CHAPTER 1

Autonomic Determinants of Vocal Expression of Emotions

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Summary

Although the autonomic component of emotional reactions is clinically important, there are little data about its precise role in the communication of emotion. This study investigated the impact of autonomic lesions on the vocal expression of emotions. A group of diabetics was chosen as a cohort because diabetic insulin-dependent patients can suffer diffuse neuropathy capable of producing profound changes affecting normal body reactions. Outcome measures were autonomic function tests, acoustic analyses of vocal emotional expression, and subjective feeling ratings. Standard autonomic function tests were performed to assess the sympathetic and parasympathetic tone (that is, prevailing base levels of sympathetic and parasympathetic activity) in 39 gender-mixed diabetic patients. For both measures subgroups were formed with scores above and below the median. Feelings of joy, anger, and sadness were induced through verbal recall of emotional experiences. The patients rated the intensity of the emotion felt during the recall. Their voices were acoustically analyzed, yielding a number of acoustic parameters related to emotions (Zei & Archinard, 2002).

Indices of global vocal activation, and vocal differentiation of emotions were computed for anger-sadness, joy-sadness, and anger-joy comparisons. The patients' self-reported subjective feeling related to each emotion was coded as well as the intensity of weeping. For each dependent variable, two-factor analysis of variance was applied with the independent variables "sympathetic tone" (high vs. low) and "parasympathetic tone" (high vs. low).

The analyses of variance (ANOVAs) yielded significant effects for vocal variables and the subjective feeling scores. Patients with low parasympathetic tone showed diminished *vocal arousal* in anger and joy and heightened *vocal arousal* in sadness. They had less intense subjective feelings of both sadness and anger. Patients with low sympathetic tone had less pronounced spectral differentiation between anger and joy conditions.

Our findings indicate that diminished autonomic control of cardiovascular reactions is associated with lower intensity of the subjective feelings of sadness and anger, and blunting of vocal signaling of both positively and negatively valenced emotional states.

Theoretical Background

Diabetic neuropathy is the most common complication of diabetes mellitus, both type 1 and type 2. Autonomic diabetic neuropathy is a form of diffuse neuropathy that affects the nerves that serve the heart and internal organs and produce changes in many processes and systems. Damage to the nerves in the cardiovascular system interferes with the body's ability to adjust blood pressure and heart rate in response to normal body reactions, exercise, stress, and emotional challenges. This means that the heart rate can stay unchanged, instead of rising and falling in response to the psycho-physiological demands. It then follows that emotional reactions, as mechanisms of the organism's adaptive functioning, are likely to be affected by impaired or diminished autonomic response.

Autonomic reactions are central to most emotion theories. The James-Lange theory (James, 1894) states that emotional feelings are consequences of peripheral physiological changes supported by the autonomic nervous system (ANS). The Cannon-Bard theory suggests that emotion occurs when the thalamus sends signals simultaneously to the cortex and the ANS, and that different emotions are associated with different patterns of autonomic arousal (Cannon, 1927). Schachter & Singer (1962) proposed a theory holding that discrete emotional experiences derive from cognitive appraisals initiated by the perception of undifferentiated autonomic arousal. As their experiment was concerned with the arousal induced by epinephrine (whose effects are almost a perfect mimicry of a discharge of the sympathetic nervous system such as increase of blood pressure, heart rate, respiration rate, etc.), their results contributed to the understanding of the importance of the sympathetic branch of the ANS and did not allow inferences as to the role of the parasympathetic division of the ANS.

Considering the fact that vagal response is very fast (in the order of 400 milliseconds compared with 20–30 seconds' latency in sympathetic stimulation), studying its role in the regulation of emotion in subjects with parasympathetic lesions appeared meaningful. Berntson and colleagues suggested a model of autonomic regulation based on the concept of "autonomic space" with orthogonal sympathetic and parasympathetic axes, such that stress-induced heart rate increase, for example, could result from an increase of the sympathetic stimulation or a decrease in the parasympathetic stimulation (Berntson, Cacioppo, & Quigley, 1991; 1993a).

In Scherer's component process theory of emotions (Scherer, 1984a; 1984b; Scherer & Scherer, 2001), ANS reactions are one of five components (cognitive appraisal, physiological arousal, expressive reaction, action tendency, and the subjective feeling). It then follows that the presence of impairment in one component should lead to a major change in emotionality. An example is emotional disorders in patients with unilateral brain lesions (Gainotti, 1991). More recently, Damasio's model assigns a major role to the emotional sensations related to the state of the smooth muscles, which in turn are under autonomic control.

It thus appears meaningful to assume that impairment of the autonomic response should lead to a major change in emotionality (Damasio, 1999).

Emotions are usually characterized along two basic dimensions (Lang, 1995; Russel, 2003):

- Arousal (aroused vs. calm), which mainly refers to the physiological arousal involved in the preparation of the organism for an appropriate reaction.
- Valence (pleasant/positive vs. unpleasant/negative), which mainly refers to the overall subjective hedonic feeling.

Our aim was to determine which dimension of an emotional experience is affected by diminished cardiovascular response: arousal, valence, or both. More specifically, the goal was to explore whether the emotions that are characterized by ergotropic arousal (e.g., anger and intense joy) are differentially affected compared with those characterized by trophotropic arousal (e.g., sadness) (Scherer, 1989a, 1989b).

Hypotheses

1. In subjects with low parasympathetic tone, sadness will be expressed and felt to a lesser degree than normally expected for emotions dominated by trophotropic arousal. This hypothesis is based on the assumption that low parasympathetic tone reflects long-term vagal withdrawal, which in turn can result in the overactivity of the counter-regulatory system, that is, the sympathetic system.
2. In subjects with low sympathetic tone, the intensity of the subjective feeling of anger and joy as well as their verbal expression will be lower than expected for emotions dominated by ergotropic arousal. This hypothesis is based on the assumption that low sympathetic tone may prevent full deployment of the states of anger or joy/elation.
3. In subjects with diminished autonomic response, the emotional expression of emotions as well as the corresponding subjective feeling states will be flattened.

Hypotheses 1 and 2 are based on the classical reciprocal model of autonomic regulation, which follows a unidimensional vector or a continuum that extends from dominant sympathetic activation on one end to dominant parasympathetic activation on the other extreme. The state of autonomic control at any given time is characterized by a point on this continuum.

Hypothesis 3 is based on an alternative model of autonomic control (Berntson, Cacioppo, & Quigley, 1991; 1993a) whereby autonomic regulation evolves in a two-dimensional space defined by orthogonal parasympathetic and sympathetic axes. According to this model autonomic control can vary independently within a bivariate "autonomic space" with reciprocal, coactive, or independent changes in the sympathetic and parasympathetic branches of the ANS. The heart being a dually and antagonistically innervated organ, the neural changes and the organ's response may be patterned in terms of coactivation of the sympathetic and parasympathetic systems. The consequent heart rate response could thus be acceleratory, deceleratory, or unchanged from prestimulus levels depending upon which activational input was greater (Berntson et al., 1991; 1993b).

Studying the relationship between diminished cardiovascular response and emotional reactions furthers our understanding of more general psychological consequences of diabetic autonomic lesions. This chapter presents the results of our study.

Methods

Subjects

Thirty-nine French-speaking diabetic patients (17 female and 22 male) varying in age (range = 31-73, mean = 56; SD = 9) and duration of illness (range = 1-36; mean =15; SD = 11) participated in the investigation. None suffered from depression or any somatic disease affecting respiration, phonation, or articulation.

Physiological Measures

Three standard autonomic function tests (Ewing, Campbell, Burt, & Clarke, 1973; Vita et al., 1986) were used to assess each patient's base level autonomic response:

1. Heart rate variability (HRV) during deep breathing at six breaths per minute, expressed as the mean heart rate difference (based on maximum minus minimum heart rate measured during three successive breathing cycles).
2. Immediate heart rate response to standing up expressed as the "30:15 ratio," i.e., the ratio of the largest R-R interval around the 30th beat after starting to stand up to the shortest R-R interval around the 15th beat. The R-R interval is defined as the time duration between two consecutive R waves of the ECG. Both tests quantify the parasympathetic control of the heart with a small sympathetic component (Valensi et al., 1997). They were done by means of Autocaft software (BBC Master, Edinburgh, UK).

Data of both of the above tests were adjusted for age (Valensi et al., 1997) and a cumulative average score (Ewing, Martyn, Young, & Clarke, 1985) was computed into a variable "parasympathetic tone."

The third test involved isometric handgrip exercise as indicator of sympathetic function. It measured the diastolic blood pressure rise during sustained handgrip for 5 minutes. The data were adjusted for gender, and the derived variable was named "sympathetic tone."

Induction of Emotions

The emotions of were self-induced by asking the subjects to verbally recall the situations in their lives which arouse joy, sadness, and anger. This self-recall method has been shown to effectively induce emotional states (McCraty, Atkinson, Tiller, Rein, & Watkins, 1995). At the end of each narrative (lasting on the average about 6 minutes), the subject immediately read aloud a standard sentence on the emotion congruent tone. The sentence read: "ALORS TU ACCEPTES CETTE AFFAIRE." It was presented in block letters without punctuation so as not to suggest any tone of voice.

According to the conceptual and empirical work of Mendolia and Kleck (Mendolia & Kleck, 1993), talking about one's emotional experience directs one's attention to the affect relevant properties of the event. Thoughts brought into awareness from such talk are emotion focused. Verbal description of an emotional experience cues mental images as well as expressive reactions that influence felt emotion (Tesser & Clary, 1978). It is thus " . . . possible to turn a recollection of an event from the past into an emotional experience in the present" (Strack, Schwarz, & Gschneidinger, 1985, p. 219). This is in agreement with Damasio's model of emotional memory retrieval (Damasio, 1989). He suggests that a unique spatiotemporal patterning of the brain activity is retroactivated during the recall of emotion episodes including specific patterns of appraisal and the peripheral somatic and autonomic reactions. According to LeDoux, emotional processing of the contents of speaking involves an integration of cortical sensory inputs to the amygdala (LeDoux, Iwata, Cicchetti, & Reis, 1988). As the central nucleus of the amygdala provides a link with efferent motor systems controlling autonomic and behavioral emotional responses, it is hypothesized that autonomic responses to verbal recall of emotional experiences are similar to those of real-life emotional reactions. Analogous neuropsychological evidence is provided by Farah (1988).

Psychological Measures

In order to control for a possible influence of personality dimensions (Scherer, 1978, 1979; 1981) and anxiety (Scherer, 1986) on voice production mechanisms (including breathing patterns) (Winkworth, 1995), the patients completed Spielberger Anxiety-state scale (Bruchon-Schweitzer, 1993) at the beginning of the interview and prior to the emotion induction. Eysenck Personality Inventory questionnaire (Eysenck, 1970) was administered at the end of the interview. The latter yielded data on extraversion and neuroticism dimensions of personality.

Measures of the Intensity of Felt Emotion, Weeping and Change in Emotionality

Upon each narrative, and after having said the standard sentence, the patient was asked to rate the degree to which he or she felt the just verbally recalled emotion. The intensity of felt emotion was coded on a four-point scale (0–3). Three variables represented the intensity of the subjective feeling related to each condition: FeelA for anger, FeelJ for joy, and FeelS for sadness. As 77% of the subjects wept during the recall of emotional experiences, the intensity of weeping was rated by the experimenter on a four-point scale (0–3), with 0 = absence of weeping; 1 = noticeable tears in the eyes; 2 = abundant tearing; 3 = abundant tearing accompanied by speaking difficulties. At the end of the interview the experimenter asked the subjects whether they thought that their emotional reactions (emotionality) had changed in the last few years. The answers were rated on a four-point scale (0–3).

In summary, the above ratings produced five variables: three related to the intensity of emotions, one to the awareness of change in emotionality, and one to the intensity of weeping.

Measurement of Vocal Expression of Emotions

The subjects' voices were digitally recorded, with the distance of the microphone to the mouth being kept constant. One hundred and seventeen samples of the standard sentence were acoustically analyzed by means of a Macintosh platform software (Keller, 1994), which yielded data on the fundamental frequency (F_0), energy envelopes, long-term average spectra, and the speaking rate.

The relationship between the emotional arousal and vocal expression was first modeled by Williams and Stevens (1972) and has received considerable empirical support (Banse & Scherer, 1996; Scherer, 1981; Simonov, Frolov, & Ivanov, 1980; Williams & Stevens, 1981). Emotional arousal is thus known to be mainly encoded in the fundamental frequency (F_0), in vocal energy, and in the speaking rate. Compared with an emotionally unmarked (neutral) speaking mode, *vocal arousal*[1] of an angry voice would typically be characterized by increased values of some or all of the above parameters, while that of a sad voice would be marked by a decrease in the same parameters. By contrast, the hedonic valence dimension of emotional reactions seems to be mainly reflected in intonation patterns and in spectral characteristics of the speaker's voice.

Drawing on our previous work on acoustic patterns of emotions (Zei & Archinard, 2002), the following vocal parameters were computed: mean F_0, F_0 coefficient of variation, F_0 max/F_0 min ratio, mean voiced energy level, voiced energy range, speaking rate, and long-term average spectra (LTAS). As described by Zei and Archinard (1998), voiced energy range was measured between two midpoint vowel nuclei and it was expressed as the difference in dB between the highest and the lowest peak in voiced energy envelopes. The speaking rate was expressed as the number of syllables uttered per second.

LTAS were computed for each voice sample, yielding 128 data points for a range of 40–5500 Hz. We used a Bark-based strategy of spectral data analysis (Hassal & Zaveri, 1979). The spectrum was divided into 13 bands, each covering a 1.5 Bark interval (Pittam & Gallois, 1986; J. Pittam, B. S. Pittam, Burnstock, & Purves, 1987), and a mean energy value for each band was computed. We thus obtained 13 spectral energy values per emotion and per subject.

Vocal Differentiation of Emotions on the Arousal Dimension

To quantify the degree of vocally expressed emotional arousal, a *vocal-arousal-index* was computed for each emotion. All the vocal variables were normalized by external reference values for healthy

[1]By analogy to the concept of autonomic arousal, we propose the term *vocal arousal* to signify the amount of vocal activation resulting from autonomic arousal.

male and female subjects, (Zei & Archinard, 2002) and a cumulative average score was computed. This procedure yielded three indices: AngerIndx, for *vocal arousal* in anger, JoyIndx for *vocal arousal* in joy, and SadnessIndx for *vocal arousal* in sadness.

To test the hypothesis of flattening of vocal differentiation between high-arousal and low-arousal conditions, an index of vocal differentiation was computed for anger-sadness and joy-sadness comparisons. This was done by calculating the ratio between the value of each vocal parameter (mean F_0, F_0 coefficient of variation, F_0 max/min ratio, voiced energy range, speaking rate) in anger condition and the respective value in sadness condition. The resulting ratios were cumulated into an average score named *vocal-differential index* (VDI). We thus obtained a VDI-anger-sadness and a VDI-joy-sadness.

Vocal Differentiation of Emotions on the Valence Dimension

To assess vocal differentiation of emotions on the valence dimension, we used spectral parameters. The spectral data for anger (a negative emotion with a high level of arousal) were compared with those for joy (a positive emotion with a high level of arousal). The approach was based on previous studies of vocal differentiation of hedonic valence in spectral analyses (Popov, Simonov, Frolov, Khachatur'iants, & Pastushenko, (1971); Zei & Archinard, 2001). The spectral value of each of the 13 bands of the LTAS in anger condition was divided by the respective value in joy condition. The frequency bands found to significantly differentiate the spectra in anger from those in joy covered a range from 600–4370 Hz. A cumulative spectral differential index (Anger/JoySpect) was computed for this range.

In summary, acoustic analyses of the patients' voices yielded 6 indices. Three represented the overall *vocal arousal* in each emotion condition: AngerIndx, JoyIndx, and SadnessIndx; two represented vocal differentiation of a high-arousal vs. a low-arousal emotion: VDI-anger-sadness, VDI-joy-sadness, and one stood for spectral differentiation of a positively valenced vs. a negatively valenced emotion: Anger/JoySpect.

Statistical Analyses

As a first step, covariance tests were applied to check for a possible influence of gender on the dependent variables. The neurological variables (parasympathetic and sympathetic tone) were used as covariates and gender as factor. Gender was significantly associated with three variables: intensity of felt anger ($F = 5.80$; $p = .021$), intensity of felt sadness ($F = 5.83$; $p = .021$), and awareness of change in emotionality ($F = 10.66$; $p = .002$). Female subjects reported higher intensity of felt anger and felt sadness as well as a stronger awareness of change in emotionality. Prior to performing further analyses, the data were adjusted for gender. Partial correlations (with neurological variables being partialed out) were computed to examine the association between dependent variables and the psychological variables (anxiety, extraversion) as well as the subjects' age and duration of illness. The results showed that anxiety score had a significant negative correlation with both AngerIndx

($r = -.41; p < .05$), and VDI-anger-sadness ($r = -.47; p < .01$), while extraversion was positively correlated with the awareness of change in emotionality ($r = .33$; $p < .05$) and the intensity of weeping ($r = .45; p < .01$). The latter also displayed a positive correlation with age ($r = .34$; $p < .05$).

As a third step subgroups were formed with scores above and below the median for the independent variables *sympathetic tone* and *parasympathetic tone*. According to the model of autonomic space (Berntson et al., 1991; Cacioppo, Klein, Berntson, & Hatfield, 1993), significant interaction effects between independent variables were expected. We therefore performed two-factor analyses of variance (ANOVA) for each dependent variable with the independent variables parasympathetic tone (high vs. low) and sympathetic tone (high vs. low). Anxiety score was used as a covariate in the ANOVAs for both AngerIndx and VDI-anger-sadness , while extraversion score served as a covariate in the ANOVA for the "awareness of change" and the intensity of weeping. For the latter, age was used as a covariate as well.

Results

Blunting of Feelings of Anger and Sadness

The ANOVAs yielded significant main effects only for the variable *parasympathetic tone*. There was no significant interaction effect between the independent variables. With respect to the main effect, significant differences were found for the intensity of felt anger ($F = 7.21$; $p = .011$), the intensity of felt sadness ($F = 12.59$; $p = .001$), the intensity of weeping ($F = 14.5$; $p = .001$), and for the awareness of change in emotionality ($F = 4.9$; $p = .034$). The subjects with a low parasympathetic tone felt lower intensity of anger and sadness, wept less, and had a higher degree of awareness of change in their emotional reactions. The following examples illustrate qualitative descriptions of change in emotionality as described by the patients with low parasympathetic tone:

> "Before, my emotions were more spontaneous."
>
> "I have fewer negative emotions."
>
> "Unpleasant emotions are better controlled, while pleasant emotions are more freely experienced."
>
> "I feel less anger and more joy."
>
> "My emotions are calmer."
>
> "I am more passive, especially regarding anger."
>
> "My emotional reactions are less spontaneous."
>
> "My emotions used to come automatically; now I don't react quickly."

Blunting of Vocal Expression of Emotional Arousal

The ANOVAs for overall *vocal arousal* indices AngerIndx, JoyIndx, and SadnessIndx as dependent variables yielded significant results only for the parasympathetic tone only. The anxiety score was used as a covariate for AngerIndx.

The individuals with low parasympathetic tone displayed lower *vocal arousal* in both anger ($F = 5.07$; $p = .031$) and joy ($F = 7.35$; $p = .01$) while they had a higher degree of *vocal arousal* in sadness ($F = 15.24$; $p = .000$) (Figure 1-1). There was no significant interaction effect between independent variables.

Diminished Vocal Differentation of Emotions

The ANOVAs for vocal-differential indices yielded highly significant main effects for the parasympathetic tone only: VDI-anger-sadness ($F = 40.85$; $p = .000$) and VDI-joy-sadness ($F = 40.59$; $p = .000$). Vocal differentiation of emotions (anger vs. sadness and joy vs. sadness) was lower in the group with low parasympathetic tone (Figure 1-2). The anxiety score was used as a covariate in the ANOVA for VDI-anger-sadness. There was a significant but weak interaction effect between the independent variables only in the ANOVA for the VDI-joy-sadness ($F = 6.6$; $p = .01$).

Blunting of Vocal Expression of Emotional Valence

The ANOVA with anger/joy spectral differential (Anger/JoySpect) as dependent variable yielded a significant main effect only for the sympathetic tone ($F = 6.82$; $p = 0.01$). The subjects with low sympathetic tone produced smaller spectral differences between anger and joy than did the subjects with high sympathetic tone (Figure 1-3). There was a significant interaction effect between parasympathetic and sympathetic tone ($F = 5.66$; $p = 0.02$).

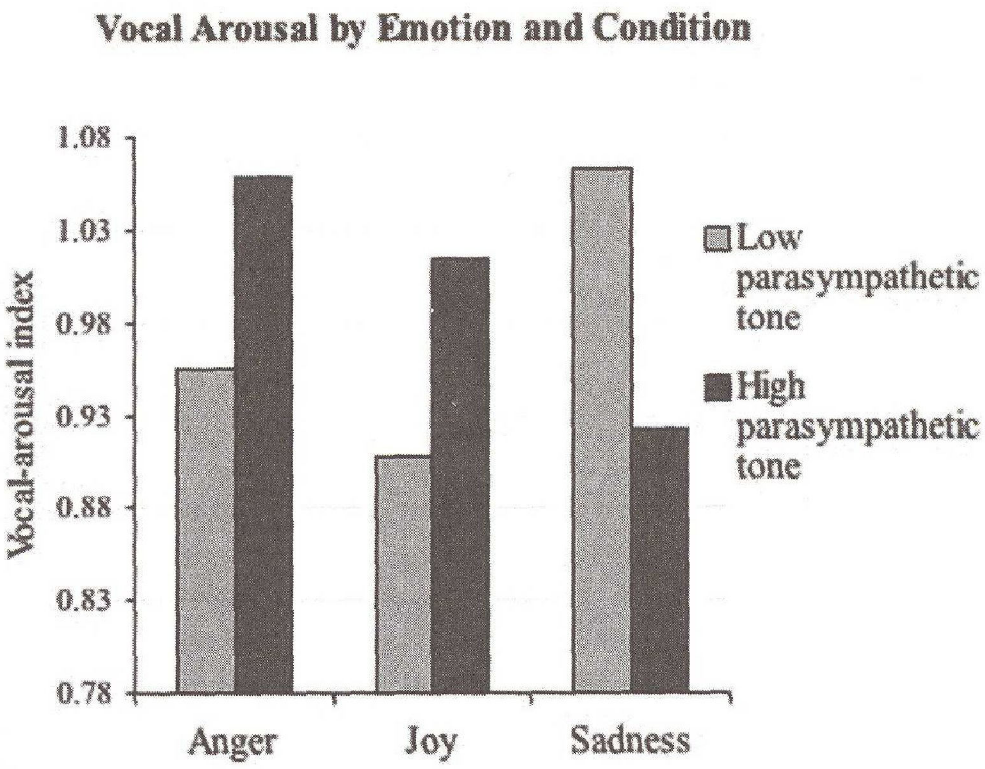

Figure 1–1. Degree of overall *vocal arousal* in anger, joy, and sadness by condition (group with low vs. group with high parasympathetic tone).

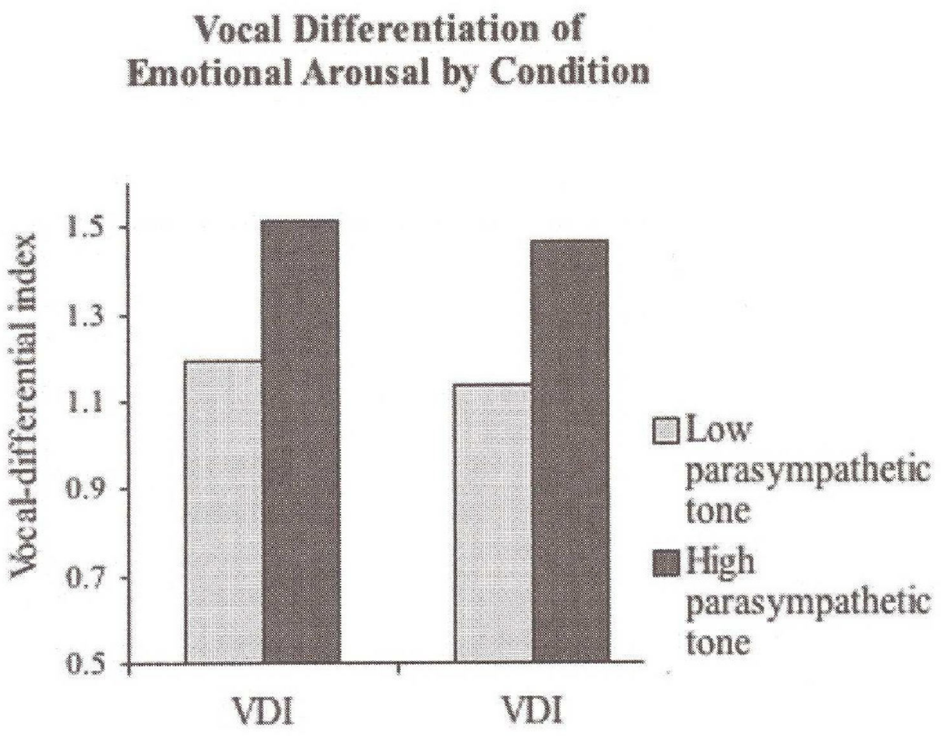

Figure 1–2. VDI = vocal-differential index reflecting the degree of vocal differentiation of emotions on the arousal dimension: anger vs. sadness and joy vs. sadness by condition (group with low vs. group with high parasympathetic tone).

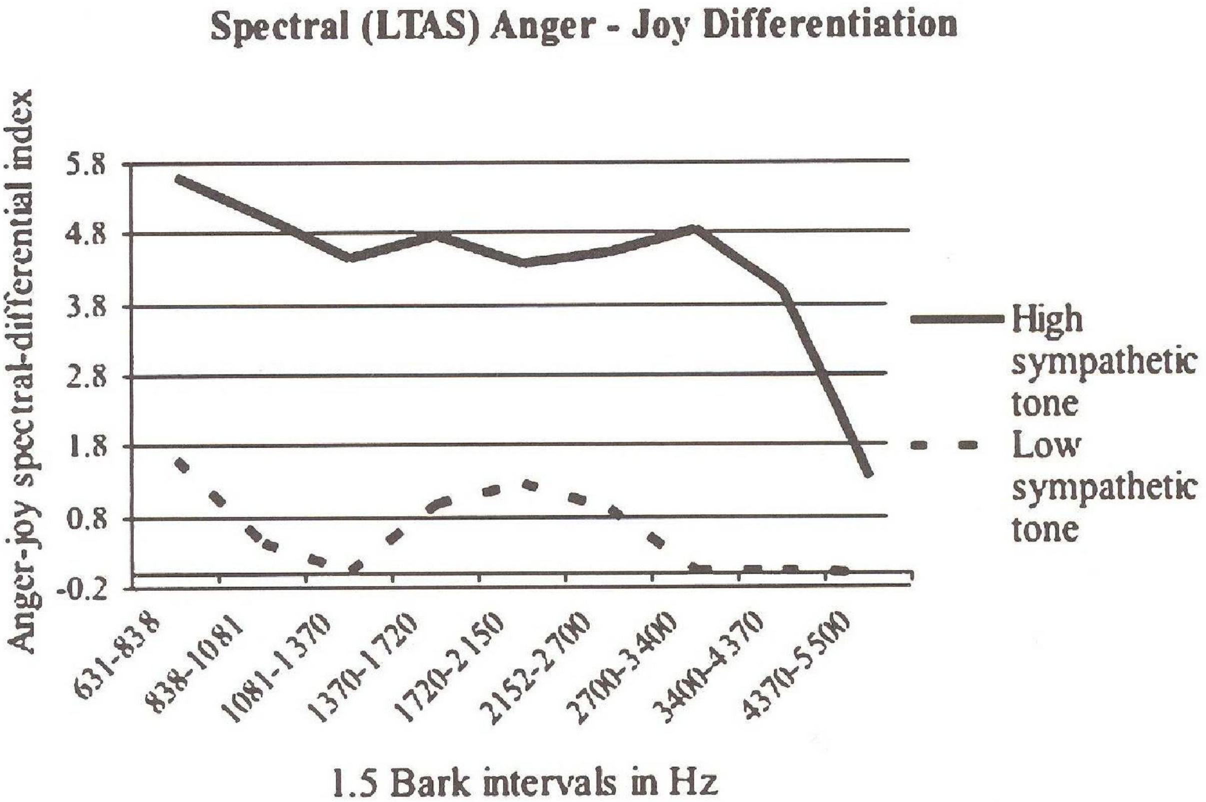

Figure 1–3. Anger-joy spectral-differential index reflecting the degree of spectral differentiation of two high-arousal emotions differing on the dimension of valence (anger vs. joy) displayed by by condition (group with low vs. group with high sympathetic tone).

Discussion

Current literature on emotionally induced autonomic arousal has been characterized by a tendency to focus more on the sympathetic than the parasympathetic system's contribution, neglecting a possible interaction between both branches of the ANS. This study allowed us to explore the relationship between the base-line levels of sympathetic and parasympathetic activity in diabetic patients and their vocally expressed emotional reactions (independent of their prominent personality traits and/or anxiety state).

Diabetics were chosen as a cohort group to test this relationship because, at an advanced stage of the disease, diabetics can exhibit autonomic neuropathy capable of producing profound changes affecting normal body reactions. This study investigated the impact of base-line autonomic tone on the vocal expression of emotions.

Marked group differences in feeling states were observed for the variable *parasympathetic tone*. The subjects with low parasympathetic tone experienced lower intensity of anger and sadness and wept less. Now, the observed diminished weeping may be due to a weaker emotional response, but it can also be related to the fact that the nerve fibers that carry the impulses to the lachrymal gland are part of the parasympathetic nervous system (Frey, 1985), so that destruction of the parasympathetic nerves (as found diabetic autonomic neuropathy) causes diminished tearing, while damage to the sympathetic nerves causes little change (DeJong, 1979).

Furthermore, individuals with low parasympathetic tone exhibited blunting on the level of vocal expression of emotions. Their overall *vocal arousal* in anger and joy was lower, while in sadness it was higher than expected for these conditions. Such a pattern of emotional flattening is congruent with the works of Porges (Porges, Arnold, & Forbes, 1973), who demonstrated that the level of vagal tone (defined as the amount of inhibitory influences on the heart by the parasympathetic nervous system) influences behavioral patterns in children, particularly in the expression and regulation of emotion (Porges, 1995; Porges & Byrne, 1992; Porges, Doussard-Roosevelt, & Maiti, 1994). Porges showed that the measurement of vagal tone could be used as an index of general reactivity predisposing an individual to be hypo- or hyperactive. Other studies relate base-level vagal activity to general expressivity (Stifter, Fox, & Porges, 1989).

Our finding about low parasympathetic tone being associated with an unusually high *vocal arousal* in sadness (emotion usually characterized by high trophotropic activation) could be explained by the fact that a long-term vagal withdrawal permits a relative overactivity of the counter-regulatory sympathetic system. It is therefore not surprising that in individuals with low parasympathetic tone the speech patterns characterizing anger or joy are poorly differentiated from those characterizing sadness. Consistent with the above results is the finding that individuals with disease induced low parasympathetic tone report a stronger feeling of change in emotionality. A different picture emerges for the sympathetic tone. Neither the overall *vocal arousal* nor the subjective feeling states were significantly associated with the sympathetic tone. Our hypothesis 2 was thus not confirmed. However, the group with high sympathetic tone differed significantly from the group with low sympathetic tone only in the spectral differentiation of emotional valence: anger vs. joy (see Figure 1-3). The subjects with high sympathetic tone showed bigger spectral differentiation.

The contribution of the parasympathetic system to emotionality has been especially emphasized within the framework of developmental psychology (Porges, 1983). Porges and colleagues describe the relation between vagal tone and emotional response in the following way (Porges et al., 1994, p. 172):

> Changes in Respiratory Sinus Arrhythmia amplitude in response to sensory, cognitive, and visceral challenges represent a "central command" to regulate vagal efferents originating in the right nucleus ambiguous and terminating in the heart, soft palate, pharynx, larynx, bronchi, and oesophagus. These changes in nucleus ambiguous regulation of peripheral autonomic activity support the expression of emotion, motion, and communication by regulating metabolic output (i.e., shifts in heart rate) and organs involved in the production of vocalisations.

These authors link the vagal control of the sino-atrial node to cardiovascular states facilitating emotion related fight-flight behaviors. Their model emphasizes the bidirectional physiological characteristics of the vagus (efferent + afferent feedback) whereby any dysfunction of the circuit could result in affective disorders. Other studies relate base-level vagal tone to general expressivity (Stifter et al., 1989).

As mentioned earlier, historically, the vagus and other components of the parasympathetic nervous system had not been incorporated in theories of emotion. Porges proposed a model whereby the vagal circuit of emotion regulation incorporates lateral brain function with the regulation of the peripheral autonomic nervous system in the expression of emotion. He convincingly showed that baseline levels of cardiac vagal tone and vagal tone reactivity are associated with behavior, the expression of emotion, and self-regulation skills.

The relation between vocal expression and the vagus is found in studies of neural control of vocalization, which have shown that vocalization is modulated by afferent input from the pulmonary and upper airways, which in turn is mediated by sensory receptors in the vagus nerve. Summation of pulmonary vagal and upper airway afferent discharge with the periaqueductal gray matter (PAG) motor output has the potential to result in a more adaptive and integrated response. Integrations of specific motor patterns for sound production by PAG neurons may offer an explanation for the well-known association between emotional and vocal control where fluctuations in emotional experiences alter the respiratory and laryngeal motor patterns in human speech and song (Davis, Zhang, Winkworth, & Bandler, 1996).

As to the interaction between parasympathetic and sympathetic activation of the ANS, our results only partially support the hypothesis of autonomic control evolving within a bivariate "autonomic space" with conjunct action of both branches. We found rather weak (albeit statistically significant) interactions between parasympathetic and sympathetic tone for both arousal and valence dimensions of emotions. No interaction was observed for the subjective feeling component of emotions. The latter was found to be associated with parasympathetic tone only.

Conclusions

Our results support the main hypothesis that diminished autonomic response is associated with emotional blunting. They also point to a major role played by the parasympathetic branch of the ANS. More specifically, patients with low parasympathetic tone feel lower intensity of anger and sadness, and display blunting of vocally expressed emotional arousal. The sympathetic branch of the ANS played a role only in the spectral differentiation of emotional valence (anger vs. joy).

To the extent that an individual's autonomic tone is inherent to his or her personality, one could expect autonomic lesions to impact some of the prominent personality traits. In a recent study, Schweiger and colleges found that individuals with high vagal tone are less inhibited and do not try to deny feelings (Schweiger, Witling, Genzel, & Block, 1998). It thus appears that our finding relating a disease induced change in the vagal tone to the awareness of change in emotionality, may have psychological consequences for the patients' personality. The assumption is based on the fact that emotion experiences provide continuity in the functioning of personality. Emotional feeling states that remain constant over time link the stability of emotion experience to personality (Barrett & Campos, 1987; Izard, Libero, Putnam, & Haynes, 1993). Caroll Izard and colleagues have convincingly demonstrated how emotions become linked to particular thoughts to form affective-cognitive structures, which in turn combine into cognition-emotion-action patterns that characterize the individual's style of adaptive behavior and contribute to the development of personality.

We can thus expect subjects with impaired cardiovascular reactions to have altered emotional experiences with subsequent consequences for the regulation of the organism's interaction with physical and social environment. Indeed, vocal signaling of emotional states serves an important function of regulating social interactions. It not only provides information about the speaker's attitudes and behavioral tendencies, but it is also informative about the speaker's acceptance of social and cultural demands and expectations (Gregory, Webster, & Huang, 1993; Rosenfeld, 1987). Altered vocal signaling of emotions may therefore impact the person's social functioning.

To conclude, we believe that damage to the nerves in the cardiovascular system not only affects the autonomic responsivity, its flexibility, and its balance, but it also induces a CNS-ANS dysregulation (Friedman & Thayer, 1998) resulting in a dysregulation of the organism's adaptive biological and social response to environmental challenges.

Acknowledgments. I extend special thanks to Professor Krzysztof Izdebski for his constructive remarks in the elaboration of the manuscript, to Dr. Yves Morel for his administration of the autonomic function tests, and to Véronique Ullmann for her work on qualitative assessment of the patients' verbal comments.

References

Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of Personality & Social Psychology*, *70*(3), 614–636.

Barrett, K. C., & Campos, J. J. (1987). Perspectives on emotional development. ii:

A functionalist approach to emotions. In J. D. Osofsky (Ed.), *Handbook of infant development* (2nd ed., pp. 555-578). Oxford, UK: John Wiley and Sons.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1991). Autonomic determinism: The modes of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological Review, 98*(4), 459-487.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993a). Cardiac psychophysiology and autonomic space in humans: Empirical perspectives and conceptual implications. *Psychological Bulletin, 114*(2), 296-322.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993b). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology, 30*(2), 183-196.

Bruchon-Schweitzer, M. (1993). *Spielberger: Inventaire d'anxiété état-trait, forme y.* Paris: Editions du Centre de Psychologie Appliquée.

Cacioppo, J. T., Klein, D. J., Berntson, G. G., & Hatfield, E. (1993). The psychophysiology of emotion. In M. Lewis & J. Haviland (Eds.), *Handbook of emotions* (pp. 119-141). New York: The Guilford Press.

Cannon, W. B. (1927). The James-Lange theory of emotion: A critical examination and an alternative theory. *American Journal of Psychology*, (39), 106-124.

Damasio, A. R. (1989). Time-locked multiregional retroactivation: A systems-level proposal for the neural substrates of recall and recognition. *Cognition, 33*(1-2), 25-62.

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness* (1st ed.). New York: Harcourt Brace.

Davis, P. J., Zhang, S. P., Winkworth, A., & Bandler, R. (1996). Neural control of vocalization: Respiratory and emotional influences. *Journal of Voice, 10*(1), 23-38.

DeJong, R. N. (1979). *The neurologic examination: Incorporating the fundamentals of neuroanatomy and neurophysiology.* Hagerstown, MD: Harper & Row.

Ewing, D. J., Campbell, I. W., Burt, A. A., & Clarke, B. F. (1973). Vascular reflexes in diabetic autonomic neuropathy. *Lancet, ii*, 1354-1356.

Ewing, D. J., Martyn, C. N., Young, R. J., & Clarke, B. F. (1985). The value of cardiovascular autonomic function tests: 10 years experience in diabetes. *Diabetes Care, 8*(5), 491-498.

Eysenck, H. J. (1970). *The structure of human personality*. London: Methuen.

Farah, M. J. (1988). Is visual imagery really visual? Overlooked evidence from neuropsychology. *Psychological Review, 95*(3), 307-317.

Frey, W. H., II (1985). *Crying: The mystery of tears*. Minneapolis, MN: Winston Press.

Friedman, B. H., & Thayer, J. F. (1998). Autonomic balance revisited: Panic anxiety and heart rate variability. *Journal of Psychosomatic Research, 44*(1), 133-151.

Gainotti, G. (1991). *Frontal lobe damage and disorders of affect and personality*. Edinburgh, UK: Churchill Livingstone.

Gregory, S. W., Webster, S., & Huang, G. (1993). Voice pitch and amplitude convergence as a metric of quality in dyadic interviews. *Language and Communication, 13*, 195-217.

Hassal, J. H., & Zaveri, K. (1979). *Acoustic noise measurements*. Naerum, Denmark: Büel & Kjaer.

Izard, C. E., Libero, D. Z., Putnam, P., & Haynes, O. M. (1993). Stability of emotion experiences and their relations to traits of personality. *Journal of Personality and Social Psychology, 64*(5), 847-860.

James, W. (1894). The physical basis of emotion. *Psychological Review* (1), 516-529.

Keller, E. (1994). Signalyze 3.0. Lausanne, Switzerland: InfoSignal.

Lang, P. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist, 50*(5), 372-385.

LeDoux, J. E., Iwata, J., Cicchetti, P., & Reis, D. J. (1988). Different projections of the central amygdaloid nucleus mediate autonomic and behavioral correlates of conditioned fear. *Journal of Neuroscience, 8*(7), 2517-2529.

McCraty, R., Atkinson, M., Tiller, W. A., Rein, G., & Watkins, A. D. (1995). The effects of emotions on short-term power spectrum analysis of heart rate variability. *American Journal of Cardiology, 76*(14), 1089-1093.

Mendolia, M., & Kleck, R. E. (1993). Effects of talking about a stressful event on arousal: Does what we talk about make a difference? *Journal of Personality and Social Psychology, 64*(2), 283-292.

Pittam, J., & Gallois, C. (1986). Predicting impressions of speakers from voice quality: Acoustic and perceptual measures. *Journal of Language and Social Psychology, 5*, 233-247.

Pittam, J., Pittam, B. S., Burnstock, G., & Purves, R. D. (1987). Discrimination of five voice qualities and prediction to perceptual ratings. *Phonetica, 44*(1), 38-49.

Popov, V. A., Simonov, P. V., Frolov, M. V., Khachatur'iants, L. S., & Pastushenko, L. T. (1971). Chastotnyi spektr rechi kak pokazatel' stepeni i kharaktera emotsional'nogo napriazheniia u cheloveka. *Zhurnal Vysshei Nervnoi Deiatelnosti Imeni I. P. Pavlova, 21*(1), 104-109.

Porges, S. W. (1983). Heart rate patterns in neonates: A potential diagnostic window to the brain. In T. Field & A. Sostek (Eds.), *Infants born at risk: Psychological, perceptual, and cognitive processes* (pp. 3-22). New York: Grune & Stratton.

Porges, S. W. (1995). Cardiac vagal tone: A physiological index of stress. *Psychophysiology, 32*(4), 301-318.

Porges, S. W., Arnold, W. R., & Forbes, E. J. (1973). Heart rate variability: An index of attentional responsivity in human newborns. *Developmental Psychology, 8*, 85-92.

Porges, S. W., & Byrne, E. A. (1992). Research methods for measurement of heart rate and respiration. *Biological Psychology, 34*(2-3), 93-130.

Porges, S. W., Doussard-Roosevelt, J. A., & Maiti, A. K. (1994). Vagal tone and the physiological regulation of emotion. *Monographs of the Society for Research in Childhood Development, 59*(2-3), 167-186.

Rosenfeld, H. M. (1987). Conversational control functions of nonverbal behavior. In A. W. Siegman & S. Feldstein (Eds.), *Nonverbal behavior and communication* (pp. 563-601). Hillsdale, NJ: Lawrence Erlbaum Associates.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110*(1), 145-172.

Schachter, S., & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review* (69), 379-399.

Scherer, K. R. (1978). Personality inference from voice quality. The loud voice of extraversion. *European Journal of Social Psychology, 8*, 4674-4687.

Scherer, K. R. (1979). Personality markers in speech. In K. R. Scherer & H. Giles (Eds.), *Social markers in speech* (pp. 147-209). Cambridge, UK: Cambridge University Press.

Scherer, K. R. (1981). Vocal indicators of stress. In J. K. Darby (Ed.), *Speech evaluation in psychiatry* (pp. 171-187). New York: Grune & Stratton.

Scherer, K. (1984a). On the nature and function of emotion: A component process approach. In K. Scherer & P. Ekman (Eds.), *Approaches to emotion* (pp. 293-318). Hillsdale, NJ: Lawrence Erlbaum Associates.

Scherer, K. R. (1984b). Emotion as a multicomponent process: A model and some cross cultural data. *Review of Personality and Social Psychology, 5*, 37-63.

Scherer, K. R. (1986). Dynamics of stress: Physiological, psychological and social perspectives. In M. H. Appley & R. Trumbull (Eds.), *Voice, stress, and emotion* (pp. 157-179). New York: Plenum Press.

Scherer, K. (1989a). Vocal correlates of emotional arousal and affective disturbance. In H. *Wagner* & A. *Manstead* (Eds.), *Handbook of social psychophysiology* (pp. 165-197). Chichester, UK: Wiley.

Scherer, K. R. (1989b). Emotion psychology can contribute to psychiatric work on affect disorders: A review. *Journal of the Royal Society of Medicine, 82*(9), 545-547.

Scherer, K. R., & Scherer, U. (1981). Speech behavior and personality. In J. K. Darby (Ed.), *Speech evaluation in psychiatry* (pp. 115–135). New York: Grune & Stratton.

Schweiger, E., Witling, W., Genzel, S., & Block, A. (1998). Relationship between sympathovagal tone and personality traits. *Personality and Individual Differences*, *25*, 327–337.

Simonov, P. V., Frolov, M. V., & Ivanov, E. A. (1980). Psychophysiological monitoring of operator's emotional stress in aviation and astronautics. *Aviation, Space, and Environmental Medicine*, *51*(1), 46–49.

Stifter, C. A., Fox, N. A., & Porges, S. W. (1989). Facial expressivity and vagal tone in five- and ten-month-old infants. *Infant Behavior and Development*, *12*, 127–113.

Strack, F., Schwarz, N., & Gschneidinger, E. (1985). Happiness and reminiscing: The role of time perspective, affect, and mode of thinking. *Journal of Personality and Social Psychology*, *49*, 1460–1469.

Tesser, A. C. L., & Clary, G. (1978). Affect control: Process constraints versus catharsis. *Cognitive Therapy and Research*, *2*(3), 265–274.

Valensi, P., Gautier, J. F., Amarenco, G., Sauvanet, J. P., Leutenegger, M., & Attali, J. R. (1997). Neuropathie autonome chez le diabetique. *Diabetes & Metabolism*, *23*(1), 89-99.

Vita, G., Princi, P., Calabro, R., Toscano, A., Manna, L., & Messina, C. (1986). Cardiovascular reflex tests. Assessment of age-adjusted normal range. *Journal of Neurological Science*, *75*(3), 263–274.

Williams, C. E., & Stevens, K. N. (1972). Emotions and speech: Some acoustical correlates. *Journal of the Acoustical Society of America*, *52*(4), 1238–1250.

Williams, C. E., & Stevens, K. N. (1981). Vocal correlates of emotional states. In J. K. Darby (Ed.), *Speech evaluation in psychiatry* (pp. 221–240). New York: Grune & Stratton.

Winkworth, A. L., Davis, P. J., Adams, R. D., & Ellis, E. (1995). Breathing patterns during spontaneous speech. *Journal of Speech and Hearing Research*, *38*(1), 124–144.

Zei, B., & Archinard, M. (1998). La variabilité du rythme cardiaque et la différentiation prosodique des émotions. In (Ed.), *Actes des XXIIèmes Journées d'Etudes sur la Parole* (pp. 167–170). June, Martigny, Switzerland.

Zei, B., & Archinard, M. (2001). Emotional Consequences of Diabetic Neuropathy [abs]. *Psychosomatic Medicine*, *63*, 186.

Zei, B., & Archinard, M. (2002). Acoustic patterns of emotions. In E. Keller, G. Bailly, A. Monagham, J. Terken, & M. Huckvale (Eds.), *Improvements in speech synthesis* (pp. 237–245). Chichester, UK: Wiley.