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Striking a chord: Moods, blood pressure, and heart rate in everyday life

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Abstract

The objective of this study was to assess the relation between the intensity of single moods and of mood combinations on blood pressure (BP) and heart rate (HR). The subjects were 203 healthy registered nurses, all women, who were studied on two work and two off days. Ambulatory BP and HR were recorded every 20 min. On each occasion subjects rated their moods on a 5-point scale. Graded increases in BP and HR were shown with higher ratings of negative moods and decreases for a mood related to energy level. Little change was observed for a positive mood. These effects depended on concurrent changes in other moods. A positive mood countered the effects of a negative mood, whereas two negative moods resulted in unique patterns of BP and HR. The energy level mood moderated the cardiovascular effects of positive and negative moods. Ambulatory methods provide a way of probing into the nature and consequences of everyday emotional experiences.

Descriptors: Mood, Emotion, Ambulatory, Blood pressure, Heart rate

The study of emotional states is a fundamental topic in psychology with continuing debate about their definition and relation to physiological processes and mental and physical health. In a recent review, Cacioppo and Gardner (1999) do not define emotion but rather summarize recent methodological developments and conceptual issues and conclude that "emotion is a short label for a very broad category of experiential, behavioral, sociodevelopmental, and biological phenomena" (p. 194). Despite the huge literature, no single viewpoint has been sufficient to account for the diversity of human emotional experience and behavior.

Emotions are seen by some researchers as brief discrete response patterns, representing a small set of "pure" emotions (see Ekman & Davidson, 1994). In the laboratory, various methods are used to induce specific emotional states and determine how they may be differentiated physiologically (e.g., Sinha, Lovallo, & Parsons, 1992). In everyday life, however, emotional experiences and reactions are not unitary, and they vary in their duration, complexity, and intensity. The term "mood" used in the present paper refers to emotional states that may persist over minutes to hours. Moods often involve combinations of different emotional states and may be mixed in nature. Pervasive emotional reactions of an either-or quality may be distinguished from multifaceted emotional experiences that include opposite feelings and blends of emotion as part of a single reaction (Lane & Schwartz, 1987). For example, anxiety in anticipation of meeting someone one does not know may differ in its quality depending on concurrent evaluations of the potential positive outcome of the encounter. Anger may differ if it is associated with anxiety or with sadness or if it is mixed with positive feelings about the target of the anger. Even for a presumed unitary emotional state such as anxiety, two subtypes (anxious apprehension and anxious arousal) appear to be associated with different physiological mechanisms (Nitschke, Heller, Palmieri, & Miller, 1999). Little attention has been given to the study of such mood mixtures, although the rich language of emotions suggests the many different shadings of emotional experience. A major objective of the present paper is to determine how combinations of common words used to judge one's emotional states are associated with cardiovascular responses, for example, the different effects on blood pressure (BP) of reports of being anxious and happy versus being anxious and angry. Inasmuch as various emotional states, such as anger and anxiety, have been implicated in the etiology of hypertension, it is important to document how different combinations of moods affect cardiovascular responses.

Emotional states also vary in their intensity, a fact that has long been acknowledged but seldom studied systematically in the laboratory, reflecting the difficulty encountered in calibrating eliciting stimuli in terms of expected emotional intensity. Recent ambulatory BP studies have begun to examine the significance of emotional intensity and of moods more generally for BP and heart rate (HR). In one of the first studies, Sokolow and his colleagues

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showed that negative affect states during ordinary daily life were associated with a rise in BP (Sokolow, Werdegar, Perloff, Cowan, & Brenenstuhl, 1970). Since then, ambulatory studies continue to document the significance of moods for BP, although the magnitude of the effects for particular moods and the direction of differences in BP between different kinds of moods vary from study to study, and the effects also vary as a function of health status and ethnicity (Brown, James, & Nordloh, 1998; Gellman et al., 1990; James, Yee, Harshfield, Blank, & Pickering, 1986; Southard, Eisler, & Skidmore, 1988). In a study of 125 men who were patients referred to a hypertension center (James & Pickering, 1991), mood ratings contributed a significant source of variation to BP; the study used 10-point mood scales, but no specific findings are given on the relation between mood intensity and BP. In a mixed sample of hypertensive and normotensive subjects, positive and negative mood were associated with higher BP, but reports of feeling tired (presence or absence) were related to a decrease in BP (Schwartz, Warren, & Pickering, 1994). A similar pattern of findings was reported by Jacob et al. (1999) who concluded that BP responses are related to the degree of engagement of a mood rather than its unpleasantness. In a study of traffic agents (Brandolo, Karlin, Alexander, Bobrow, & Schwartz, 1999), out of a variety of positive and negative moods, only happiness showed an effect; the lower the level the lower the systolic BP. In healthy subjects, small increases in BP were observed for both negative and positive mood compared to bored mood (Raikkonen, Matthews, Flory, Owens, & Gump, 1999). In a community sample of employed people, BP and HR were elevated during periods of high negative affect and high arousal (alert) (Kamarck et al., 1998). These mood effects were independent of one another. In an earlier study in our laboratory, we used cluster analysis to distinguish groups of subjects according to the pattern of average daily moods (Shapiro, Jamner, & Goldstein, 1997). Subjects with mood patterns characterized as negative across the board showed the highest levels of BP, especially the profile involving a high frequency of reports of anger combined with anxiety and other negative moods. These subjects tended to have high scores on trait measures of hostility and anxiety. Other findings in the study suggested that positive mood may undo the effects of negative mood. No data were presented on the relation between momentary self reports of mood states and BP or HR.

Various methods have been used to obtain self reports of moods and emotional states. These include lists of mood terms in which a subject simply checks those that apply (Schwartz et al., 1994). This method is economical in the time needed to respond but does not permit the subject to indicate how intensely each mood is experienced. Examples are mild irritation versus extreme anger or mild apprehension versus fear. Another approach uses a structural model in which the subject checks one position on a circular dimension (circumplex) reflecting the "totality of the person's affective state space" (Jacob et al., 1999). This method assumes that one's multidimensional emotional experience can be readily integrated and simply coded by the subject into a single point on the circular scale. There is no simple consensus on the particular dimensions making up such a structure (Barrett & Russell, 1999). The most common self-report method and the one used in the present study asks subjects to rate their moods on numerical scales (see Jamner, Shapiro, & Alberts, 1998, for a more complete discussion of diary self-report methods).

Little information is reported in the above papers on the specific changes in BP and HR at different levels of intensity, and the effects of blended or combined emotional states has not been addressed. Further knowledge about these questions has both methodological implications, for example, on the choice of mood terms and design of mood self-report scales, and theoretical implications for the psychophysiology of hypertension and emotion more generally. In our view, the study of moods requires a broad theoretical perspective in which emotions are seen as involving parallel multiple coupled systems. The physiological mechanisms by which these systems are integrated and activate different cardiovascular and other physiological responses are only beginning to be addressed (see Lane & Schwartz, 1987; Nitschke et al., 1999). Moods reflect the output of these parallel subsystems, which are capable of influencing one another, such as in conflicting emotions. This framework would predict different physiological effects as a function of their net or integrated outputs.

The present research focused on the degree to which BP and HR are related to the intensity of single mood states and of paired mood states studied in everyday life. Multiple mood reports and associated physiological response levels were examined in a variety of naturally occurring events. Even though the external situations varied considerably from occasion to occasion, by examining a large number of observations, it was possible to determine how the intensity of different single moods and mood combinations were related to BP and HR. The research was partly motivated by the fact that 24-hr ambulatory BP compared to clinic-based casual assessments is a better predictor of the course and complications of hypertension (Parati, Pomidossi, Albini, Malaspina, & Mancia, 1987), and it addresses the question of whether the changes in BP associated with moods contribute to this association

The data were obtained from a large sample of premenopausal women, all of whom were working as nurses. The aim of the main project was to evaluate relations between ambulatory blood pressure and occupational stress, psychosocial factors, and individual characteristics in working women (see Goldstein, Shapiro, Chicz-DeMet, & Guthrie, 1999). The present objectives were (1) to examine the relation between levels of mood intensity and BP and HR at each observation over the course of numerous mood reports, and (2) to evaluate the relation between different combinations of mood states and BP and HR.

Based on the findings in the literature on specific mood effects and our own work on average daily moods and BP and HR (Shapiro et al., 1997), we hypothesized that the higher the intensity of a negative mood the higher the BP and HR. We also expected that concurrent high intensity levels of paired negative moods would be associated with further BP and HR elevations. Level of intensity of moods of a positive nature, however, should have little effect on BP or HR. However, the more positive the mood the more it should counter the effects of a negative mood.

Methods

Subjects

The subjects were 203 healthy registered nurses, premenopausal women between the ages of 24 and 50 [37.7 (6.6), mean (*SD*)], currently employed in hospitals and clinics in the Los Angeles area, with at least one year of experience in nursing; 49% were assigned to medical-surgical units, 29% to clinics, 15% to ICUs, and 7% to emergency rooms. Subjects worked on daytime 8-hr (48%), 12-hr (50%), or 10-hr shifts (2%). Exclusions were health problems, use of medications or oral contraceptives, severe obesity (BMI > 30 kg/m^2), pregnancy or childbirth within the last 12 months, or irregular menstrual cycle. The sample included 58% White, 14% African, 15% Latino, and 13% Asian Americans; 43%

were married and 57% had one or more children at home. Mean casual BP was 110.8 (7.9)/70.0 (6.4) mmHg.

Procedure

After an initial orientation session, 24-hr ambulatory BP was recorded from subjects on four separate days, a work day and an off day in each of two phases of the menstrual cycle. The follicular phase occurred 4–8 days after the onset of menstruation, and the luteal phase occurred 5–10 days after the surge in luteinizing hormones. The specific time periods were adjusted for cycle length. Ovulation was confirmed by plasma progesterone level. The order of sessions was counterbalanced for day and phase. Complete data were obtained on 171 nurses. The remaining 32 subjects completed at least one work day and one off day in one or the other phase. As similar patterns of findings were obtained in the sample of 171 as in the total sample, the entire set was used. For each subject, the daily recordings began at approximately the same time of day. An assistant met the subject about one half hour before her work shift began and at a comparable time on off days and applied the BP monitor to the nondominant arm. Subjects were asked to keep their arms still and at their side each time the device operated. They were also shown how operation of the device could be aborted if necessary by pressing a switch on the monitor.

Ambulatory Blood Pressure Monitor

The Accutracker II (Suntech Medical Instruments, Raleigh, NC) was programmed to operate every 20 min during waking hours and every 60 min during sleep on a quasi-random schedule. Only daytime waking data are considered in this report. On each occasion, single readings of systolic BP (SBP), diastolic BP (DBP), and HR were obtained. This instrument uses the auscultatory method of measuring BP and operates silently. The data were edited for artifacts and outliers using Accutracker error codes and following set rules. Acceptable SBP readings ranged from 75 to 200 mmHg, DBP from 40 to 120 mmHg, and HR from 40 to 150 bpm. If one or more of the three measures was excluded, the others were also removed. Eleven percent of the readings were excluded all together.

Diary and Mood Assessment

Subjects were asked to fill out a paper-and-pencil diary on each blood pressure cuff operation. They were able to complete the diary on 90% of the occasions with slight variations in compliance over days. On the average, 46 sets of diary entries per day per subject were available for analysis. The diary asked subjects to provide information on various topics of relevance to the aims of the parent study. With regard to the objectives of the present paper, subjects rated each of ten mood words from "none" to "extreme amount" using a 5-point numerical scale: stressed, happy, frustrated, alert, angry, sad, conflicted, tired, anxious, in control.

To simplify the presentation, five moods were selected for detailed study, based on preliminary analyses. An exploratory principal components analysis with varimax rotation of the entire set of mood ratings yielded two orthogonal dimensions with eigenvalues greater than 1.0. The first consisted of negative words, accounting for 31.6% of the total variance, and the second consisted of positive words, accounting for 20.2% of the variance. The negative moods were sad, stressed, frustrated, angry, conflicted, and anxious with factor loadings from .595 to .800. The positive moods were happy, alert, and in control with factor loadings from .611 to .866. Tired was the only mood not highly associated with either factor. A similar pattern of findings was obtained from a principal components analysis of mean mood ratings per subject. The independence of positive and negative moods accords with the conclusion that positive and negative affect comprise bivalent dimensions (Cacioppo & Gardner, 1999). From these results, we chose five moods out of the ten: one negative word (stressed) and one positive word (happy) plus a third relatively independent term (tired) that may be described as an indicator of energy level. The choice of stressed and happy was based on the wider dispersion of intensity levels in these compared to the other moods in the negative and positive sets, respectively. Two other moods (anxious, angry) were also included because of the commonly explored role of anxiety and anger in hypertension and BP regulation.

Data Analysis

The data set consisted of multiple longitudinal readings of SBP, DBP, and HR, each measured contemporaneously with five mood ratings of varying intensity (1–5). As exemplified in recent papers (Jacob et al., 1999, Raikkonen et al., 1999; Schwartz et al., 1994), random effects regression models are considered most appropriate for these kinds of repeated measures data. These models consider both within- and between-subject variability, and allow for random and fixed effects (mixed modeling) as well as a variable number of observations per subject and missing data. PROC MIXED (SAS Institute) was the program employed for general linear mixed modeling.

The mixed model expands the standard linear regression model to the random effects model as follows:

$$\mathbf{Y}_i = \mathbf{X}_{i\,B_i} + \mathbf{Z}_{i\,U_I} + \mathbf{e}_i$$

where **Y** is the vector of dependent observations, **X** is the known matrix of values of the independent variables, **b** is the vector of regression parameters, **u** is an unknown vector of random effects with known model matrix **Z**, **e** is an unknown random error vector that is no longer required to be independent, and the is denote that the observations and known matrixes are specific to each subject (Laird & Ware, 1982).

Repeated daily measurements over time in every research subject constitute a cluster of observations. The random effects model can account for the heterogeneity from one such cluster of observations to another and thereby model the lack of independence. This approach is particularly suitable to the present study because the periodicity of mood and physiological measurement is likely to be highly heterogeneous. Modeling each subject as a random effect using this procedure would somewhat accommodate the interindividual variation in mood-BP or mood-HR relationships, and allow a standardized evaluation of these relationships by essentially treating the subject's cluster of observations as a random sample of intercepts and slopes (regression parameters) from some underlying population distribution. Each subject acts as her own control over time. For each model, a common regression slope was estimated and statistical significance of fixed effects (mood on BP or mood on HR) was attributed to p values < 0.05 for two-sided t statistics. Serial correlation in independent and dependent variables can lead to a lack of independence in residual errors and bias the estimation of statistical significance. To account for this, each model included an autoregressive parameter (AR1) (Laird & Ware, 1982). Moods were treated as class variables in the analyses.

Previous ambulatory studies approach the analysis of mood data in different ways. Raikkonen et al. (1999) assert without explanation that it is important in the models to control for other determinants of BP such as concurrent posture, location, physical inactivity, and drug or alcohol intake. For Jacob et al. (1999), the decision to include or exclude a potential covariate is seen as dependent on whether it is considered more proximal than mood in its relation to the dependent variable, in this case BP or HR. A covariate may be intrinsically related to a mood state. For example, anger may be associated with increased muscle tension or agitation. Or the effects of covariates on BP and HR might be mediated by the moods or emotional states they induce. For example, a sitting position may more likely be associated with positive rather than negative mood (Brown et al., 1998), although this study also concluded that these relationships are coincidental rather than causal. Gellman et al. (1990) reported that significant effects of mood were observed when subjects were sitting but not when they were standing. They concluded that the increased BP needed to sustain subjects in a standing position overrides the effects of mood, but they also noted that differences in movements and activity in the two postures rather than posture per se may account for the finding. Under conditions controlled for activity level, sitting and standing BP differ only slightly (Goldstein & Shapiro, 1988), and there is no basis for assuming that mood is related to BP in any bodily position. As Jacob et al. (1999) point out, by controlling for some or all of these variables, the real mood-BP relation might be obscured or eliminated. Our position is that there is no sure way to know what factors are more proximal than mood as determinants of BP and HR. Our objective was to directly quantify relations between BP and HR and subjects' ratings of the intensity of single and paired moods.

First, the intensity of each single mood was related to each dependent variable: SBP, DBP, HR. Then, each model was repeated entering in two mood variables at a time and their interaction (ten pairings of the five moods) to determine how different combinations of moods, each at five levels of intensity, was associated with BP and HR. In displaying the results for the mood combinations, surface contour plots of mood/blood pressure relationships were fitted using a distance-weighted-least-squares (DWLS) smoothing procedure (McLain, 1974). DWLS produces smoothed values at any desired collection of values along the x and y scales. The surface curve is fitted through a set of points by least squares. For DWLS, every point on the smoothed surface requires a weighted quadratic multiple regression on all the points. The resulting locally weighted three-dimensional surface is allowed to flex locally to fit the data better than through linear or low-order polynomial smoothing. The DWLS fit was computed at 200 equally spaced values along the x and y scales, beginning with the minimum values of x_i and ending at the maximum. The amount of flex was controlled by a tension factor of .30 indicating that 30% of the data are used to smooth each value on the curve.

Day and menstrual cycle were not considered as variables. There were small differences in the mood ratings as a function of work or off day, and no differences were related to menstrual phase. As the design was balanced, moods were sampled in a more or less equivalent fashion for the four days of study, and all moods reported over the four days were considered to comprise the data set.

Results

Table 1 provides descriptive data on the percentage of reports at each level of intensity of each mood. In general, subjects reported negative moods infrequently, especially at the highest intensity levels. For the three negative moods (stressed, anxious, angry), most reports were at level 1 (none), ranging from 59% for stressed to 94% for angry. For negative mood intensities above level 2, the frequencies were small, ranging from 2% for angry to 12% for stressed. Anger was either not experienced or not reported very often in these subjects. The distribution of happy showed a more uniform level of response for intensity with the highest frequency in level 3. Ratings of tired were somewhat similar in spread to those for stressed but with greater endorsement of higher intensities.

Table 1. *Percent Mood Rating at Each Level of Intensity*

	Level				
	1	2	3	4	5
Stressed	59.5	29.8	9.6	1.7	0.4
Happy	10.4	20.4	34.7	23.3	11.1
Tired	42.7	30.2	18.2	7.1	1.9
Anxious	76.8	17.2	4.8	1.1	0.2
Angry	93.9	4.6	1.1	0.3	0.2

Note: The total number of ratings for each mood varies from 34,876 for anxious to 34,889 for stressed.

Figure 1 shows the relation between mood intensity and SBP, DBP, and HR, respectively, for each of the five moods. With the exception of happy, mood intensity was associated with a clear pattern of significant change in cardiovascular response levels, an increase for the three negative moods and a decrease for tired. The change in SBP from level 1 (none) to level 5 (extreme amount) varied from 2.5 mmHg for angry to 6.3 mmHg for stressed; for DBP, the change varied from 3.2 mmHg for angry to 3.9 mmHg for stressed; for HR, the range of change was 3.0 bpm for anxious to 5.3 bpm for stressed. For tired, all three measures showed a decline (5 mmHg for SBP and DBP and 6 bpm for HR). Although the effect for happy was significant for DBP, the change with intensity was very small. SBP and HR were not significantly associated with the intensity of happy.

In the 30 analyses of combined moods (10 mood pairs $\times$ 3 dependent measures), the mood-pair interaction reached the $p < .1$ level in 13 analyses. Of these, 9 were significant at $p < .05$. Out of the 13, 5 involved a negative-energy, 2 a positive-energy, 3 a positive-negative, and 3 a negative-negative mood pairing. We selected four cases with clearly interpretable patterns to exemplify each of these different types of mood combinations. These are displayed in 3-dimensional graphs. As shown in Figure 2, at low levels of happy, DBP was related to ratings of anxious but was unrelated to anxious at higher levels of happy. Thus, a happy mood appeared to undo the anxious-induced DBP elevation. In Figure 3, in which anxious is associated with another negative mood (angry), with anger rated at 1 (none), little change in SBP occurred with increasing intensity of anxious. However, with higher levels of angry (ratings of 2 to 3), SBP increased with higher intensities of anxious with a peak occurring at a moderate level of angry and a high intensity of anxious. A lesser peak in SBP occurred when both angry and anxious were at higher intensity. Angry in the absence of an anxious mood generates a pronounced peak in SBP. Stressed and tired showed a different pattern (Figure 4). The peak levels of DBP were found at high levels of stressed and low levels of tired. Stressed seemed more directly related to DBP at low as compared to high intensities of tired. In general, increasing ratings of tired were associated with decreasing levels of DBP, with this effect being more pronounced at higher levels of stressed. When

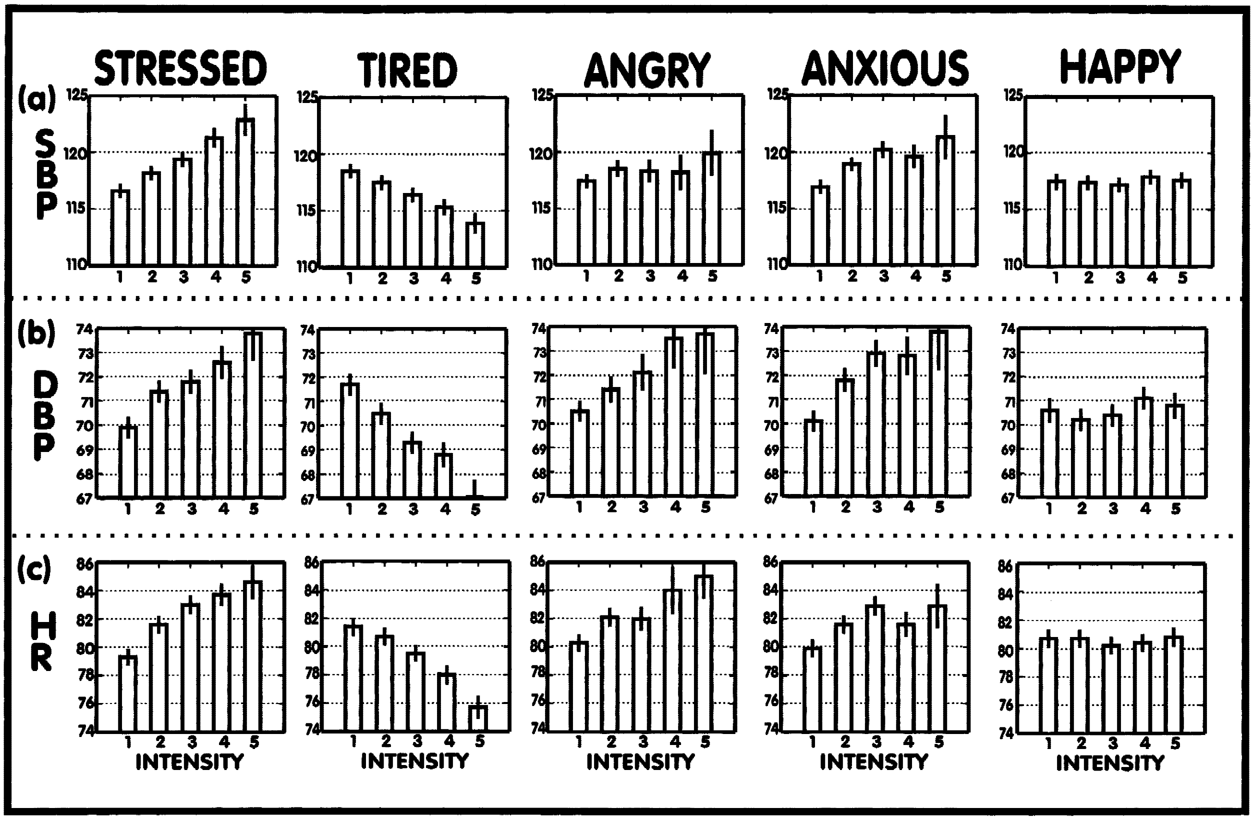

Figure 1. SBP, DBP, and HR levels for five moods at each level of intensity. For each mood effect, $df = 4{,}35000$. All the effects for stressed, tired, and anxious were significant at the .0001 level. For angry, all effects reached the .05 level. For happy, only the DBP effect was significant ($p < .005$). The F values for each mood for SBP, DBP, and HR, respectively, were as follows: stressed, 37.54, 29.79, 83.73; tired, 29.43, 52.91, 49.97; angry, 2.48, 5.23, 13.73; anxious, 26.03, 29.32, 29.23; and happy, 1.64, 3.96, 2.24.

happy was paired with tired (Figure 5), happy was relatively unrelated to DBP at lower ratings of tired, but showed a more direct relation with DBP when tired was rated higher. That is, happy was inversely related to DBP with higher ratings of tired. From the perspective of ratings of tired, a clearer negative relation was observed at higher levels of happy, whereas there was little relation with DBP at lower ratings of happy.

Discussion

The aim of this study was to see how the experience of moods sampled frequently by means of a diary in everyday situations on four days was related to concurrent physiological responses recorded with an ambulatory device. We selected five moods to determine how the intensity of each one by itself or in combination with each other mood was associated with BP and HR. For moods evaluated singly, the cardiovascular measures increased in a graded fashion with increases in the intensity level of negative moods (stressed, anxious, angry). A reverse pattern was shown for tired, a mood that probably reflects how energetic one feels. A positive mood (happy) showed little change with intensity level.

When moods were analyzed two at a time, significant interactions were observed, indicating that any one mood may have different implications for BP or HR, depending on concurrent changes in other moods. A positive mood may undo the effects of a negative mood, whereas the effects of multiple negative moods are more complex. When both are at relatively high levels of intensity, the physiological effects may be augmented. One's energy level (feeling tired) may also interact with the effect of either a positive or a negative mood on BP and HR.

The fact that the changes in BP and HR as a function of the intensity of single moods were as large and as consistent as they appear was not expected, given that subjects were making these judgments under all kinds of conditions on both work days and off days, at varying times of the day and evening, and in a large variety of settings and social contexts. As BP and HR are affected by many variables, the potential "noise" might well have hidden any effect of mood intensity. Moreover, subjects reported that they filled out the diaries quickly and with little deliberation. Yet the numbers picked by subjects to rate their moods were sufficient to yield consistent differences in BP and HR as the moods changed in intensity. The BP and HR effects of mood intensity were larger than those reported previously in ambulatory studies (e.g., Raikkonen et al., 1999). The direction of change in BP and HR for negative moods is consistent with earlier studies; however little change in BP or HR was observed for the intensity of happy, the positive mood used in the present study. The decrease in BP and HR in the case of tired accords with the findings of Jacob et al. (1999) and Schwartz et al. (1994), although their diary methods differed from ours. The importance of energy level as a factor mediating the BP effects of mood was also shown when tired occurred in combination with other moods.

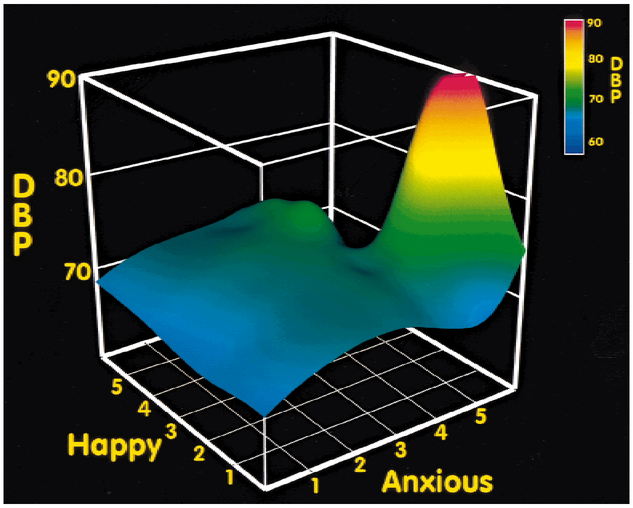

Figure 2. Changes in DBP as a function of the moods happy and anxious, $F(16{,}35000) = 1.93$, $p < .02$.

The structure of moods into negative and positive dimensions corresponds with the distinctions made in many earlier studies of emotion, and in this case the dimensions appear to be independent. Neuroanatomical evidence suggests that pleasant and unpleasant emotions have different neural substrates with greater activation of certain areas of the brain as measured by positron emission tomography (Lane et al., 1997) and electroencephalography (Heller, 1993; Davidson, 1993). A third dimension of mood was suggested by the results for the word "tired" which was not associated with either positive or negative moods. With higher ratings of tired, BP and HR decreased. Other studies have found comparable mood effects using such related words as "bored" or "sleepy" (Jacob et al., 1999; Raikkonen et al., 1999). Whether this dimension should be viewed as an emotional process or as an energy- or activation-moderating factor is unclear. The moods in the present

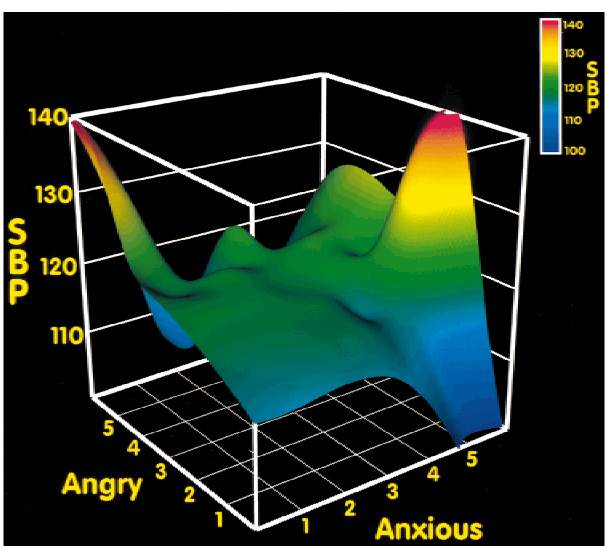

Figure 3. Changes in SBP as a function of the moods angry and anxious, $F(16{,}35000) = 2.14$, $p < .005$.

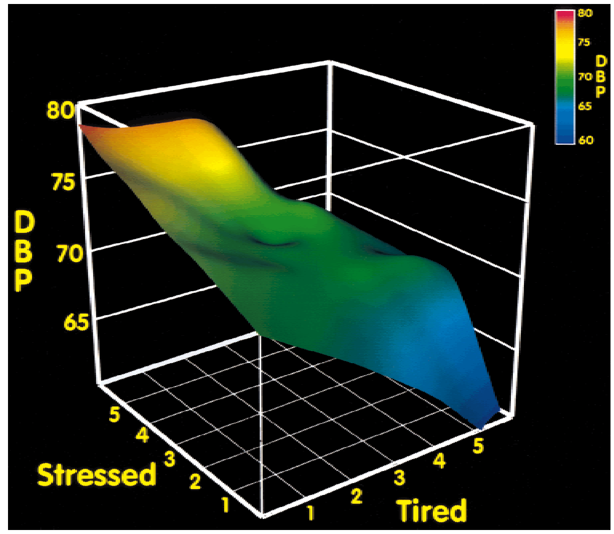

Figure 4. Changes in DBP as a function of the moods stressed and tired, $F(16{,}35000) = 1.76$, $p < .03$.

diary were selected on the basis of our previous work. How the structure would be affected by a different set of mood terms remains uncertain.

Whether one should rely on these dimensional structures is also open to question. Although the three negative moods discussed in this study presumably represent the same dimension, they were not identical in terms of their relation to BP or as shown by the findings on the interactive effects on BP of pairs of negative moods. Moreover, although the two dimensions (positive, negative) appear to be independent, based on the exploratory factor analyses, significant interactions were found with pairs of negative and positive moods. These interactions indicate nonlinear relations between pairs of moods and BP (or HR). In the analyses, mood intensity was treated as a class variable, thus making it possible to discern these relations easily. Even within

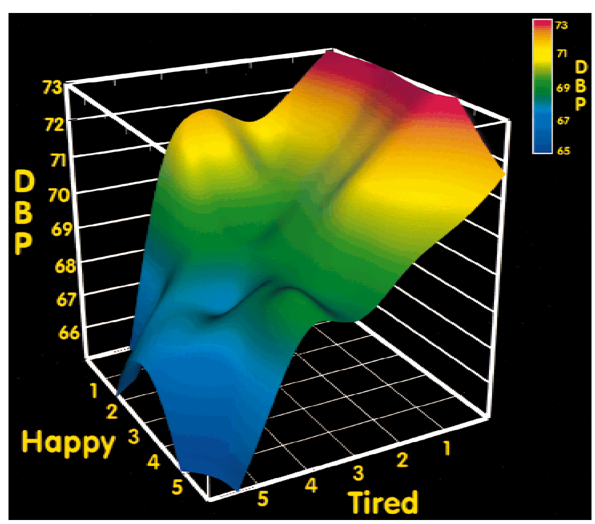

Figure 5. Changes in DBP as a function of the moods happy and tired, $F(16{,}35000) = 2.36$, $p < .02$.

any single presumably unitary emotional state such as anxiety, two subtypes of anxiety (anxious apprehension and anxious arousal) were found associated with different patterns of hemispheric asymmetry in alpha electroencephalographic activity (Nitschke et al., 1999). Furthermore, individuals appear to differ in whether they label their affective states using a discrete emotion focus or a valence (dimensional) focus (Barrett, 1998). These considerations formed a basis for our decision to focus on specific mood terms in organizing the data for this report. Subtle distinctions in emotional processing may be captured by further study of the linguistics of emotion in natural settings as well as in the laboratory.

Clearly, the words people use to describe their emotional states can tell us something meaningful about their contemporaneous physiological responses. The large number of mood reports may have made it more likely to get significant effects by averaging out the effects of other factors. Moreover, the fact that the data were obtained in everyday situations may have also contributed to the significance of the effects. As in laboratory studies with contrived stimuli, these subjects were exposed to novel conditions, although the situations they encountered were within a range of conditions more or less familiar to them. In addition, subjects could resort to their usual ways of coping with either negative or positive circumstances as well as changes in energy level. This may have contributed to the significance of the findings.

Given that a relatively small number of ratings of negative moods occurred in the extreme categories (ratings of 4 and 5), the question arises as to the generalizability of the findings on mood intensity, BP, and HR. The statistical program used to analyze the data models the variations within subjects and models subjects as random effects, thus allowing us to make inferences about the fixed effects that are relevant to the population of random effects that is at worst limited to female nurses. Moreover, as a further test, we compared BP and HR for the average ratings between each pair of intensity levels of the different moods, selecting only those subjects who were represented at the respective levels. The results of these analyses (paired t tests) confirm the overall findings obtained with the random regression models. Interpretations of the two-way mood interactions as depicted in surface-contour plots are more qualitative in nature. Given that the graphs involve many points with a variable distribution of reports in the different cells, these mood interactions require more intensive study and replication.

A further issue concerns the uniqueness of this subject population and the restriction to women subjects. Unpublished ambulatory data collected in our laboratory from a sample of 98 college student women studied on a single day were compared to the nurses' data. The nurses were more likely to report "none" by about 10–15% for such mood terms as stressed, anxiety, and fatigue (tired) with little difference for happy. The differences may relate to age or occupation. Age may be associated with decreased emotionality and greater emotional control (Gross, Carstensen, Tsai, Skorpen, & Hsu, 1997). In their work, nurses are constantly exposed to people in distress, pain, threat, and despair. To be able to function effectively, they may learn to keep their emotional responses under control or to suppress such reactions. Conceivably, this relates to the fact that happy by itself in the present study appeared to have little effect on BP or HR, unlike the higher levels of BP associated with positive mood in some earlier studies. Positive mood did moderate the effects of negative mood. Emotional suppression would be likely to obscure the relation between mood intensity and BP or HR (Shapiro, Jamner, & Goldstein, 1993). However, women in general may be more likely than men to acknowledge or focus on certain kinds of emotional states (Barrett, Robin, Pietromonaco, & Eyssell, 1998). Gender differences and other social and cultural factors affecting the meaning and significance of mood experience and mood report need further study.

The importance of mood combinations has been demonstrated in this study. The significance of certain moods for BP or HR depends on the experience of other concurrent moods. These findings support the previous findings on differences in BP and HR associated with different mood profiles characteristic of subgroups of subjects (Shapiro et al., 1997), and the present data extend the importance of combined moods to momentary changes in mood state. That is, the relation between BP and mood state is affected by the profile of concurrent moods. Positive mood may serve as an antidote for the effects of negative moods on BP, whereas the effects of a given negative mood may depend on other associated negative moods. Energy level can also moderate the effects of positive or negative moods. Although the importance of mood combinations, for example a mixture of positive and negative emotional states, has been noted in clinical observations, the issue has been almost entirely neglected in ambulatory studies or in laboratory studies focused on "pure" emotions. The specific nature of the mood interactions observed in the present sample may differ from what may be found in other samples of women or in men.

Parenthetically, in this paper we have sometimes referred to the effects of mood on BP and HR. The term "effect" is used in a statistical sense only and was not intended to indicate that moods cause the cardiovascular effects. The causal interrelations cannot be determined from these kinds of observations.

In conclusion, the findings suggest that daily experiences of negative mood may be associated with higher BP levels in general and thus may contribute to the risk for hypertension and associated disorders. The greater the reported intensity, the greater the effects. The nature of the association depends on how such moods are coupled with other moods that may counter or augment the effects. A study by Szczepanski et al. (1997) on neurohormonal responses and negative mood supports this conclusion. Distressed moods in employed women were significantly associated with norepinephrine excretion and pressured moods with cortisol, epinephrine, and norepinephrine secretion. The association between mood and BP or HR may also depend on one's habitual behavioral dispositions and coping styles (anger/hostility, anxiety, defensiveness) (Raikkonen et al., 1999, Shapiro et al., 1997). The nature of the causal connections between these critical variables (moods, traits, cardiovascular levels and reactivity, hormonal changes, situational factors) and how they affect risk for cardiovascular disorders deserves intensive study.

Finally, the findings of this study have implications for our understanding of relations between emotions and cardiovascular and other physiological response systems and for the psychophysiology of emotions more generally. In past research, great progress has been made in the study of discrete brief emotions. However, emotional experiences often involve blends of complementary or conflicting feelings of longer duration. In line with the present findings, such theoretical perspectives deserve further elaboration and empirical study. Further research is needed on the interplay of different emotions and the physiological mechanisms underlying the interplay. The ambulatory methods used in the present study provide an important means of further probing into the nature of complex emotional experiences.

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