instead of planned comparisons because our hypotheses required comparing all three sets of means, rather than the two orthogonal comparisons permitted when conducting planned comparisons. We compared all three means because we were interested in examining both whether each of the emotions (anger and sadness) differed from baseline and whether they differed from each other.

Four of the six measures (WPM, mF0, F0-range, and amplitude-range) increased significantly from baseline to anger. Such increases were consistent with our hypotheses. In contrast with our expectations, however, the two remaining measures (PPQ and APQ) did not increase from baseline to anger. One of the six measures (PPQ) showed a significant increase from baseline to sadness. Such an increase was consistent with our hypotheses. However, in contrast with our hypotheses, WPM, mF0, F0-range, and amplitude-range did not increase with sadness. We had no hypothesis regarding how APQ might respond to sadness, and indeed, there was no significant increase or decrease in relation to baseline.

Four of the six measures (mF0, F0-range, amplitude-range, and APQ) evidenced higher mean scores during anger than during sadness. These findings were consistent with our hypotheses based on prior research. However, in contrast with our expectation that PPQ levels would be similar for sadness and anger, we found PPQ levels to be higher for sadness than for anger. Also, in contrast with our hypothesis that WPM would be lower for sadness than for anger, we found no such between-emotion differences. No main effect for order was found. The F and partial eta-square values for main effects and interaction are presented in Table 3. Post hoc comparisons for baseline, anger, and sadness mean scores are presented in Table 1.

Two of the six ANOVAs, those examining amplitude-range and PPQ, yielded significant Emotion × Order interactions (see Table 3). To probe the Emotion × Order interaction for amplitude-range, we examined the simple main effect of emotion for each order of

Table 1
Summary of Results for Study 1

Measure	Baseline (B) *M*	Baseline (B) *SD*	Anger (A) *M*	Anger (A) *SD*	Sadness (S) *M*	Sadness (S) *SD*	Significant changes
WPM							
Anger-first	195.82	18.54	230.90	19.70	212.04	21.82	B < A
Sadness-first	189.85	27.26	202.61	30.00	208.90	15.07	
Total	193.01	22.50	217.59	28.28	210.57	18.44	
mF0							
Anger-first	186.89	34.66	206.94	37.02	177.90	36.75	B < A, S < A
Sadness-first	199.75	20.27	231.57	33.99	199.21	29.01	
Total	192.94	28.71	218.53	36.76	187.93	33.78	
F0-range							
Anger-first	107.49	28.17	138.50	42.61	122.70	44.29	B < A, S < A
Sadness-first	116.06	27.46	160.21	41.87	113.25	21.43	
Total	111.52	27.32	148.72	42.42	112.96	34.37	
Amplitude-range							
Anger-first	23.76	6.67	29.51	6.30	22.42	5.53	B < A, S < A
Sadness-first	23.12	1.56	24.03	2.63	22.12	2.98	
Total	23.50	4.84	26.93	5.60	22.30	4.40	
PPQ							
Anger-first	2.19	0.47	1.96	0.49	2.93	0.54	B < S, A < S
Sadness-first	1.83	0.25	2.01	0.44	2.32	0.45	
Total	2.02	0.42	1.98	0.45	2.64	0.58	
APQ							
Anger-first	14.62	3.29	13.59	2.92	15.50	2.51	S < A
Sadness-first	13.12	2.96	12.10	2.65	13.65	2.88	
Total	13.91	3.14	12.89	2.81	14.63	2.77	

Note. WPM = words per minute; mF0 = mean fundamental frequency; F0-range = fundamental frequency range; PPQ = pitch-perturbation quotient; APQ = amplitude-perturbation quotient. $N = 17$. In the anger-first condition, $n = 9$. In the sadness-first condition, $n = 8$. mF0 and F0-range are expressed in hertz, and amplitude-range is expressed in normalized decibels.

induction. In the sadness-first order of induction, the simple main effect for emotion was not significant. On the other hand, in the anger-first order of induction, a significant simple main effect for emotion, $F(2, 16) = 11.86$, $p < .001$, $\eta_p^2 = .60$ was found. Consequently, we conducted Tukey's HSD tests, with $p = .05$, to compare baseline, anger, and sadness mean scores. Results indicated that, in the anger-first condition, amplitude-range values were significantly larger during anger than during sadness and baseline. Amplitude-range values were not significantly different for sadness than for baseline. Results for amplitude-range are represented in Figure 1.

To probe the Emotion × Order interaction for PPQ, we first examined the simple main effect of emotion for each order of induction. Because both simple main effects were significant, $F(2, 16) = 15.10$, $p < .001$, $\eta_p^2 = .65$, and $F(2, 14) = 9.52$, $p < .01$, $\eta_p^2 = .58$, for anger-first and sadness-first, respectively, we compared PPQ change scores from baseline to sadness in the anger-first order of induction with those in the sadness-first order of induction and compared PPQ change scores from anger to sadness in the anger-first order of induction with those in the sadness-first order of induction. Results showed that PPQ change scores from baseline to sadness in the anger-first were not significantly differ-

Table 2
Intercorrelations Among Acoustical Parameters for Study 1

Measure	1	2	3	4	5	6
1. WPM	—					
2. mF0	.10	—				
3. F0-range	.31*	.70***	—			
4. Amp.-range	.10	.40**	.16	—		
5. PPQ	.05	−.42**	−.15	−.33*	—	
6. APQ	.04	−.67***	−.26	−.23	.53***	—

Note. WPM = words per minute; mF0 = mean fundamental frequency; F0-range = fundamental frequency range; amp.-range = amplitude-range; PPQ = pitch-perturbation quotient; APQ = amplitude-perturbation quotient. $N = 17$.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3
Main Effects and Interactions Found in Study 1

	Effect					
	Order		Emotion		Emotion × Order	
Measure	$F(1, 15)$	η_p^2	$F(2, 30)$	η_p^2	$F(2, 30)$	η_p^2
WPM	3.02	.17	6.04**	.29	1.86	.11
mF0	2.04	.12	11.65***	.44	0.39	.03
F0-range	0.60	.04	9.77***	.39	0.61	.04
Amplitude-range	1.05	.07	13.22***	.47	5.08*	.25
PPQ	2.99	.17	20.99***	.58	4.53*	.23
APQ	1.96	.12	3.23*	.18	0.05	.00

Note. WPM = words per minute; mF0 = mean fundamental frequency; F0-range = fundamental frequency range; PPQ = pitch-perturbation quotient; APQ = amplitude-perturbation quotient. Note that each variable is expressed in different units of measurement (i.e., mF0 and F0-range are expressed in hertz, and amplitude-range is expressed in normalized decibels). $N = 22$.
* $p < .05$. ** $p < .01$. *** $p < .001$.

ent from those in the sadness-first order of induction. However, PPQ change scores from anger to sadness were significantly larger in the anger-first than in the sadness-first order of induction, $F(1, 15) = 8.88$, $p < .01$, $\eta_p^2 = .37$. Results for PPQ are summarized in Figure 2.

The results of this mood-induction study suggest that certain vocal acoustical parameters can distinguish between anger, sadness and emotionally neutral speech in the context of a mood-induction procedure that, on many dimensions, was similar to the process of psychotherapy. The results also show that voice parameters may be used to identify clinically important shifts in clients' emotional experiences, such as the shift from unresolved anger to sadness. This finding replicates a similar finding from previous research examining physiological responses (i.e., finger temperature) to unresolved anger and sadness using the same mood-induction procedure and with the same population. In light of these promising results, we decided to conduct a second study in an effort to replicate these findings under less controlled conditions that even more closely approximated the actual process of psychotherapy.

Study 2

Participants presenting with unresolved anger underwent a single, analogue session of relationship-oriented, emotion-focused, experiential therapy. The session, composed of a sequence of interventions derived from attachment-based family therapy (e.g., Diamond & Siqueland, 1998) and process-experiential therapy (e.g., Elliott et al., 2004), was designed to first elicit unresolved anger and then facilitate the accessing and expression of associated vulnerable emotions (i.e., sadness, loneliness) thought to be fused with and/or underlie and maintain such anger. Participants' vocal acoustical profiles associated with moments of anger and sadness elicited during such sessions were analyzed. This study explored the same hypotheses explored in Study 1.

Method

Participants

Participants were 22 individuals who underwent a single, analogue, relationship-oriented, emotion-focused, experiential therapy

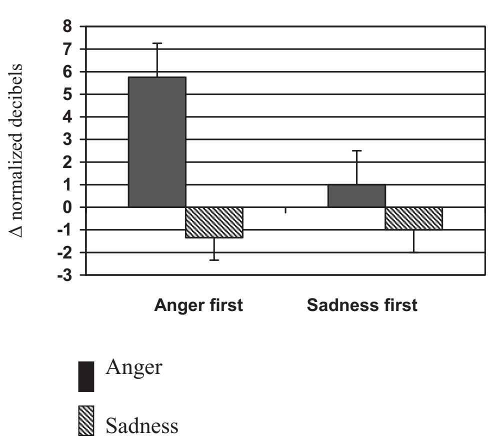

Figure 1. Mean change scores from baseline level for amplitude-range (in normalized decibels +*SE*) according to emotion and order.

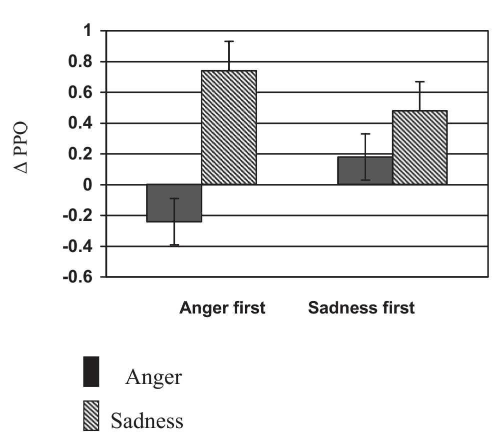

Figure 2. Mean change scores from baseline level for pitch-perturbation quotient (PPQ; +*SE*) according to emotion and order.

session for unresolved anger. These participants were drawn from a larger group of 71 participants who underwent such analogue sessions in the context of a larger study of psychotherapy process (for further details, see the *Sampling Procedure* section below). Participants were recruited in the same manner, met the same inclusion and exclusion criteria and bore the same demographic characteristics as participants in Study 1. All were female university students between 21 and 25 years of age ($M = 23.50$, $SD = 2.70$) and received research credit in return for their time.

Four female clinical psychologists conducted the interviews. They ranged in age from 26 to 34 years and each had 2 to 4 years of clinical training. They were taught the interview procedure (i.e., sequence of interventions) by Gary M. Diamond, who is one of the codevelopers of attachment-based family therapy. Gary M. Diamond also provided live videotape supervision of the sessions to ensure adherence and competence.

Instruments

Recording voice signals and acoustical analysis. Equipment used to record voice signals and the software used for acoustical analyses were the same as in Study 1.

Observational coding of emotions. Participants' expressions of anger and sadness over the course of the session were measured using the Specific Affect Coding System (SPAFF; Gottman, McCoy, Coan, & Collier, 1996). The SPAFF is an observational instrument that captures expressions of anger and sadness (among other emotions) on the basis of a gestalt that integrates not only facial and vocal cues but also content and cultural cues. The SPAFF is based on a "cultural rather than physical features perspective" (Shapiro & Gottman, 2004, p. 194). In prior research, observers were able to obtain good interrater reliability, with kappa coefficients of .79 (Waldinger et al., 2004). In this study, SPAFF ratings were performed by a female, 26-year-old, master's-level clinical psychologist who had completed 10 hr of computer-based training in the instrument. At the end of the training, the rater reached 90% accuracy on the computerized SPAFF reliability check.

Procedure

Analogue session. Each individual participant was led by a research assistant into a room similar to that described in Study 1. Once the participant signed a consent form explaining the nature of the analogue session, she was seated and fitted with a headset with a fixed microphone attached. The interviewer, who was seated across from the participant throughout the interview, then initiated the baseline stage of the procedure. The purpose of this stage was to obtain a baseline reading of the participant's vocal acoustical characteristics during emotionally neutral conditions. During the baseline stage, the interviewer engaged the participant in a conversation about ordinary, day-to-day topics, asking the participant questions about where she lived, what she liked to do, how many brothers and sisters she had, and so forth. The baseline stage lasted for approximately 5 min.

After the baseline stage, the interviewer initiated the relationship-oriented, emotion-focused, analogue therapy session. The session consisted of three interventions designed to first evoke the participant's experience and expression of unresolved anger toward the significant other and then evoke and process associated underlying, vulnerable emotions, such as sadness. The three interventions were delivered in the following sequence: empathy, relational reframe, and then empty chair. The first intervention, *empathy*, involved eliciting and empathizing with the participant's anger. During this intervention, the interviewer asked for details regarding the anger-provoking event(s) and validated the participant's feelings. The second intervention employed was the *relational reframe* (Diamond & Siqueland, 1998). The relational reframe consisted of questions that served to shift participants' focus away from their blaming attributions and onto the quality of the relationship between themselves and the significant other. More specifically, the relational reframe focused on the loss associated with the relational rupture. For example, the therapist might say, "It sounds like you have been furious with your father for years. I wonder if you also miss him." Typically, such interventions are accompanied by a shift from anger to more vulnerable emotions, such as sadness, loneliness, and longing. The third intervention was the *empty chair*. During this intervention, the interviewer asked the participant to shift from speaking *about* her feelings of loss and sadness to directly *expressing these emotions in the first person*, as if the significant other (i.e., attachment figure) was seated across from her in the room.

Interviewers were given guidelines regarding when to move from intervention to intervention. Each intervention needed to last no less than 4 min and no more than 10 min. Within those parameters, interviewers were free to use their clinical judgment to determine when the participant had sufficiently engaged in the particular task at hand (e.g., spoke about loss during the relational reframe, expressed loss and sadness directly in the first person during the empty chair) and was ready to move to the next intervention.

Sampling procedure. An a priori decision was made to sample approximately 20 sessions for analysis. The number 20 was chosen because, on one hand, it represents a particularly large sample size for studies of voice properties and, on the other hand, it was the largest sample we could reasonably consider in light of the labor intensive nature of the analyses conducted. Sessions were chosen for inclusion based on the following procedure. Two bachelor's-level coders randomly chose sessions, one at a time, from among the pool of 71 cases. After each session was chosen, the coders independently reviewed the session to determine whether it included at least one 30-s segment of unresolved anger and at least one 30-s segment of sadness. After coding 35 randomly selected sessions, the coders had identified 22 sessions regarding which they reached absolute agreement about the presence of both unresolved anger and sadness.

These 22 sessions were then submitted to an independent master's-level coder trained in the SPAFF instrument. The coder was instructed to view each of the 22 DVDs and identify at least one 30-s segment reflecting unresolved anger and at least one 30-s segment reflecting sadness. These segments were then submitted for acoustical analysis. When more than one segment of anger and/or sadness was identified for a given session, one of the segments was randomly chosen for acoustical analysis. In 21 out of 22 sessions, the coder identified more than one segment containing anger. In 19 of these sessions, she identified more than four segments containing anger. In 19 out of 22 sessions the coder identified more than one segment containing sadness, and in 15 of these sessions, she identified more than four segments containing sadness.

Results

Unit of Analysis and Data Reduction

Anger segments submitted for analyses were, on average, 49.22 s ($SD = 33.84$) long. Sadness segments submitted for analyses were, on average, 46.22 s ($SD = 37.63$) long. To represent the baseline (i.e., emotionally neutral) condition, we chose the last minute of the baseline stage from each session. To obtain articulation rate (i.e., WPM) and acoustical measures (i.e., mF0, F0-range, amplitude-range and PPQ) for each emotion (i.e., baseline, anger, and sadness), we followed a similar segmentation (i.e., into utterances) and data-reduction procedure as that described in Study 1.

Main Analyses

Table 4 presents mean values and standard deviations obtained for each measure according to emotion. Table 5 presents the intercorrelations among the five dependent measures analyzed in this study.

To examine whether any of the dependent measures (i.e., WPM, mF0, F0-range and amplitude-range, PPQ and APQ) varied according to type of emotion (i.e., baseline, anger, and sadness), we conducted six one-way repeated-measures ANOVAs, with emotion serving as the repeated independent measure and one of the six voice parameters serving as the dependent measure. Again, we decided not to conduct an omnibus multivariate ANOVA for the same reasons described in Study 1. Four of the six ANOVAs, those examining WPM, mF0, F0-range, and PPQ, yielded a significant effect for emotion (see Table 4). To probe the source of these effects, we conducted post hoc Tukey's HSD tests, with $p = .05$, comparing the means for baseline, anger, and sadness. Three of the four measures (WMP, mF0, and F0-range) evidenced increases from baseline to anger. These increases were consistent with our hypotheses. However, in contrast with our hypothesis, PPQ values did not increase from baseline to anger. On the other hand, PPQ values did increase from baseline to sadness, a finding consistent with our hypotheses. Contrary to our expectations, WPM, mF0, and F0-range did not decrease from baseline to sadness. We also compared sadness and anger on WPM, mF0, F0-range, and PPQ. WPM, mF0, and F0-range scores were higher during anger than sadness, consistent with our hypothesis. Also as hypothesized, PPQ did not differ for sadness versus anger. Post hoc comparisons are presented in Table 4.

Table 5
Intercorrelations Among Acoustical Parameters for Study 2

Measure	1	2	3	4	5	6
1. WPM	—					
2. mF0	.20	—				
3. F0-range	.14	$.73^{**}$	—			
4. Amp.-range	−.22	.08	−.01	—		
5. PPQ	−.07	$-.25^{*}$	.07	−.03	—	
6. APQ	−.08	$-.47^{**}$	−.20	$.28^{*}$	$.39^{**}$	—

Note. WPM = words per minute; mF0 = mean fundamental frequency; F0-range = fundamental frequency range; amp.-range = amplitude range; PPQ = pitch-perturbation quotient; APQ = amplitude-perturbation quotient.
$^{*}p < .05$. $^{**}p < .01$.

General Discussion

These two studies examined the feasibility of using voice measures to identify and distinguish between verbal expressions of unresolved anger and sadness, and shifts between these emotions, in a setting similar to psychotherapy. Results from both the mood-induction and the analogue therapy procedures converged to show that vocal acoustical parameters can be used to identify the presence of unresolved anger and sadness, as well as distinguish between these two emotions. The vocal acoustical signature of anger was particularly robust and characterized by increased articulation rate, and increases in subjectively perceived pitch (mF0) and pitch variability (F0-range), relative to neutral baseline speech. In contrast, sadness was characterized by increases in nonperceptible fluctuations in pitch (PPQ). In terms of distinguishing between unresolved anger and sadness, results from both studies

Table 4
Summary of Results for Study 2

Measure	Baseline (B)		Anger (A)		Sadness (S)		Effect of emotion		Significant changes
	M	*SD*	*M*	*SD*	*M*	*SD*	$F(2, 42)$	η_p^2	
WPM	190.09	40.50	223.67	37.28	187.92	35.05	7.43^{**}	.26	B < A, S < A
mF0	191.92	16.54	209.71	31.92	192.94	19.34	8.73^{***}	.29	B < A, S < A
F0-range	92.95	27.98	126.66	52.31	94.63	22.38	7.07^{**}	.25	B < A, S < A
Amplitude-range	13.05	3.14	13.28	2.82	14.14	3.70	1.00	.05	
PPQ	2.05	0.52	2.18	0.39	2.45	0.74	3.93^{*}	.16	B < S
APQ	13.07	2.57	13.39	1.79	13.62	2.68	.38	.02	

Note. WPM = words per minute; mF0 = mean fundamental frequency; F0-range = fundamental frequency range; PPQ = pitch-perturbation quotient. Note that each variable is expressed in different units of measurement (i.e., mF0 and F0-range are expressed in hertz, and amplitude-range is expressed in normalized decibels). $N = 22$.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

showed that anger was associated with greater levels of subjectively perceived pitch (mF0) and pitch range (F0-range) than was sadness. Furthermore, the results of the mood-induction procedure indicated that sadness was associated with greater nonperceptible fluctuations in pitch (PPQ) than anger. Together these findings suggest that, indeed, it may be feasible to employ vocal acoustical parameters to monitor clients' emotions over the course of psychotherapy.

Our findings for anger were consistent with those of prior research showing that anger was associated with an increase in articulation rate, average F0 (subjectively perceived pitch), and vocal dynamics (Scherer et al., 2003). This type of acoustical profile likely reflects activation of the sympathetic branch of the nervous system (e.g., Cacioppo, Klein, Bernston, & Hartfield, 1993). Such activation increases muscle tension in the vocal folds and respiratory tract, leading to increases in mF0 (subjectively perceived pitch), F0-range (pitch variability) and amplitude-range (loudness variability) values (e.g., Titze, 2000). It is worth noting that increases in mF0 (subjectively perceived pitch) and in voice-dynamic parameters, such as F0-range (pitch variability) and amplitude-range (subjectively perceived as loudness), are relatively easy for the untrained human ear to perceive, underscoring the social and perhaps evolutionary function of being able to communicate and perceive anger quickly and unequivocally (e.g., Scherer, 1995).

The finding that sadness was associated with increases in F0-perturbation (PPQ), or nonperceptible pitch fluctuations, was robust, appearing in both the mood-induction and analogue session studies. This finding replicates the results of a study by Juslin and Laukka (2001), who found an increase in F0 perturbation for sadness elicited when asking participants to act as if they were experiencing sadness. This increase in fluctuations in the voice signal suggests that sadness was associated with a state of diminished neurological and aerodynamic control over the vibratory pattern of the vocal folds (e.g., Titze, 2000). It is interesting to note that a number of previous studies have linked increased PPQ with anxiety (Fuller, Horii, & Conner, 1992; Ozdas, Shiavi, Silverman, Silverman, & Wilkes, 2004). It is important to remember that the participants in this study were accustomed to experiencing anger, an emotion that typically bestows a sense of control. For such participants, being induced to experience and express less familiar and more vulnerable emotions, such as sadness and loss, may have led them to experience anxiety and resulted in their attempting to down regulate their arousal, resulting in greater F0-perturbation (i.e., PPQ) levels. Indeed, some researchers have suggested that increased PPQ may be the result of simultaneous increases in sympathetic and parasympathetic activity (Ozdas et al., 2004), a physiological state consistent with attempts to down regulate anxiety.

Not only did acoustical parameters indicate the presence of unresolved anger and sadness, as well as distinguish between these two emotions, but such measures also indicated clinically important shifts from unresolved anger to underlying sadness, a shift central to the theory and practice of relationship-oriented, emotion-focused treatments such as attachment-based family therapy. Results from the mood-induction procedure indicated that increases in F0-perturbation (i.e., PPQ), reflecting a decrease in neurological or aerodynamic control, were more pronounced when sadness was experienced and expressed after the participant first experienced and expressed anger (see Figure 2). In fact, PPQ increased from baseline to sadness, on average, 52% more when sadness was evoked after anger than when it was evoked prior to anger. This finding is virtually identical to our findings from a previous study examining physiological responses to unresolved anger and sadness in this same population (i.e., individuals suffering from unresolved anger), in which we used a similar mood-induction procedure (Rochman & Diamond, 2008). In the previous study, participants' levels of sympathetic activation, as measured by decreases in finger temperature, increased when participants shifted from anger to sadness and were greater when sadness was evoked subsequent to anger than when it was evoked prior to anger. It seems that, among people suffering from unresolved anger, the experience and expression of unresolved anger contains elements of, and perhaps primes individuals to experience, related vulnerable emotions, such as loss, sadness, and anxiety. This finding is consistent with the conceptualization of primary and secondary emotions found in the work of Greenberg and Safran (1987), which suggests that unresolved anger can be fused with or even serve to regulate or defend against interrupted or avoided primary, vulnerable emotions, such as shame, fear, and sadness. Indeed, clinical experience suggests that the successful treatment of unresolved anger typically involves first accessing that anger and only then attempting to identify and access underlying primary, vulnerable emotions (e.g., shame, fear, sadness) related to the events and/or relationships at hand. These findings suggest that, with clients suffering from unresolved anger, the process of treatment may need to involve working through the anger to reach the pain.

Whereas anger may have facilitated the subsequent experience of sadness, results from the mood-induction procedure suggest that sadness may have moderated or tempered the subsequent experience of anger. This process can be seen in the results regarding amplitude-range (see Figure 1). When anger was evoked first, speech loudness varied greatly (in relation to emotionally neutral speech), as would be expected. However, when sadness was evoked first, there was no increase in loudness variability when participants were subsequently induced to express anger. It may be that once participants engaged in their underlying hurt and sense of loss, anger no longer served a defensive, protective purpose and, thus, was not associated with exceptionally high levels of physiological activation.

In contrast with our hypotheses, we did not find expected decreases in WPM, mF0, F0-range, and amplitude-range for sadness. Such decreases have been found in most studies examining acoustical parameters and sadness (e.g., Scherer et al., 2003). One possibility is that the sadness experienced and expressed in this study, a sadness associated with relational loss, was linked to increases in anxiety, which, in turn, was manifested as quicker speech, higher pitch (i.e., mF0) and greater voice dynamics (i.e., F0-range and amplitude-range). Regarding WPM, another possibility is that this nonfinding was a function of the unit of analysis employed. In this study, only continuous (i.e., fluent) samples of speech were analyzed, whereas in prior research, investigators analyzed both the fluent and dysfluent parts of speech. It may be that decreases in speech rate associated with sadness are due to increases in the length of pauses between speaking. If so, the analytic procedure used in our studies (i.e., Studies 1 and 2) would not have captured that phenomenon.

Another unexpected nonfinding was that amplitude-perturbation (i.e., APQ) did not differentiate between anger and baseline or anger and sadness. This nonfinding was particularly surprising in light of the fact that amplitude-perturbation is considered to be sensitive to physiological changes (Titze, 2000) associated with anger and sadness (Cacioppo et al., 1993). In theory, the physiological activation and increased muscle control associated with anger should lead to diminished APQ values, because tension of the muscles in the respiratory system should translate into relatively stable voice loudness. On the other hand, sadness should evoke a state of diminished control over the muscles surrounding the respiratory system, leading to decreased stability in voice loudness and, therefore, increased APQ values. However, we did find that APQ values, in relation to baseline, were higher for anger than for sadness. A closer inspection of the data suggests that this between-emotion difference was attributable to absolute, although nonsignificant, increases from baseline to anger and decreases from baseline to sadness.

We also did not find any correlations between participants' self-reported intensity of emotional experience and acoustical measures. This finding is reminiscent of findings from our earlier study (Rochman & Diamond, 2008) examining physiological measures and emotions, where we found only small and intermittent associations between self-reported anger intensity and sympathetic activation on one hand and self-reported sadness intensity and parasympathetic activation on the other. It seems that individuals vary in their capacity to perceive their own levels of physiological activation (Katkin, 1985) and, because such a capacity is important in the process of judging one's own level of emotional intensity (Cacioppo, Berntson, & Klein, 1992; James, 1884; Schachter & Singer, 1962), some individuals may experience intense physiological arousal (e.g., which would impact their vocal acoustics) but not necessarily recognize this arousal or report intense emotional experiences (Wiens, Mezzacappa, & Katkin, 2000). Another possibility is that, in our sample, self-reported levels of emotional intensity varied little (i.e., most participants reported consistently high levels of emotional intensity), potentially creating a ceiling effect and, thus, reducing the likelihood of finding a correlation with changes in acoustical measures. In any case, the lack of correlation between subjectively perceived emotion intensity and vocal acoustical measures suggests that emotion intensity levels are best captured using a multi-method measurement procedure.

Worth mentioning among the methodological strengths of this study is the combination of both experimental control and ecological validity. The first procedure, the mood-induction procedure, was designed to experimentally elicit the expression of unresolved anger and associated sadness in relation to a significant other. The advantage of such a procedure is that it increases the likelihood that participants are actually intensely experiencing and expressing the phenomena of interest: unresolved anger and related sadness of the type typically addressed in psychotherapy. Such a design increases internal validity, although it comes at the expense of ecological validity (e.g., therapy does not typically involve asking clients to remain focused on and intensify a given emotion over a 4-min period, although in some cases it might). In contrast, the second procedure, the analogue therapy sessions, served to examine unresolved anger and sadness and voice properties during a procedure very similar to the actual process of attachment-based family therapy and other experiential, relationship-oriented and emotion-focused therapies. Clients were not instructed to elicit the emotions of interests but, instead, were permitted to experience and express such emotions as they emerged, as is the case during an actual therapy session. The advantage of the analogue design is that it bears greater ecological validity. The disadvantage is the uncertainty regarding exactly which emotion(s) the participants were experiencing at any given moment (i.e., lower internal validity). Together, these two designs complement one another. The consistent results across the two paradigms suggest that the findings are both internally and externally valid.

Regarding methodological limitations, it is important to note that our sample is representative of a nonclinical population only. In the context of certain psychological disorders, such as depression, emotions may impact upon the production and the acoustics of voice in complex and different ways. Furthermore, all participants were female, and it remains unclear the degree to which these results generalize to men. It is also important to note that Daniel Rochman conducted the mood-induction procedure in Study 1. It may be that by doing so, he inadvertently induced participants to experience one of the emotions more intensely at certain stages of the induction procedure, leading to the Emotion × Order interactions found in Study 1. However, the likelihood of this being the case is very small because the mood-induction procedure was highly standardized. Another limitation is that the determination regarding whether participants had sufficiently engaged in the mood-induction procedure (i.e., Study 1), and SPAFF ratings (i.e., in Study 2), were each conducted by a single rater, raising the question of how reliable and generalizable these ratings were. Regarding the SPAFF ratings, however, it is worth noting that the rater was trained to criteria set by the instrument developers, a procedure inherently more valid than simply obtaining interrater reliability between multiple coders. Finally, it is worth noting that the correlations between dependent measures were based on small sample sizes raising questions regarding the stability of these correlations.

Despite these limitations, this study represents an important first step in using acoustical measures to objectively and unobtrusively identify clients' emotional experiences in the context of therapy sessions. The ability to obtain continuous, objective measures of clients' emotions could have enormous implications for both psychotherapy researchers and clinical practice. In terms of psychotherapy research, such data could help better examine when clients experience certain emotions and shifts between emotions; how such experiences are facilitated or inhibited by various in-session processes, including therapist interventions; and the relationship between patterns of emotional experience and treatment outcome. Such information is an important building block for developing and improving emotion-focused treatment models.

In terms of clinical practice, this research represents a first step toward the development of a new measurement technology that, in the future, would enable therapists (and clients) to continuously monitor clients' emotional states online over the course of therapy. Such a technology could be used to inform the therapist of clinically significant changes in clients' emotional states, changes that might not be evident on the basis of client behavior alone. Such information could be used to guide moment-to-moment intervention strategies. Online readings of clients' emotional functioning could also be presented to the clients themselves during the course of the therapy session, in a manner similar to the way online physiological responses are presented to clients during biofeedback. Such readings could be used, for example, to train clients who experience diffuse emotional states to better link their physiological experience with more differentiated, affect-related language.

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