Emotions, Qualia, and Consciousness, Ed: A. Kazniak. pp 278-284.

Istituto Italiano per gli studi filosofici
Series on Biophysics and Biocybernetics
Vol.10- Biocybernetics

THE ROLE OF AUTONOMIC BALANCE IN EXPERIENCING EMOTIONS

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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 non-verbal vocal expression. Extraversion, as personality trait, and state anxiety, are included in the experimental design. The results lend support to the hypothesis that 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 behavioral dispositions. The latter are supported by the autonomic nervous system (ANS),

Most studies on the ANS component of emotional reactions have focused on the sympathetic activation (for an extensive survey, see Cacioppo, Klein, Berntson, & Hatfield, 1993). However, the 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 the amount of inhibitory influences on the heart by the parasympathetic nervous system) influences the expression and regulation of emotion as well as behavioral 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 HRV 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 subjective feeling would be linked to autonomic arousal.

The influence of autonomic activation on vocal behavior was first modeled 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 the 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, 1995), 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.

3. 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 ; mean =15 ; sd = 11), served as subjects for the study. Some of the patients had low levels of vagal tone due to lesions of the ANS, known as autonomic neuropathy.

3.2 Physiological and Psychological Measures

Two standard tests of the autonomic function (Vita *et al.*, 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 the Speilberger State Anxiety Scale and the 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, in 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 of 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
- 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 a 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 *et al.*, 1986). A cumulated score on both tests was taken as the HRV index for each patient.

On the basis of curve-fitting, and upon inspection of partial correlations with the HRV index (controlling for age, anxiety state and extroversion), as well as linear multiple regression analyses, three vocal parameters appeared as significantly related to the HRV index. These were: F0 max/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, while others use mainly energy parameters, 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 Differential 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 linear multiple regressions (stepwise method) with Vocal Arousal Differential Index as the 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 with 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 to anxiety state.

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 a higher degree of subjective feeling for both sadness and anger than did 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 show 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. The correlation between the degree of crying and HRV index (controlled for anxiety, extroversion, gender and age) was calculated, revealing a highly significant relationship (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 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 for the results concerning subjective feeling, it appears meaningful to consider an explanation whereby higher levels of HRV may 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 *et al.* (1986), where subjects with high heart rate variability displayed more accurate perception of their own heart 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.

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