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The relationship of hostility, negative affect and ethnicity to cardiovascular responses: an ambulatory study in Singapore

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Abstract

This study tested the hypotheses that ambulatory heart rate and blood pressure would be higher for individuals high but not low in hostility when they experienced negative affect or social stress and that this interaction would be stronger for Indians compared with other Singapore ethnic groups. Ambulatory blood pressure monitoring was done on 108 male Singapore patrol officers as they went about their daily duties. After each BP measurement participants completed a computerized questionnaire including items on emotional experience. Individuals high in hostility showed higher systolic blood pressure when reporting negative affect whereas this was not true for those low in hostility. Ethnic differences were obtained such that Indians showed an increase in mean arterial pressure when angered whereas MAP was negatively related to anger for Malays and unrelated for Chinese. Also a three-way interaction between ethnicity, hostility, and social stress indicated that hostility and social stress interacted in their effects on DBP for Indian participants but not for Chinese or Malays. Finally, a three-way interaction was obtained between ethnicity, hostility and negative affect for heart rate in which heart rate increased with increasing levels of negative affect for Chinese high in hostility and Malays low in hostility but decreased with increasing negative affect for all other participants. These data are consistent with higher CHD rates among individuals high in hostility and also provide additional evidence on ethnic differences in cardiovascular reactivity in Singapore.

Keywords: Ambulatory monitoring; Cardiovascular responses; Emotion; Hostility; Ethnic differences; Singapore

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1. Introduction

Over the past two decades evidence of a strong association between CHD and hostility has accumulated (Barefoot et al., 1983; Miller et al., 1996; Shekelle et al., 1983; Williams et al., 1980). For example, Barefoot and his colleagues (Barefoot et al., 1983) found a seven-fold increase in CHD over a 25 year period for men scoring high on the Cook and Medley (1954) Hostility (Ho) Scale as compared with those scoring low. Similar findings have been obtained in other studies and a meta-analysis has found that this relationship remains strong even when other risk factors for CHD are controlled for (Miller et al., 1996).

The psychophysiological reactivity model (Smith, 1992) hypothesizes that hostility contributes to the development of CHD through its association with heightened reactivity to stress on the part of highly hostile individuals. Such individuals are believed to show greater increases in heart rate (HR), blood pressure (BP) and the secretion of stress-related hormones when faced with certain types of stressors, in particular those that involve interpersonal challenge or social stress. Individuals high in hostility are expected to experience anger more frequently and intensely and this greater experience of anger is believed to produce greater physiological reactivity which is, in turn, hypothesized to accelerate the development of coronary artery disease and eventually CHD (Smith, 1992; Williams, 1994).

There is little evidence for heightened reactivity as a general response across all tasks or situations on the part of high hostile individuals. However, heightened reactivity has been found when individuals high in hostility are exposed to situations that can be considered social threatening (Smith, 1992; Suls and Wan, 1993) such as when research participants are harassed, involved in a social interaction task involving a high level of self-disclosure, or engaged in debate. Greater physiological reactivity has, in turn, been associated with later development of atherosclerosis and CHD (Kamarck et al., 1997; Manuck, 1994).

Although there is growing evidence for the relationship of anger/hostility to cardiovascular reactivity (CVR) and CHD, the cross-cultural validity of this relationship has only recently begun to be explored. Evidence for this relationship comes primarily from studies in the United States and other Western countries and most studies have involved Caucasians (Everson et al., 1995; Suarez et al., 1998; Suarez and Williams, 1990) with a few done among African-Americans (Durel et al., 1989). To date only a handful of studies have examined this relationship in Asia or with Asian populations. The few existing studies suggest that the relationship between anger/hostility and CVR may well differ by ethnic group. For example, a recent study comparing CVR among Chinese and Indian males (Bishop and Robinson, 2000) found significant differences between these groups in responses to harassment. Among Chinese the pattern obtained was similar to that found in North America, with high anger individuals showing increased CVR to harassment as compared with tasks with no harassment but no differences in CVR between harassment and no harassment for those low in anger. However, low anger Indians showed increases in CVR in response to harassment that were parallel to those for high anger Chinese whereas high anger Indians showed high levels of CVR regardless of harassment. Another study (Why et al., 2003) found evidence for different patterns of hemodynamic response between Chinese, Indians, and Malays. For Indians cardiac output was a positive function of hostility whereas vascular resistance was negatively associated with hostility, suggesting that Indians high in hostility may be cardiac reactors (Kasprowicz et al., 1990), a pattern not found among Chinese or Malays.

These differences in CVR between Indians and other ethnic groups in Singapore are particularly interesting in light of the fact that Indian Singaporeans die of heart disease at much higher rates than do Chinese or Malay Singaporeans. Hughes and his colleagues (Hughes et al., 1990) found that for males aged 30 to 69 the CHD death rates for Indians were 3.8 times those for Chinese and 1.9 times those for Malays. A similar but less marked pattern was observed for females. This pattern of high CHD rates among Indians has also been found in other countries such as the United Kingdom (Marmot et al., 1984), Canada (Anand et al., 2000), South Africa (Walker, 1980), and Trinidad (Miller et al., 1982). Since CVR has been shown to be associated with atherosclerosis and CHD, the differential pattern of CVR among Indians described above would appear to be consistent with their higher CHD rates.

The relationship between hostility and CVR has typically been tested using various stressors in the laboratory (Suls and Wan, 1993). Although laboratory studies are an excellent means of establishing empirical relationships under controlled conditions, they may not be reflective of responses to daily stressors in the natural environment. As such ambulatory studies are needed to cross-check results from the laboratory. Ambulatory studies provide ecological validity by examining BP and HR responses as they occur in the natural environment but suffer from the lack of control that is inherent in observational studies (Stone and Shiffman, 1994). By examining the same hypotheses in both laboratory and ambulatory studies it is possible to use the strengths of each to offset the weaknesses of the other.

Ambulatory studies have provided data generally supporting the hypothesized relationship of anger and hostility to BP and HR responses (Benotsch et al., 1997; Guyll and Contrada, 1998; Shapiro et al., 1997) and a recent meta-analysis of the relationship of trait anger and anger expression to ambulatory blood pressure showed modest relationship between trait anger and systolic blood pressure (Schum et al., 2003). However, to date, none of the studies of ambulatory blood pressure (ABP) responses has been done with Asian populations. As such, the main purpose of the present study was to examine the relationship between hostility, situations involving anger producing experiences and BP responses in an Asian population and with a specific focus on ethnic differences in cardiovascular responses as a function of dispositional hostility and the experience of anger producing stressors.

Two approaches were used in defining affect producing experiences. First, participants were asked to indicate their emotional state (i.e., the extent to which they were feeling angry, frustrated, sad, stressed, and happy) at each ambulatory blood pressure (ABP) reading. We expected to find an interaction between hostility and the experience of negative emotions such that individuals high in hostility would show increases in BP and HR when reporting the experience of negative emotions whereas this would not be true for those low in hostility.

The second method examined characteristics of social interactions reported by participants. If hostility has its effects on cardiovascular responses primarily in situations that are socially challenging (Suls and Wan, 1993) then there should be an interaction between hostility and social stress such that BP and HR would be higher for highly hostile individuals when they report socially stressful interactions than when they report non-stressful interactions whereas this would not be true for those low in hostility. In line with previous results showing ethnic differences in CVR, we expected the hypothesized patterns for both negative affect and social stress would be stronger in Indians than in Chinese or Malays.

In testing these hypotheses we adopted the strategy of Ecological Momentary Assessment (EMA) (Stone et al., 1999; Stone and Shiffman, 1994) which assesses phenomena at the moment they occur in natural settings so as to maximize ecological validity. As such, we measured BP and HR approximately every 30 min over up to a 10 h period as the participants went about their everyday activities. In addition, each time measurements were taken the participants were to answer a questionnaire using a palmtop computer. In this way it is possible to relate blood pressure and HR measurements to time varying psychological as well as control variables. Since the data from both the ambulatory blood pressure monitor and the computerized questionnaire are time and date stamped it is possible to ensure that the questionnaire is answered in a timely fashion and to match questionnaire entries with HR and BP measurements.

2. Method

The present study was part of a larger project focused on stress among police officers in Singapore. Other portions of the project were concerned with job stress (Bishop et al., 2003), coping (Bishop et al., 2001), social support (Tong et al., 2004) and laboratory investigation of CVR (Why et al., 2003).

2.1. Participants

Altogether, 243 male patrol officers (81 Chinese, 81 Malay and 81 Indian), who had been with the Singapore Police Force for at least 1 year, participated in the overall project. All participants were Singapore citizens or permanent residents as this is a requirement for service in the police force. Every effort was made to ensure that those participating comprised a representative sample of officers stratified by ethnicity although logistical constraints made it impossible to draw a truly random sample. All participation was voluntary and participants were assured that their individual data were strictly confidential. Data were collected in two phases the first of which was concerned with the collection of questionnaire data as well as the Structured Interview (SI) for Type A which was used to obtain hostility scores. Data collection procedures for the first portion of the study are described in Bishop et al. (2001) and Tong et al. (2004). All interviews and questionnaires were conducted in English, a language in which all participants were fluent.

The ambulatory monitoring occurred approximately 1 year after the first phase of data collection and involved 118 (39 Chinese, 33 Malays and 46 Indians) of the 243 original participants. Participants were excluded from the ambulatory monitoring if they had resigned from the SPF (10), were no longer on patrol duties (40), were on 12-h rather than 8-h shifts (24), reported a history of CHD or hypertension or had baseline readings suggesting undiagnosed hypertension (28), had medical problems that precluded participation (4) or were not contactable (14). In addition, 7 officers declined to participate. Finally, the data for 10 officers participating in the ambulatory monitoring was excluded from the analysis due to BP readings indicating hypertension (3), assignment to duties other than patrol officer (2) and equipment problems (5). Participants were also screened for use of medications affecting blood pressure and none in the final sample reported such usage.

Demographics for the final sample of 108 are shown in Table 1. Ethnic groups did not differ by age, $F(2,105)=1.67$, p ns, or the transformed Hostile Behavior Index (HBI), $F(2,105)=1.22$, p ns. However, near significant differences were found between ethnic groups for BMI, $F(2,103)=2.74$, $p=.07$, total family income, $\chi^2(8, N=108)=13.37$, $p=.10$, and family history of hypertension, $\chi^2(2, N=108)=4.74$, $p=.0935$. It can also be seen that differences in religious beliefs were closely related to ethnicity, which is to be expected. Also, there were significant

Table 1
Demographics of sample

	Chinese	Malays	Indians	Total
N	36	31	41	108
Age	25.5 (5.1)	27.5 (4.9)	27.8 (6.5)	26.9 (5.7)
BMI	22.1 (2.5)	23.7 (2.8)	23.2 (3.0)	23.0 (2.8)
Transformed HBI	−1.20 (0.5)	−1.04 (0.5)	−1.06 (0.4)	−1.10 (0.5)
Marital status				
Married	7 (19.4%)	17 (54.8%)	16 (39.0%)	40 (37.0%)
Single/Separated/Divorced	29 (80.6%)	14 (45.2%)	25 (61.0%)	68 (63.0%)
Religion				
Free thinker	5 (13.9%)	1 (3.2%)	0 (0.0%)	6 (5.6%)
Buddhist/Taoist	29 (80.6%)	0 (0.0%)	0 (0.0%)	29 (26.9%)
Christian	2 (5.6%)	0 (0.0%)	2 (4.9%)	4 (3.7%)
Muslim	0 (0.0%)	29 (93.5%)	16 (39.0%)	45 (41.7%)
Hindu	0 (0.0%)	0 (0.0%)	21 (51.2%)	21 (19.4%)
Missing	0 (0.0%)	1 (3.2%)	2 (4.9%)	2 (1.9%)
Family income				
<=S$1499/month	5 (13.9%)	1 (3.2%)	7 (17.1%)	12 (12.0%)
S$1500–S$2499/month	10 (27.8%)	14 (45.2%)	7 (17.1%)	30 (28.7%)
S$2500–S$3499/month	7 (19.4%)	8 (25.8%)	14 (34.1%)	29 (26.9%)
S$3500–S$4499/month	8 (22.2%)	7 (22.6%)	6 (14.6%)	22 (19.4%)
>=S$4500/month	6 (16.7%)	1 (3.2%)	7 (17.1%)	14 (13.0%)
Family history of heart disease	3 (8.3%)	9 (29.0%)	13 (31.7%)	25 (23.1%)
Family history of hypertension	11 (32.4%)	18 (58.1%)	21 (51.2%)	50 (46.3%)

With the exception of age BMI and transformed HBI numbers indicate number of participants with percentages in parentheses. For age BMI and transformed HBI the numbers are means with standard deviations in parentheses.

differences in family history of heart disease, $\chi^2(2, N=108)=6.43$, $p=.04$, and marital status, $\chi^2(2, N=108)=9.07$, $p=.0107$. In light of these ethnic differences, BMI, family history of heart disease, family history of hypertension, family income, and martial status were included as covariates in the analyses reported below. Comparison of the demographic characteristics of the ambulatory sample with the remaining participants in the larger study showed no significant differences indicating that the ambulatory sample was representative of the larger sample.

2.2. Equipment

The Accutracker II ambulatory blood pressure monitor (Suntech Medical Instruments, Raleigh, NC) was used for the ambulatory monitoring of BP and HR. Following the general recommendation of Pickering (1991), the deflation rate was set at 3 mm Hg/s. BP and HR measures were taken at an average interval of 30 min with a random deviation of plus or minus 5 min. Participants were told to start their questionnaire entries in the hand-held computer once the blood pressure cuff finished deflating. Questionnaire items were presented on a Palm IIIx handheld computer (3Com, Santa Clara, CA) using Pendragon Forms (Pendragon Software, Libertyville, IL). Officers wore a custom-made carrying-case, containing the Accutracker II and the Palm IIIx, attached to the belt.

2.3. Measures

2.3.1. Hostility

Hostility was measured through the use of the Interpersonal Hostility Assessment Technique (IHAT) (Haney et al., 1996) as applied to the SI. The IHAT has been validated as a measure of hostility which shows strong relationships with facial indicators of hostility (Brummett et al., 1998) as well as coronary artery disease (Haney et al., 1996). The SI was obtained through individual interviews done by two male interviewers. To obtain an estimate of inter-rater reliability for the IHAT, approximately 25% of the tape-recorded interviews were randomly selected and assessed by two female researchers who were trained by Thomas Haney, the developer of the IHAT. Component scores for Irritation, Hostile Evade/Withhold, Indirect Challenge, and Direct Challenge were combined and divided by the total number of questions asked during the interview to yield the Hostile Behavior Index (HBI). The intra-class correlation between the two raters was .75, $p<.001$. All remaining interviews were assessed by one rater. As the raw HBI scores were significantly skewed a logarithmic transformation of the HBI scores was done to obtain a normal distribution. A check of the transformed HBI scores indicated that they were normally distributed.

2.3.2. Control items

Interpretation of ambulatory BP and HR requires taking account of several time-varying factors known to contribute to BP and HR variability including posture (Gellman et al., 1990), consumption of caffeine (Smits et al., 1985), smoking cigarettes (Cellina et al., 1975), and talking (Pickering, 1991). As such at each BP reading participants were asked to answer a series of items concerning posture (standing, sitting, lying down), physical activity level (inactive, some movement, moderate, strenuous), temperature (comfortable, too hot, too cold), whether they were talking (yes, no), whether they had recently eaten (yes, no), consumed caffeine (yes, no), or smoked (yes, no) and whether they had taken any medication or drugs (yes, no). These items were used to obtain control variables for use as covariates in data analyses reported below.

2.3.3. Covariate selection

Nine potential time varying covariates were defined on the basis of questionnaire control items described above, including physical activity, standing, sitting, hot, cold, talking, smoking, caffeine and meal consumption. Physical activity, talking, smoking, caffeine consumption and meal consumption were coded using the categories described above. Standing and sitting were coded from the posture variable by creating two dichotomous variables in which standing was coded as “1” when the participant indicated he was standing and “0” otherwise whereas sitting was coded as “1” when the participant indicated he was sitting and “0” otherwise. Similarly, hot and cold were coded from the temperature variable by coding “1” when the person indicated that he was hot or cold, respectively, and “0” otherwise.

To select the variables to be used as covariates in the final analyses of the ambulatory data, separate random effects regression analyses were first carried out on each potential covariate. Since endorsement of the item for consumption of medication occurred on only 1% of questionnaire entries, this variable was excluded as a covariate. The dependent variables, SBP, DBP, MAP and HR, were analysed separately. Each potential covariate was tested individually against each dependent variable. Those potential covariates showing a significant bivariate relationship with at least one dependent variable were retained for later use. Feeling too cold had no significant effects on any of the dependent variables and was excluded from later analyses. The eight remaining covariates along with the person level variables of BMI, family history of heart disease, family history of hypertension, family income, and martial status were then used for each dependent variable (Table 2).

2.3.4. Negative affect

Ratings of negative emotion were obtained by asking participants at each BP measurement to rate the extent to which they were feeling happy, sad, angry, frustrated, and stressed. Intensity for each emotion was rated on a four-point scale, from 1 (not at all) to 4 (very much so). To examine the underlying structure of these items correlations were computed across all observations for each participant. Within participant correlations were then transformed using Fisher's z and averaged across participants to get pooled correlations. Principle components analysis on these correlations obtained one component accounting for 47.9% of the variance. Inspection of the loadings for this component showed high loadings for frustrated (0.84), angry (0.78), stressed (0.74) and sad (0.62) and a low negative loading for happy (−0.40). An index of negative affect was computed by averaging the ratings for frustrated, angry, stressed and sad. This index showed acceptable internal consistency, α=0.74.

Table 2
Unstandardized regression estimates for covariates

Effect	DF	SBP	DBP	MAP	HR
Intercept	80	101.51***	56.31***	71.27***	68.95***
Physical activity	868	0.07	0.34	0.22	2.55***
Standing	868	2.55	−1.71	−0.41	4.96*
Sitting	868	−0.37	−2.52	−1.90	0.59
Hot	868	3.39*	3.33**	3.39**	5.30***
Talking	868	1.74*	1.23	1.40*	0.51
Smoke	868	1.04	1.33	1.31	2.51*
Meal	868	−0.40	−0.44	−0.41	1.05
Caffeine	868	2.12	1.64	1.83	−0.10
BMI	80	0.76*	0.65**	0.72**	0.17
Family history of heart disease	80	1.74	1.64	2.52	0.81
Family history of hypertension	80	−3.34	−1.66	−2.16	−2.65
Marital status	80	−1.20	0.50	−0.04	−1.71
Family income	80	0.60	0.42	0.48	0.26

* $p<.05$.
** $p<.01$.
*** $p<.001$.

2.3.5. Social stress

Four items were used to gather information about quality of social interactions. At measurements when the participant indicated having been in an interaction within the past 10 min ratings were obtained of interaction pleasantness, extent of argument or conflict, helpfulness or supportiveness of other person and satisfaction with the interaction. Pleasantness was measured on a five-point Likert-type scale, from 1 (very unpleasant) to 5 (very pleasant) whereas the other items were rated from 1 (not at all) to 4 (very much so). Principal components analysis using the procedures described above yielded a one-factor which accounted for 47.0% of the variance. Examination of the component loadings indicated that the items for satisfaction, pleasantness and supportiveness of the interaction all loaded positively (loadings ranged from 0.66 to 0.80) whereas conflict had a lower negative loading (−0.48). An index of social stress was obtained by taking the average of satisfaction, quality and supportiveness and reversing the result. This index showed acceptable internal consistency with α=0.62. Due to its low loading the conflict item was not included in the overall index of social stress.

2.3.6. Blood pressure and heart rate

To control for the effects of the participants' rotating shift work on circadian rhythms ambulatory measurements were taken on the first morning shift in the rotation for each officer. This shift begins at 8 am with officers required to report for a briefing at 7:30 am. On the day of the monitoring participants met the research team at 7 am to be fitted with the blood pressure monitor. After being fitted with the monitor test runs were made to ensure that the equipment was operating properly following which the officers sat quietly for 10 min before two sitting and two standing baselines were taken.

Following baseline readings participants were familiarized with the use of the electronic questionnaire. Participants were told to take the deflation of the blood pressure cuff as a cue to begin completion of the questionnaire and to take out the palmtop computer only after the completion of the BP reading so as to minimize measurement problems due to arm movements. A set of written instructions along with contact numbers of research team members was taped underneath the cover of the palmtop computer in case the participant encountered any problems. The measurement did not interfere with the operational capabilities of the officers.

The morning shift ends at 3 pm. The officers were encouraged to continue wearing the monitor after the shift hours so that there would be more readings. A few officers had prior engagements and left promptly at 3 pm but most met the research team again between 4 and 6 pm. At the end of the ambulatory recording period additional baseline readings were taken, after which the equipment was detached from the officer. On average officers wore the monitors for 8.77 h.

2.4. Data analysis

2.4.1. Artifactual readings

The criteria outlined by Marler et al. (1988) were used to eliminate artifactual BP and HR readings. Both SBP and DBP values were excluded from analyses if SBP>250 mm Hg or <70 mm Hg, DBP>150 mm Hg or <45 mm Hg, or SBP/DBP>3 or <[1.065+(.00125*DBP)]. Heart rates above 200 beats per minute (bpm) or below 40 bpm were also excluded from analyses. In addition, error codes generated by the Accutracker II were used to eliminate readings that were tagged as being questionable. Mean arterial pressure (MAP) was computed as (SBP+2*DBP)/3 for each reading for which both valid SBP and DBP readings were available.

2.4.2. Matching of questionnaire and ABP data

A maximum of 10 min between the time and date stamped questionnaire and ABP readings was allowed for a match to be made at a given time period. Lags in the timing of questionnaire were expected since police officers might be preoccupied with work at the time of the ABP reading.

2.5. Statistical methods

Multilevel random-coefficients regression has been recommended for the analysis of EMA data (Schwartz and Stone, 1998). In the present study SAS PROC MIXED (Littell et al., 1996) was used. PROC MIXED is a generalization of the general linear model and can handle unbalanced data, which are unavoidable in an ambulatory study such as this, as well as both between- and within-subject effects. Between-subject effects specified in the model were hostility and ethnicity. Within-subject effects were the momentary experiences of negative affect and social stress during the monitoring.

Raw scores of momentary affect and social stress are likely to contain unknown between-subject effects. As such Schwartz and Stone (1998) recommend creating a within-person (WP) measure obtained by taking the difference between each real-time score and the person's mean. This produces a person-centered measure with a mean of zero that is uncorrelated with between-subject factors.

Mixed models provide an advantage over repeated measures analyses conducted using standard ANOVA programs in that repeated measures ANOVA requires complete data for all cases as well as an equal number of observations for each case whereas missing data can be readily handled with mixed models as can an unequal number of observations for each case. In addition, mixed models allow the investigator to compare different error structures to determine the error structure most appropriate for the data before inferences about the F statistics are made (Littell et al., 1996). The basic assumption of ANOVA is compound symmetry whereas serial autocorrelation is hypothesized to be relevant for ABP data because measurements obtained more closely in time can be expected to be more highly correlated. A combination of these two error structures is the most general of these three structures (cf. Brondolo et al., 1999).

Examination of Akaike's Information Criterion and Schwarz's Bayesian criterion for alternative error structures showed that a combination of autoregressive order 1 and compound symmetry best fit the data. As such the combined error structure was used for all analyses.

3. Results

3.1. Data quality

During the ambulatory monitoring 2401 readings were attempted on the final sample of 108 participants. Out of these, 1758 (73.2%) were valid and 643 (26.8%) were erroneous or artifactual. Also, 1335 diary entries were collected from the 108 patrol officers. Altogether the final data set contained 1895 observation periods or an average of 17.5 observation periods for each participant. Out of these 1895 observation periods, there were 1733 (91.5%) valid BP readings and 162 (8.5%) missing readings. In addition, there were 1208 diary entries (63.7% of observation periods), out of which 1128 (93.4%) could be matched to BP readings. Overall, it was possible to match diary entries to 65.1% of the valid BP readings.

Out of the 108 participants, 78 (72.2%) provided at least 50% matched diary entries while another 13 provided a minimum of six matched diary entries, which was set as the minimum number of matched entries. This final pool of 91 officers consisted of 31 Chinese, 31 Malays and 29 Indians. HBI scores were not significantly related to compliance, $r(89)=-.03$, p ns.

3.2. Emotion and social interaction variables

Frequency distributions for emotion and social interaction variables indicated that, as expected, negative emotions were reported for a minority of the observation periods. For sadness respondents rated their sadness as being a "2" ("a little") or above 20.4% of the time whereas the comparable figures for anger was 22.9%, frustration 38%, and stressed 42.2%. ANOVA on mean ratings for each emotion revealed no significant differences between ethnic groups in levels of these emotions or in the composite negative emotion index. Also correlations between emotions and transformed HBI scores ranged from -0.05 to 0.06 with none of the correlations statistically significant. Similarly, social interactions were rated as generally positive. For 50.2% of all interactions participants rated the interaction as being "pleasant" or "very pleasant"; for 41.8% of the interaction they indicated that the other person(s) had been either somewhat or very supportive and for 60.4% of the interactions they indicated that they were somewhat or very satisfied with the interaction. Again, ANOVAs revealed no significant differences between ethnic groups in these items nor in the composite index of social stress and the correlation between transformed HBI scores and the composite social stress index was small and non-significant, $r(89)=0.16$.

3.3. Main analyses

Multilevel random-coefficients regression was conducted to test each hypothesis with SBP, DBP, MAP, and HR tested separately. Covariates were first entered into the equation, followed by within-person averages of the measures of negative affect, social stress or individual emotions, as appropriate, ethnicity, transformed HBI scores, and finally the time varying measure of negative affect, social stress or specific emotions, as appropriate, and interaction terms were entered.

3.3.1. Negative affect

In support of the hypothesis that individuals with high HBI scores would show higher BP when reporting negative affect whereas those with low HBI scores would not a significant HBI by Negative Affect interaction effect was obtained for SBP, $F(1,862)=5.50$, $p=.0193$ (Fig. 1). As HBI was entered as a continuous variable low and high levels of the HBI were determined by calculating one standard deviation below and above the mean, respectively. Separate regression equations relating negative affect to dependent variables were then obtained for participants with high and low HBI scores using procedures described by Aiken and West (1991). Participants who had low scores on the HBI showed no difference in SBP as a function of negative affect, whereas participants with high HBI scores had an increase in SBP when they experienced higher levels

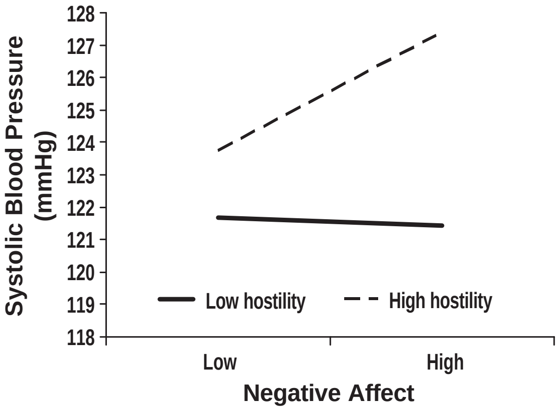

Fig. 1. Interaction of hostility and negative emotion for systolic blood pressure.

of negative emotions. This effect was not significant for HR, DBP or MAP.

Separating the individual components of negative affect, it appears that this effect is primarily due to frustration and to a lesser extent perceived stress. The HBI by Frustration interaction for SBP was statistically significant, $F(1,862)=6.90$, $p=.0088$, and showed a pattern very similar to the one for Negative Affect. The HBI by Stress interaction was marginally significant, $F(1,862)=3.22$, $p=.0729$, and showed the same pattern.

Although the hypothesized ethnic differences were not obtained for SBP or DBP, ethnic differences were obtained for HR and MAP. For HR a significant interaction was obtained between ethnicity and negative affect, $F(2,862)=3.06$, $p=.0473$, and a near significant interaction was obtained between ethnicity, HBI, and negative affect, $F(2,862)=2.92$, $p=.0546$. Examination of the three-way interaction (Fig. 2) showed somewhat different patterns for the three ethnic groups. For Chinese officers with high HBI increasing levels of negative affected were associated with higher levels of HR whereas the opposite was true for Chinese officers with low HBI. This pattern was reversed for Malays. For Indians increasing levels of negative affect were associated with lower HR regardless of HBI. Examining individual emotions indicated that this pattern was mostly due to significant three-way interactions for frustration, $F(2,862)=3.57$, $p=.0285$, and sadness, $F(2,862)=5.93$, $p=.0028$. Examination of the graphs for these interactions showed that the patterns for these two emotions were

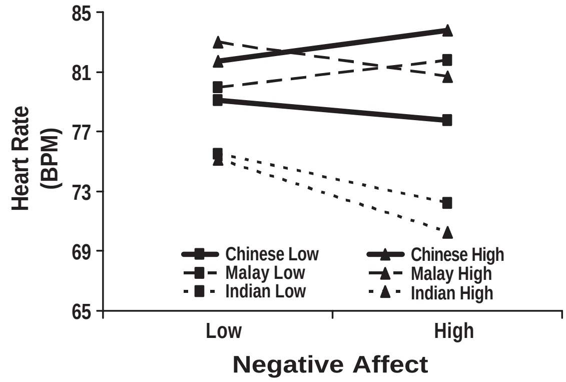

Fig. 2. Interaction of ethnicity, hostility, and negative affect for heart rate.

very similar to Fig. 2. When the simple interactions of HBI and emotion were tested for each ethnic group only the HBI by sadness interaction for Malays was statistically significant, $F(1,352)=14.80$, $p=.0001$.

For MAP a near significant interaction was obtained between ethnicity and anger, $F(2,862)=2.87$, $p=.0573$. This interaction, shown in Fig. 3, indicated that for Chinese officers anger levels were unrelated to MAP whereas higher levels of reported situational anger were related to lower MAP for Malays but higher MAP for Indians.

3.3.2. Social stress

Analyses of the effects of social stress showed a significant ethnicity by HBI by social stress interaction for DBP, $F(2,673)=6.17$, $p=.0022$. Simple interaction analysis by ethnic group showed that the HBI by social stress interaction was significant for

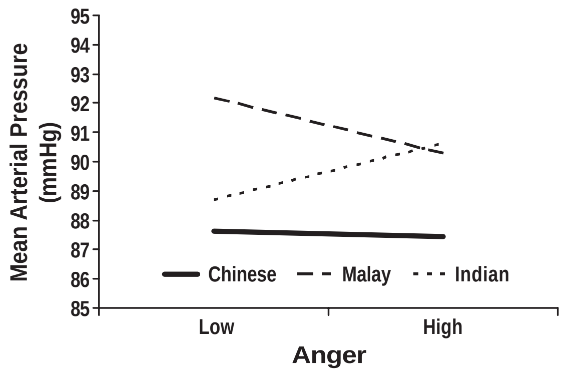

Fig. 3. Interaction of ethnicity and anger for mean arterial pressure.

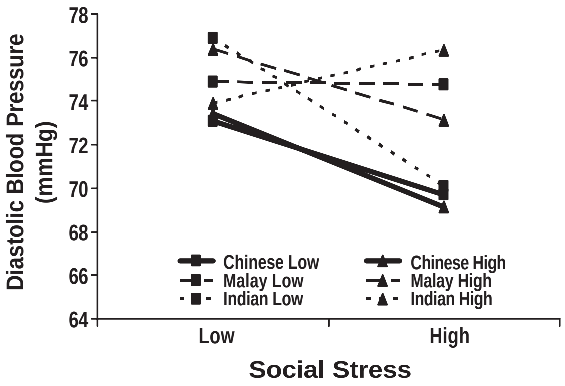

Fig. 4. Interaction of ethnicity, hostility, and social stress for diastolic blood pressure.

Indians, $F(1,194)=10.58$, $p=.0013$, but not for Chinese, $F(1,184)=.01$ $p=.9654$, or Malays, $F(1,279)=2.52$, $p=.1146$. Examination of the interaction for Indians, showed that for those with low HBI scores the relationship between social stress and DBP was negative whereas it was positive for those with high HBI scores (Fig. 4).

3.3.3. Other findings

Significant main effects for ethnicity were found for DBP, $F(2,74)=4.11$, $p=.0203$, and HR, $F(2,74)=5.48$, $p=.006$, across all readings for the ambulatory period. Examination of the means revealed that Malays, $M=74.77$ mm Hg, and Indians, $M=74.30$, had higher average DBP than Chinese, $M=70.53$. For HR, Indians had significantly lower HR, $M=73.25$ bpm, than did Chinese, $M=80.59$, or Malays, $M=81.30$.

4. Discussion

The significant interaction between hostility and negative emotion for SBP is in line with both laboratory studies of hostility and CVR (Everson et al., 1995; Suarez et al., 1998; Suarez and Williams, 1990; Suls and Wan, 1993) and ambulatory studies of the effects of hostility and negative emotion on cardiovascular responses (Benotsch et al., 1997; Guyll and Contrada, 1998) and provides additional support for the hypothesis that individuals high in hostility tend to show exaggerated cardiovascular response to situations involving anger and related emotions. SBP for individuals low on the HBI showed no relationship to negative affect.

Evidence for ethnic differences comes from results obtained for DBP, MAP and HR. A three-way interaction between ethnicity, hostility and social stress for DBP showed that for Indians with high HBI scores DBP was a positive function of social stress whereas for Indians with low HBI scores higher levels of social stress were related to lower DBP. Simple interaction analysis showed that this interaction was not obtained for either Chinese or Malays. Further, MAP was a positive function of anger for Indians while the relationship was negative for Malays. For Chinese participants MAP was unrelated to anger. These results are consistent with the finding by Bishop and Robinson (2000) in which Indians showed a strong SBP response to an anger provoking stimulus (harassment) regardless of trait anger, whereas among Chinese a strong response was obtained only for those high in trait anger. The MAP results for Malays, however, would appear to be inconsistent with those of Why et al. (2003) who found SBP to be an increasing function of hostility for Malays when performing an anger recall interview.

The results for HR are intriguing in that HR was an increasing function of negative affect for Chinese with high HBI scores and Malays with low HBI scores but a decreasing function of negative affect for everyone else. Indians, in particular, showed lower HR with increasing negative affect irrespective of HBI scores. The finding of reduced HR as a function of negative affect in four of the six ethnicity by hostility groups is contrary most findings concerning the effects of negative emotion on HR. With few exceptions studies examining the relationship of negative emotion, whether conducted in the laboratory or by ambulatory methods, have found an increase in HR as a results of negative emotion (cf. Brosschot and Thayer, 2003; Ekman et al., 1983; Labouvie-Vief et al., 2003). An exception to this is the finding by Eisenberg et al. (1988) that preschool children showed HR deceleration in response to sad films. One possible interpretation of these findings and those for MAP is that in this sample Indians responded to anger provoking situations with increased vasoconstriction and decreased heart rate whereas the others showed more of a cardiac response.[1] In the absence of evidence on hemodyamics, however, this interpretation is speculative and at the very least needs to be replicated before drawing strong conclusions.

Laboratory studies of CVR in Singapore have found evidence of differences in CVR between ethnic groups that is consistent with the higher rates of CHD found for Indians in epidemiological studies (Bishop and Robinson, 2000; Why et al., 2003). In particular, Indians who are high in hostility or trait anger tend to show a stronger response to anger provoking stimuli and also appear to be cardiac reactors. Additional evidence for ethnic differences in CVR was obtained in the three-way interaction between ethnicity, hostility and social stress for DBP and the near significant interaction between ethnicity and anger for MAP found in the present study. Again, these results suggest a stronger reaction by Indians as a function of dispositional hostility as well as anger provoking situations, suggesting possible factors that may put Indians at higher risk of CHD.

At this point it is not clear why Indians show stronger cardiovascular responses in anger provoking situations. One possibility is that it may have to do with cultural differences in the way emotions are experienced and expressed. Emotions have strong cultural underpinnings and a considerable amount of research has shown that members of different cultures often experience emotions differently and in different situations (Kitayama and Markus, 1994; Scherer et al., 1988). As such it may be the case that Indians tend to have stronger emotional responses to situations involving anger and social stress with this reflected in differential BP responses. Another possibility is that the differences in CVR may reflect genetic differences. Recent studies have shown that CVR is related to polymorphisms in the serotonin transporter gene (Williams et al., 2001). Although this connection has yet to be explored in relation to ethnic differences in CVR involving Indians, genetic differences of this type may possibly play a role and should be examined. These explanations are definitely not mutually exclusive and are only two of the possibilities. Whatever the cause the ethnic differences obtained in CVR are consistent with higher CHD rates among Indians.

[1] Appreciation is expressed to an anonymous reviewer for suggesting this interpretation.

When interpreting these findings it is important to keep the limitations of this study clearly in mind. First, the sample only consisted of male patrol officers who are relatively young and as such the results may not be generalizable to women or to different age or occupational groups. Additionally, the average physical fitness of the patrol officers can be assumed to be above that for the general population as they are required to undergo a physical fitness test every year. As such, before drawing firm conclusions about ethnic differences in CVR it is important that these results be replicated in a broader sample. Also the dataset was relatively small with only 108 participants and a maximum 10 h ambulatory recording period. Efforts are currently under way to replicate these results with a larger sample, including both males and females, and monitored over a multi-day period.

Finally, this study investigated only ambulatory HR and BP and no effort was made to examine the hemodynamics underlying the BP changes observed. Evidence of ethnic differences in hemodynamics (Why et al., 2003) suggests that examination of such hemodynamics could be very enlightening. Recent advances in impedance cardiography make ambulatory impedance monitoring feasible (Sherwood et al., 2000) and a logical next step would be to investigate ethnic differences in the hemodynamics of blood pressure responses to naturally occurring everyday events. This is being investigated in a study currently in progress.

In conclusion, the results of the study support the hypothesis that individuals high in hostility tend to show elevated BP responses when experiencing negative emotion. In addition, further evidence was obtained suggesting stronger cardiovascular responses to anger and social stress among Indians as compared with Chinese and Malays, a difference that is consistent with higher CHD rates among Indians. Future research is needed to replicate these results with other samples and explore the underlying hemodynamics involved.

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