ISTITUTO ITALIANO PER GLI STUDI FILOSOFICI
SERIES ON BIOPHYSICS AND BIOCYBERNETICS,
COORDINATING EDITOR : CLOE TADDEI-FERRETTI
Vol.10 - Biocybernetics 2001

Emotions, Qualia, and Consciousness,
Edited by Alfred Kazniak
World Scientific

THE ROLE OF AUTONOMIC BALANCE IN EXPERIENCING EMOTIONS

pp 278-284

BRANKA ZEI and MARC ARCHINARD
Geneva University Hospitals, Liaison Psychiatry,
51 Blvd de la Cluse, CH 1205 Geneva, Switzerland

ABSTRACT

This research explores the role of the physiological component of emotional arousal. The concept of autonomic balance is presented theoretically and operationalized through measurement of heart rate variability (HRV). The role of the latter is examined in its relation to emotional arousal, as reflected in both subjective feeling and nonverbal vocal expression. Extraversion, as personality trait, and state anxiety, are included in the experimental design. The results lend support to the hypothesis that the subjects with low HRV experience flattening of emotional reactions mainly in vocal expression, but also in subjective feeling. Implications of the findings are discussed in terms of the influence of HRV on interoception, and emotional awareness.

1. Introduction and Theoretical Framework

Emotions have been characterised as psycho-physiological phenomena that include cognitions, visceral, humoral and immunological reactions, vocal and other non verbal expressive displays as well as activation of behavioural dispositions. The latter are supported by the autonomic nervous system (ANS).

Most studies on the ANS component of emotional reactions have focused on sympathetic activation (for an extensive survey sees Cacciopo, Klein, Berntson, & Hatfield, 1993). However, thee role of the parasympathetic branch of the ANS has not received equal attention in research involving adults. Within the framework of developmental psychology (Porges et al., 1994) research has demonstrated that the base-level of vagal tone (defined as amount of inhibitory influences on the heart by the parasympathetic nervous system influences the expression and regulation of emotion as well as behavioural patterns in children (Porges 1992, 1995; Porges et al., 1994). The base-level vagal tone has thus been related to autonomic responsivity in general. The latter has more recently been conceptualised in terms of autonomic balance (Friedman & Thayer, 1998) which is reliably quantified through measurement of heart rate variability (HRV). Although higher HRV is associated with normal emotional reactions, low HRT appears to be related to a series of affective and cognitive disturbances (Eysenck, 1985, Friedman & Thayer 1996; Klein, Cnaani, Harel, Braun, & Ben-Haim, 1995; Yeragani, Balon, & Pohl, 1990; Yeragani, et al.,1995).
In order to explore the neurological underpinnings of emotions, we considered it meaningful to study the relationship between vagal tone as indicator of autonomic balance, and emotional

reactions reflected in vocal arousal and subjective feeling. We also assumed that the degree of awareness of the subjective feeling could be linked to autonomic arousal.
The influence of emotional autonomic activation on vocal behaviour was first modelled by Williams and Stevens (1972) in terms of direct causal relationships between dominantly sympathetic or dominantly parasympathetic activation on the one hand and voice intensity, vocal cord vibration and timing of speech on the other. We thus defined *vocal arousal* as a set of speech characteristics related to an emotional state. Porges et al (1994) provided a precise description of the link between vagal tone and vocal expression of emotion. Following the vocal feedback hypothesis (Hatfield, Hsee, Costello & Denney, 1995) whereby the degree of subjective experience is influenced by proprioceptive and auditory feedback, we assumed that the degree of emotional awareness could also be correlated with the degree of vocal arousal.

2. Hypotheses:

The basic vagal tone (expressed in HRV index units) influences emotional reactions in that the subjects with low HRV were predicted to display:

- A general flattening of vocal arousal and weaker vocal differentiation of emotions More specifically, vocal arousal being predicted as higher in anger than in sadness (Scherer & Zei, 1988; Scherer, Banse, Wallbott, & Goldbeck, 1991; Banse & Scherer, 1996), vocal differentiation of high versus low vocal arousal states would be diminished in subjects with low vagal tone.
- Lower levels of subjective emotional feeling.
- The awareness of an emotional state would be positively correlated with the degree of vocal arousal.

Methods

3.1 Subjects

Forty diabetic patients (18 female and 22 male) varying in age (range= 31-73 years, mean = 56; sd=9) and duration of illness(range 1-36 years; meN =15; SD=11) served as subjects for the study. Some of the patients has low levels of vagal tone due to leesions of the ANS known as autonomic neuropathy.

3.2. Physiological and Psychological Measures

Two standard tests of the autonomic function (Vita G; Princi P. 1986) were applied. They both measure the heart rate variability in two conditions: (1) Heart rate difference in deep breathing and (2) Lying-to standing heart rate ratio. The results were age adjusted and combined into a composite HRV index. Psychological measures included Speilberger state anxiety scale and Eysenck personality inventory.

3.3 Induction of emotions and vocal data

The subjects were asked to verbally recall their personal emotional experiences of joy, anger, and sadness. At the end of each recall they were asked to pronounce, on a mood congruent tone, the sentence “ALORS TU ACCEPTES CETTE AFFAIRE” ("So you accept the deal"). The sentence was presented in writing without punctuation so as not to suggest any tone of voice. The subjects were then asked whether they had subjectively felt (and to what degree) the emotion described during their recall. The results were coded on a scale: 0-3, (ranging from "not at all" to "very much"). The subjects’ voices were recorded on a DAT recorder. The distance of the microphone to the mouth was kept constant.

3.4 Acoustical Analyses

One hundred and twenty samples of the standard sentence were acoustically analysed.
Three categories of vocal arousal indicators were extracted:
(1) Fundamental frequency (F0) of vocal cord vibrations computed from the signal digitised at 44 kHz. The following F0 parameters were extracted from the pitch curves and expressed in Hz.

- Mean, median, mode
- Range between 5^{th} - 95^{th} percentile, 5^{th} percentile
- Maximum/minimum ratio, sd, coefficient of variation.

(2) Acoustic energy computed from the raw signal values. The following energy parameters were extracted from the amplitude envelopes and expressed in pseudo-decibel units:

- Maximum voiced energy
- Minimum voiced energy
- Mean voiced energy
- Voiced energy range. The measurement was done at mid-point values of vowel nuclei.

(3) Speed of delivery expressed in the number of syllables uttered per second. Prior to the measurement of the total signal length, all inter syntagmatic pauses had been edited out. The speed of delivery thus corresponded more closely to articulation speed. The latter was expected to be slower in sadness than in anger.
All the acoustical analyses were done by means of Macintosh platform software "Signalyze" (Keller 1995).

3.5 Data Transformations and Creation of New Variables

In order to make the data directly comparable on a common scale, z-scores were calculated for all vocal parameters. Autonomic tests results were age adjusted and normalised against external reference values from healthy subjects (Vita & Princi, 1986). A cumulated score on both tests was taken as HRV index for each patient.

On the basis of curve fitting and upon inspection of partial correlations with HRV index (controlling for age, anxiety state and extroversion), as well as linear multiple regression analyses three vocal parameters appeared as significantly related to HRV index. These were: F0Max/min ratio, voiced energy range and the rate of delivery. We then calculated a summary score reflecting the overall degree of vocal arousal (Vocal Arousal Index) for each condition (anger, joy, sadness). We justify cumulating the three parameters into a composite score by the fact that while each of them can vary independently, they often maintain trading relationships and appear in configurations representing the speaker's personal way of signalling affect. Some speakers use mainly pitch parameters, others use mainly energy parameters or speed of delivery or any combination of the three basic dimensions of prosody.

Since we expected the subjects with high HRV index to exhibit higher Vocal Arousal Index in anger than in sadness, we then calculated the delta between the vocal arousal index obtained in expressing anger and that obtained for sadness. Each subject was thus characterised by his/her Vocal Arousal Delta Index (ΔdB+ΔMax/MIN+Δrate) reflecting the degree of his/her vocal differentiation between anger and sadness.

4. Results

4.1 Vocal Arousal

We performed liner multiple regressions (stepwise method) with Vocal Arousal Delta Index as dependent variable and HRV index, demographic and psychological variables as independent variables. The results of the regressions show a highly significant effect for HRV index (T = 7.189; p < = .0001) and a much lesser effect for state anxiety (T = -2.052; p .0470). The HRV index alone explained 58% of data variance while the multiple R=.79. None of the other variables contributed significantly. From these results we can conclude that vocal differentiation of emotions is related, above all, to the HRV and marginally on the state anxiety.

4.2 Self-Reported Subjective Feeling

Seventy-five percent of subjects reported felt anger (mean = 1.7; sd = 1.24), 97.5 % reported felt joy (mean = 2.5; sd = .78) and 95 % of the subjects reported felt sadness.

Mann-Whitney U tests with groups obtained by median split on HRV index, showed significant differences in the degree of felt sadness (Z = - 3.3; P=.0009), and anger (Z = - 2.4; P = .02). The groups with higher HRV reported higher degree of subjective feeling for both sadness and anger than those with lower HRV. By contrast the correlations between Vocal Arousal Index and the degree of subjective feeling (controlled for demographic and psychological variables) did not reveal any significant correlation.

An unexpected finding concerned weeping episodes. Seventy seven percent of subjects wept during the recall of sadness. The degree of weeping was coded from 0-3 with: 0 = absence of visible weeping; 1 = noticeable tears in the eyes; 2 = tears running down the face; 3 = tears running down the face accompanied by speaking difficulties. Correlations between the degree of crying and HRV index (controlled for anxiety, extroversion, gender and age) were calculated. They revealed highly significant correlations (r = .56, P = .000).

5. Discussion

Our hypothesis 1 was confirmed in that, HRV index as indicator of autonomic balance was found to be related to emotional arousal. The subjects with lower HRV exhibited a flattening of emotional reactions in two domains: vocal arousal and subjective emotional feeling. More specifically: (1) vocal differentiation between anger and sadness was smaller in subjects with low HRV compared with those with higher HRV, and (2) the degree of self reported subjective feeling was proportional to degree of HRV.

As for the unexpected finding concerning the degree of weeping being proportional to the HRV index, we had two complementary interpretations: (1) in neuropathic subjects the destruction of the parasympathetic nerves causes diminished tearing, and (2) the emotional experience of sadness is altogether lesser in subjects with low HRV.

Our hypothesis 2 was not confirmed in that the degree of subjective feeling was not found to be related to the degree of vocal arousal.

Our results concerning the flattening of emotional reactions agree with those of Andreasen and colleagues (Andreasen et al 1981) whose experiment demonstrated that affective flattening is reflected in speech in a diminished variance in both amplitude and fundamental frequency of speech. The authors consider the acoustic analysis of voice patterns as an objective means of evaluating flatness of affect.

As to the results concerning subjective feeling, it appears meaningful to consider an explanation whereby higher levels of HRV could enhance the interoception of one’s own cardiac response to emotional stress and consequently result in a higher degree of emotional awareness. Such a hypothesis would be in agreement with the findings of Davis (Davis, M.

R., Langer, A. W., Sutter, J. R., Gelling, P. D., & Marlin, M., 1986) where the subjects with high heart rate variability displayed more accurate perception of their own heart beat rates. In view of these findings it appears meaningful to assume that awareness of the strength of a subjective emotional feeling covaries with the degree of autonomic arousal and its interoception. The latter thus appears to be related to HRV index as indicator of basic non-emotional autonomic responsivity and/or autonomic balance.

References:

Andreasen, N. C., Alpert, M., Martz, M. J. (1981) Acoustic Analysis. Arch Gen Psychiatry, 38, 281-285.

Banse, R., & Scherer, K.R. (1996). Acoustic Profiles in Vocal Emotion Expression. Journal of Personality and Social Psychology, 70, No 3, 614-636.

Bruchon-Schweitzer, M. (1983). C.D. Spielberger: Inventaire d'anxiété état-trait, Forme Y. Consulting Psychologists Press Inc.

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.

Davis, M. R., Langer, A. W., Sutter, J. R., Gelling, P. D., & Marlin, M. (1986). Relative discriminability of heartbeat-contingent stimuli under three procedures for assessing cardiac perception. Psychophysiology, 23, 76-81.

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

Eysenck, H.J., & Eysenck M.J. (1985). Personality and individual differences. New York: Plenum Press.

Friedman, B.H., & Thayer, J.F. (1996). Spectral characteristics of heart period variability in shock avoidance and cold face stress in normal subjects. Clin Autonom Res, 6, 147-152.

Friedman, B.H., & Thayer, J.F. (1998). Autonomic balance revisited: Panic anxiety and heart rate variability. Journal of Psychosomatic Research, 44, No 1, 133-151. Elsevier Science Publishers B.V.

Hatfield, E., Hsee, C. K., Costello, J., Schalekamp Weisman, M., Denney, C. (1995). The impact of Vocal Feedback on Emotional Experience and Expression. Journal of Social Behavior and Personality, Vol 10, 2, 293-312.

Klein, E., Cnaani, E., Harel, T., Braun, S., & Ben-Haim, S.A. (1995). Altered heart rate variability in panic disorder patients. Biol Psychiatry 37, 18-24.

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

Scherer, K. R., & Banse, R. ; Wallbott, H.G., & Goldbeck, T. (1991). Vocal cues in Emotion Encoding and Decoding. In A.M. Isen (Eds.), Motivation and Emotion, 15, No 2, New York: Plenum Publishing Corporation.

Scherer, K.R., & Zei, B. (1988). Vocal Indicators of Affective disorders. Psychotherapy and Psychosomatics, 49, 179-186.

Vita, G., Princi, P., Calabro, R., Toscano, A., Manna, L., & Messina, C. (1986). Cardiovascular Reflex Tests. Journal of the Neurological Sciences, 75, 263-274. Elsevier: Science Publishers B.V. (Biomedical Division).

Williams, C. E., & Stevens, K.N. (1972). Emotions and speech: Some acoustical correlates. J Acoust Soc Am, 52, 1238-1250

Yeragani, V.K., Pohl, R., Srinivasan K., Balon, R., Ramesh, C., & Berchou, R. (1995). Effects of isoproterenol on heart rate variability patients with panic disorder. Psychiatry Res, 56, 289-293.

Yeragani, V.K., Balon, R., & Pohl, R., (1990). Decreased R-R variance in panic disorder patients. Acta Psychiatrica Scand, 81, 554-559.