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Facial flushing during provocation in women

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Abstract

Facial flushing was studied in 38 young women who scored high or low on trait anger. To induce anger in the subjects, their task was to solve a difficult puzzle, with or without harassment from a female research assistant. Facial blood flow increased in response to provocation, together with increases in cardiovascular and electrodermal activity. Flushing was associated with large increases in electrodermal activity and small increases in diastolic blood pressure. Subjects high in trait anger reported most anger and embarrassment, but physiological activity did not differ from subjects with low trait anger. The findings suggest that sympathetically mediated vasodilatation in facial blood vessels competes with cutaneous vasoconstriction during anger. Unpleasant sensations of facial warmth might heighten aversive emotional experiences, but dilatation of facial blood vessels could also act as a type of "safety valve" by opposing increases in blood pressure. An angry predisposition may influence the subjective experience of anger in women, but does not seem to have a major influence on physiological reactivity to mild provocation.

Descriptors: Anger, Embarrassment, Facial blood flow, Cardiovascular reactivity

Mobilization of the sympathetic nervous system and vagal withdrawal mediates an increase in blood pressure and heart rate during provocation, presumably in preparation for the "fight–flight" response (Folkow, 1982). In general, blood is diverted from skin and the viscera to muscle during this response; however, the face, which often flushes during anger (e.g., Darwin, 1872/1965), is a curious exception to this rule. Variables that might influence facial flushing were explored recently in a questionnaire study that contained scenarios of situations involving interpersonal threat or conflict (Drummond, 1997a). The consensus from this study was that flushing is associated with anger and pallor with fear; flushing was thought to be linked with a propensity for blushing, and pallor with a propensity for blanching in various threatening and distressing situations.

Surprisingly few laboratory studies have attempted to investigate psychological influences on facial blood flow during anger. In one of the few such studies, changes in facial blood flow were measured while male and female subjects attempted to solve difficult mental arithmetic problems (Drummond, 1994). To induce feelings of frustration, the difficulty of the task was adjusted by computer to ensure that the success rate was only 50%. In addition, monetary earnings were withdrawn half way through the task in some subjects. Forehead and cheek blood flow increased shortly after the onset of the task and cheek blood flow increased again toward the end of the task, whereas vasoconstriction in the fingers persisted throughout the task. Loss of earnings had little influence on mood or vascular activity. The expected relationship between anger ratings and facial flushing was not confirmed, possibly because most subjects rated themselves as only "slightly angry" by the end of the task.

The general aim of the present study was to investigate influences on facial flushing during more intense provocation. Harassing subjects while they attempt a difficult task is a simple and effective way to provoke anger (Burns & Katkin, 1993; Engebretson, Matthews, & Scheier, 1989; Faber & Burns, 1996; Felsten, 1995; Siegman, Anderson, Herbst, Boyle, & Wilkinson, 1992; Suarez, Harlan, Peoples, & Williams, 1993). In most of the studies cited above, increases in cardiovascular activity were greater than normal in hostile subjects when they were harassed, presumably because they got angrier than normal (but see Felsten, 1995). In the present study, subjects high or low on the trait anger scale of Spielberger's state-trait anger expression inventory (Spielberger, 1991) were selected for inclusion, because the experimental task was expected to be particularly effective in eliciting anger in those with high trait anger scores. To induce feelings of frustration in subjects, the task was to assemble an apparently simple three-dimensional jig-saw puzzle that was actually difficult to solve; to provoke anger, half of the subjects in each group were the target of derogatory comments from a research assistant.

According to conventional stereotypes of men and women, males are more prone to angry aggression than females, and women are expected to control anger to a greater extent than men. Although there is little empirical evidence of sex differences in the experience of anger (Frost & Averill, 1982), men and women may become angry for different reasons (Cupach & Canary, 1995). For example, physical or verbal aggression may be more provocative for males than females, particularly when the aggressor is a male (Frodi, 1977). In general, cardiovascular responses to harassment

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are greater in males than in females (Burns, 1995; Burns & Katkin, 1993; Lai & Linden, 1992; Lawler, Harralson, Armstead, & Schmied, 1993), possibly because women respond differently to this type of provocation than men. In particular, women tend to feel hurt whereas men are more likely to react with defiance (Frost & Averill, 1982); furthermore, embarrassment may limit the experience or physiological expression of anger in women in this type of situation. Cardiovascular responses typically are greatest in harassed, high-hostile subjects, whether male (Engebretson et al., 1989; Everson, McKey, & Lovallo, 1995) or female (Suarez et al., 1993). Nevertheless, because the emotional response to provocation may differ fundamentally between men and women, the physiological effects of provocation need to be studied separately in each sex.

In the present study, the relationship between facial flushing, anger, embarrassment, and general cardiovascular activity was examined in women. It was hypothesized that facial flushing and other measures of cardiovascular activity would increase most in hostile, harassed women. In addition, the association between ratings of anger and embarrassment was investigated to determine whether embarrassment influenced the subjective experience or physiological expression of anger during provocation.

Method

Subjects

The sample consisted of 38 female undergraduate psychology students, selected from 316 students who completed the trait anger scale of the State-Trait Anger Expression Inventory (Spielberger, 1991). In the entire group, trait anger averaged 19.3 ± 4.3 (*SD*). Nineteen subjects from the lower half of this distribution formed the low trait anger group (mean trait anger 15.1 ± 1.4, range 12–17), and 19 subjects from the upper half of the distribution formed the high trait anger group (mean trait anger 25.4 ± 2.7, range 20–30). The female research assistant who collected the data was unaware of the subject's trait anger score. Ages were similar in the two groups, averaging 24.6 ± 7.3 years in the low trait anger group, and 22.8 ± 7.3 years in the high trait anger group. Each subject gave informed consent for the procedures, which were approved by the Murdoch University Ethics Committee.

Apparatus

Changes in facial and finger blood flow, heart period, electrodermal activity, and blood pressure were monitored before and during an anger-provoking task. To detect changes in skin blood flow, pulse transducers (photoplethysmographs, Grass Instruments, Quincy, MA) were attached to the left side of the forehead and to the middle finger of the subject's nondominant hand with adhesive tape. The pulse transducers detected relative changes in blood flow, but did not measure flow in absolute terms (Drummond & Lance, 1981; 1992). Changes in skin conductance were detected via Beckman cup electrodes filled with Johnson and Johnson KY Lubricating Jelly and attached with adhesive washers to the index and ring fingers of the nondominant hand. Skin conductance responses were displayed on a Grass chart recorder to an accuracy of ± 0.1 μS. Blood pressure was measured every 2 min via an Ohio 2105 Automatic Blood Pressure Monitor (Madison, WI) from the subject's nondominant arm. Systolic and diastolic blood pressures were detected oscillometrically (Geddes, 1970) and displayed digitally on the monitor's front panel to an accuracy of 5 mmHg when checked against the auscultatory method (cuff deflation was set at 5 mmHg/s).

Procedure

The experiment was carried out in a temperature-controlled laboratory maintained at 22±1°C. Shortly after arriving at the laboratory, the subject filled out a rating scale consisting of the state anger scale of the state-trait anger expression inventory (Spielberger, 1991) which was mixed with 10 other items to disguise the focus of the scale. Two of the items ("I feel self-conscious" and "I am embarrassed") were included in statistical analyses (see below), and the other eight items were used as fillers. In an attempt to balance the affective content of the scale, most of the filler items referred to various aspects of positive affect (e.g., "I feel like smiling" and "I am enthusiastic"). The eight filler items were not included in statistical analyses because they were not relevant to the research question. Subjects rated each item on a 4-point scale, in which 1 corresponded to "not at all" and 4 to "very much so." Physiological monitoring devices were then attached, and the subject sat quietly for 10 min or until recordings stabilized. Blood pressure was measured every 2 min during this baseline period.

The subject was then shown an assembled six-piece, three-dimensional puzzle that formed a cube, and was told that her task was to assemble the disassembled cube as quickly as possible. Despite the apparent simplicity of the task, only one subject managed to assemble the cube within the 20 min allotted to the task; in this case, the cube was disassembled and the subject spent the remaining time trying (unsuccessfully) to reassemble the cube. The subjects used only one hand to assemble the cube, because a pulse transducer and skin conductance electrodes were attached to the other hand. The research assistant sat in the same room, but was out of the subject's line of vision while the subject attempted to assemble the cube.

Blood pressure was measured 1 min after the start of the task, and thereafter at 2-min intervals. Between each blood pressure measurement, the research assistant made a disparaging comment (the harassment condition) or an encouraging remark (the control condition). Examples of disparaging comments included: "Haven't you even got the first few pieces yet?" (after 4 min of trying), and "Do you realize that you are making a lot of stupid mistakes?" (after 14 min). Comments at comparable times in the control condition included: "Finding the first few pieces is difficult, isn't it?" and "Can you see that it is mainly trial and error?"

Because the task was expected to have a slowly developing cumulative effect on mood, the subject filled out the rating scale again 10 and 20 min into the task, worded in the past tense to indicate how she felt during the past 10 min. Subjects were debriefed before leaving.

Data Reduction

The 10 items of the state anger scale ("I am furious," "I feel irritated," "I feel angry," "I feel like yelling at somebody," "I feel like breaking things," "I am mad," "I feel like banging on the table," "I feel like hitting someone," "I am burned up," and "I feel like swearing") were averaged to yield anger ratings before, at the midpoint, and the end of the task. Because ratings of embarrassment correlated moderately with ratings for self-consciousness ($r = .56$, $p < .001$), the two ratings were averaged to yield an estimate of discomfort due to embarrassment at each point during the experiment.

Heart period, pulse amplitude, and skin conductance responses were measured for 30 s during the first, third, and fifth minutes before the task. Heart period was calculated from the number of pulses detected during each 30-s epoch, whereas pulse amplitude represented the average trough-to-peak height of pulses. A skin conductance response was defined as a trough-to-peak increase of at least 0.1 μS. The cumulative amplitude of skin conductance responses during each 30-s epoch was calculated. The levels during the three 30-s epochs were averaged to obtain reliable estimates of physiological activity before the task. The last three blood pressure levels measured before the task were also averaged. During the task, physiological activity was measured for 15 s before and after each comment (which was made every 2 min, between blood pressure measurements). Because the recorded amplitude of pulses was influenced by individual differences such as skin pigmentation and the closeness of vessels to the skin surface, changes in pulse amplitude during the task were expressed as a percentage of the amplitude recorded before the task. The difference between levels measured before and during the task was calculated for blood pressure, heart period, and skin conductance. To increase the reliability of responses and to simplify statistical analyses, physiological responses were averaged over the first and second 10-min parts of the task.

Statistical Analyses

The change in anger ratings over the course of the task was investigated in a 2 × 2 × 3 (Trait Anger [high, low] × Condition [harassment, control] × Time [before, middle, and end of task]) analysis of variance (ANOVA). The multivariate approach (SPSS for Windows, version 6.1) was used to test effects involving the time factor (Vasey & Thayer, 1987). An exploratory multivariate analysis (MANOVA) to test the effects of trait anger on responses to the 10 items of the state anger scale at the end of the task was also computed. Changes in embarrassment over the course of the task were investigated in a repeated-measures ANOVA with the same factors as those for anger ratings.

To minimize Type 1 errors, physiological responses (with the exception of blood pressure) were investigated together in a 2 × 2 × 2 × 2 (Trait Anger [high, low] × Condition [harassment, control] × Comments [before, after] × Time [the first and second parts of the task]) MANOVA with four dependent variables (changes in forehead and finger pulse amplitude, electrodermal responses, and changes in heart period). Significant effects were further investigated in univariate analyses; the source of significant univariate interactions was then explored with paired *t* tests (because each factor had only two levels, adjustment of the criterion of statistical significance to control for Type 1 errors was not necessary). The immediate effect of the comments on blood pressure could not be ascertained because blood pressure was measured only once every 2 min. Therefore, changes in systolic and diastolic blood pressure during the task were investigated together in a MANOVA with factors of trait anger, condition, and time. Significant effects were investigated as outlined above for the other physiological variables. To delineate the relationship between anger, embarrassment, and physiological reactivity during the task, mean change scores were calculated for each measure. The correlation among change scores was then investigated with Pearson's coefficient.

Results

Anger and Embarrassment Ratings

One subject in the harassment condition withdrew from the experiment shortly after the start of the task. Anger ratings in the other 37 subjects are shown in Figure 1. Ratings increased from an average of "not at all" angry before the task to "somewhat" angry during the task, main effect for time, $F(2,32) = 10.8$, $p < .001$; in addition, ratings were greater in the high trait anger group than in the low trait anger group, $F(1,53) = 5.43$, $p < .05$. Mean anger ratings did not differ between the harassment and control conditions (the main effect and interactions involving the harassment factor were not significant); however, an exploratory MANOVA for the 10 items of the state anger scale indicated that by the end of the task, ratings for "I am furious" were greater in harassed than control subjects, multivariate test of statistical significance for all 10 items, $F(10,24) = 2.71$, $p < .05$; univariate test for "I am furious," $F(1,33) = 7.53$, $p < .01$.

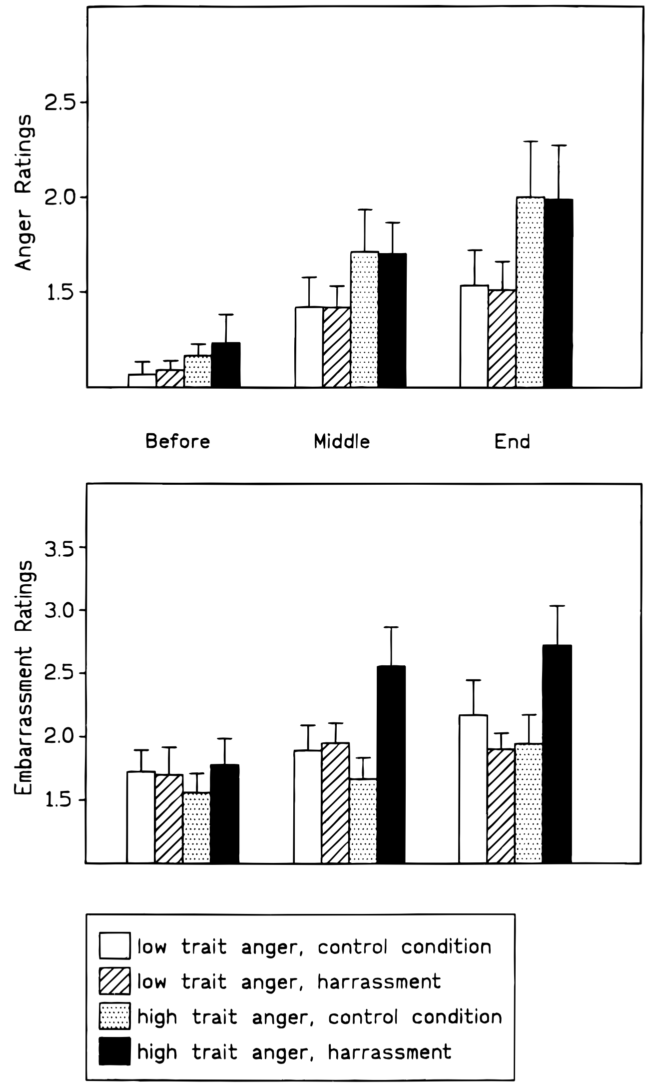

Figure 1. Anger and embarrassment ratings during the task. Anger ratings increased in all four groups, but more so in subjects with high than low trait anger scores. Embarrassment ratings increased most in harassed, high trait anger subjects. In Figures 1–4, error bars represent standard errors.

In general, embarrassment ratings increased in parallel with anger ratings, $r(35) = .34$, $p < .05$. As shown in Figure 1, embarrassment ratings increased over the course of the task, main effect for time, $F(2,32) = 7.09$, $p < .01$, and the interaction between trait anger and condition was statistically significant, $F(1,33) = 4.16$, $p < .05$. The interaction between trait anger, condition, and time was not significant; nevertheless, the basis of the Trait Anger × Condition interaction appeared to be an increase in embarrassment ratings during the task in harassed, high trait anger subjects (Figure 1). Exploratory analyses indicated that embarrassment ratings did not differ among groups before the task and increased significantly during the task only in harassed, high trait anger subjects ($p < .05$); furthermore, embarrassment ratings were greater in this group than in each of the other three groups during the task ($p < .05$ with Duncan's correction for multiple comparisons).

Physiological Activity

Before the task, neither blood pressure, heart period nor electrodermal activity differed between the high and low trait anger groups (Table 1). Changes in physiological activity during the task are shown in Figures 2–4, and the results of the multivariate and univariate ANOVAs are presented in Table 2. MANOVA for changes in forehead and finger pulse amplitude, electrodermal activity, and heart period indicated significant main effects for time and comment, and significant interactions between time and condition, and between time, comment, and condition (Table 2). The MANOVA for changes in blood pressure identified significant main effects for condition and time (Table 2). Of particular note, none of the main effects or interactions involving trait anger were significant in multivariate or univariate analyses.

Time course of physiological activity and response to the comments. Univariate investigation of the significant time effect indicated that increases in blood pressure and electrodermal activity, and decreases in heart period, were greater in the first part of the task than the second (Figures 3 and 4); in contrast, decreases in finger pulse amplitude were greater in the second part of the task (Figure 2). When averaged over conditions, forehead pulse amplitude increased to the same extent in the first and second parts of the task (Figure 2). Forehead pulse amplitude and electrodermal activity increased in response to the comments, whereas finger pulse amplitude and heart period decreased (see Figures 2 and 3).

Effects of harassment. Univariate analyses indicated that increases in systolic but not diastolic blood pressure were greater in harassed than control subjects (see Table 2 and Figure 4). Harassment also influenced facial flushing, more so in the second part of the task than the first (Table 2 and Figure 2). Investigation of the significant Condition × Time interaction for forehead pulse amplitude indicated that increases were greater in the harassment condition than in the control condition during the second half of the task ($p < .05$) but not the first; furthermore, forehead pulse amplitude increased from the first to the second half of the task in the harassment condition ($p < .05$) but not in the control condition. Skin conductance responses were greater in the harassment condition than in the control condition, particularly in the first part of the task after the research assistant made a derogatory comment (Figure 3). Investigation of the significant three-way interaction between condition, time, and comment (Table 2) indicated that the cumulative amplitude of skin conductance responses to comments was greater in the harassment condition than in the control condition in the first part of the task ($p < .01$) but not the second; in addition, responses to comments decreased from the first to the second part of the task in the harassment condition ($p < .01$) but not in the control condition.

Physiological response pattern. Correlational analyses identified relationships among changes in different physiological modalities (Table 3). In particular, increases in forehead pulse amplitude were greatest in subjects with the smallest increases in diastolic blood pressure, $r(34) = -.43$, $p < .01$, and the greatest increases in electrodermal activity, $r(35) = .38$, $p < .05$. In contrast, decreases in finger pulse amplitude were greatest in subjects with the greatest increases in electrodermal activity, $r(35) = -.42$, $p < .01$.

Association between mood ratings and facial flushing. In the group as a whole, correlational analyses failed to detect relationships among changes in physiological activity and changes in an-

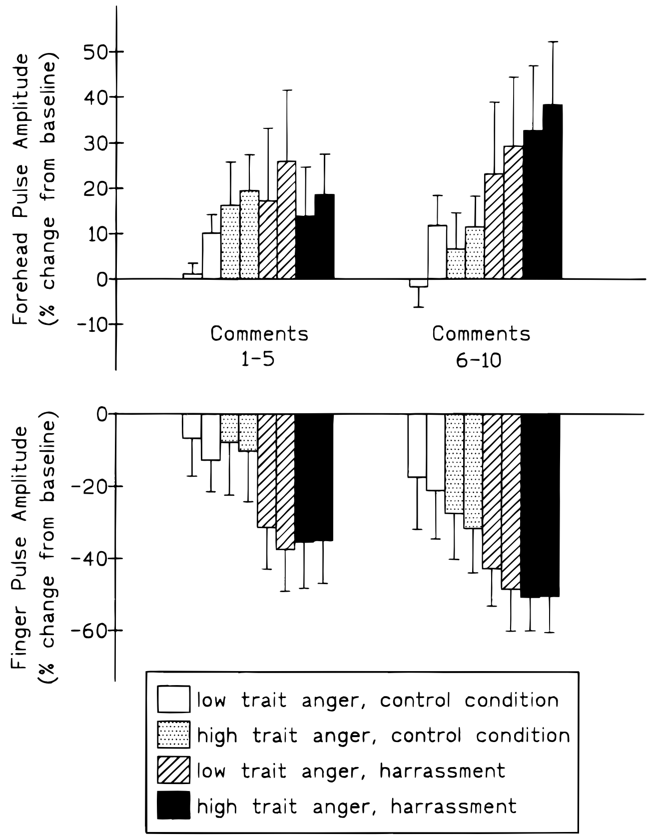

Figure 2. Vascular activity during the first and second parts of the task. In Figures 2 and 3, the first bar of each pair represents the level before the comment, whereas the second bar represents the level after the comment. Pulse amplitude increased in the forehead, particularly in the harassment condition, but decreased in the finger.

Table 1. *Physiological Activity at Baseline in Subjects with High or Low Trait Anger (± SD)*

	High anger ($N = 18$)	Low anger ($N = 19$)
Systolic blood pressure (mmHg)	114 ± 10	119 ± 10
Diastolic blood pressure (mmHg)	69 ± 8	70 ± 8
Heart period (ms)	762 ± 150	816 ± 138
Electrodermal activity (μS/min)	2.5 ± 5.2	4.9 ± 9.9

Physiological activity at baseline did not differ between high and low trait anger subjects.

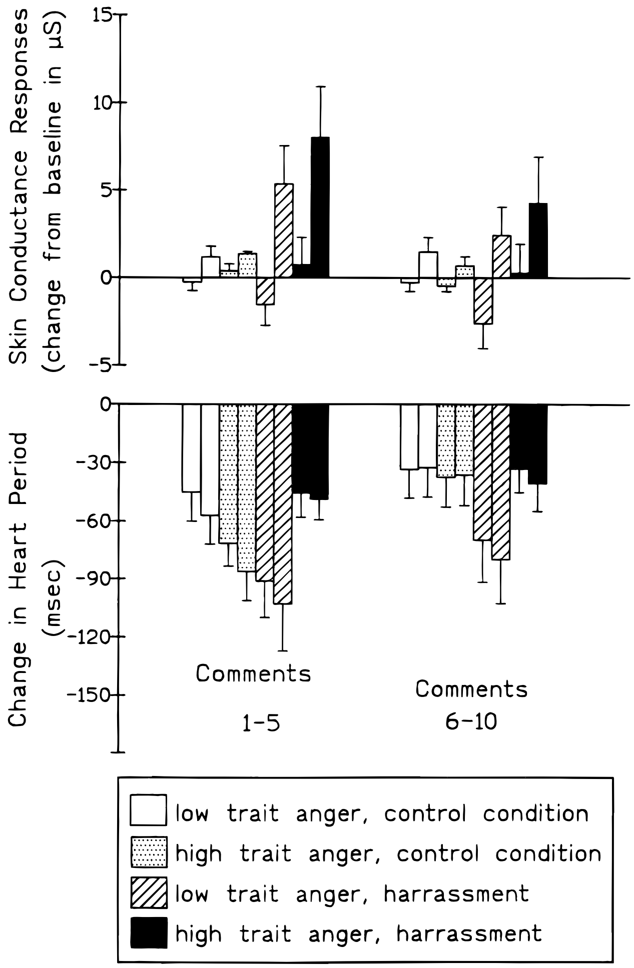

Figure 3. Cardiac and electrodermal responses during the task. Heart period decreased from baseline during the task and after comments (indicating cardiac acceleration). Skin conductance responses were greater to Comments 1–5 in the harassment condition than in the control condition.

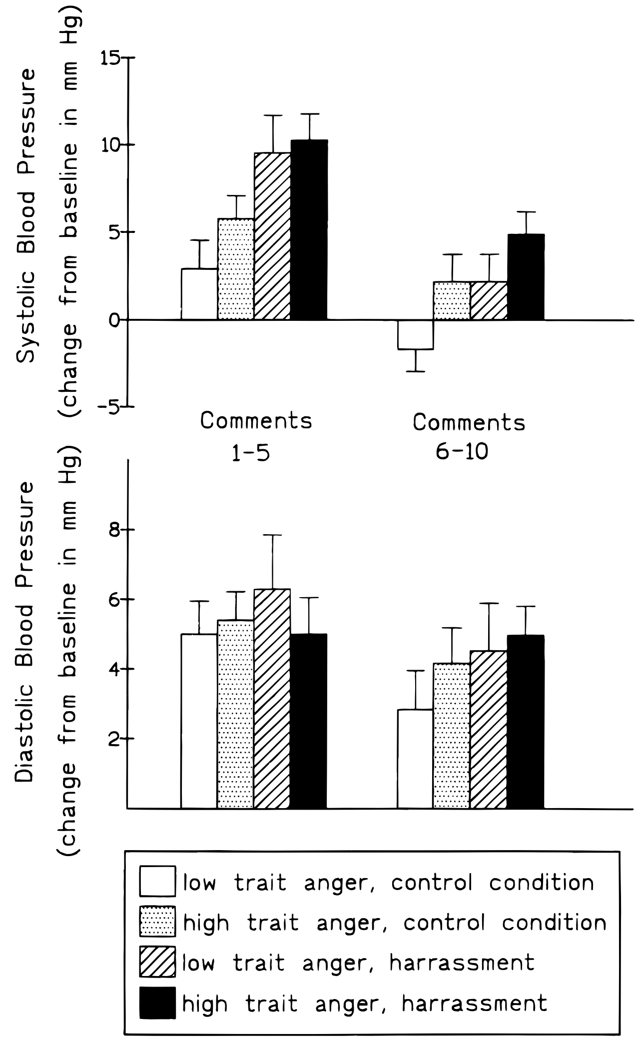

Figure 4. Changes in blood pressure during the task. Increases in systolic blood pressure were greater in the harassment condition than in the control condition.

ger or embarrassment ratings (Table 3). Because increases in forehead pulse amplitude were greater in the harassment than the control condition, the association between facial flushing and anger ratings was investigated separately in each condition. To control for possible effects of embarrassment on facial blood flow, the embarrassment rating was entered as a covariate in partial correlation analyses. These analyses identified an association between anger ratings and increases in forehead pulse amplitude in the control condition, $r(15) = .52$, $p < .05$, but not in the harassment condition.

Discussion

The Effect of the Task on the Subjective Experience of Anger

The increase in anger ratings over the course of the task indicated that most subjects found the task frustrating. By the end of the task, the average rating corresponded to "somewhat angry," implying that the task was only mildly provocative for most subjects. The increase was greatest in subjects who rated themselves highly on trait anger; similar findings have been reported previously for hostile men and women during harassment (Everson et al., 1995; Felsten, 1995; Suarez & Williams, 1989). Surprisingly, anger ratings were unaffected by harassment with the exception of ratings for "I am furious." Perhaps this item mirrored the effect of harassment on women more closely than items such as "I feel like swearing" or "I feel like hitting someone."

Embarrassment ratings increased in parallel with anger ratings, and were greater in harassed, high trait anger subjects than in other subjects. Thus, the experience of anger may have been tempered to some extent by feelings of humiliation at being unable to solve an apparently simple puzzle (i.e., some subjects in the harassment condition may have thought that the research assistant's comments were justified). The submissive and affiliative behaviors displayed during embarrassment probably help to reduce aggression and restore social relations (Keltner & Buswell, 1997). Because most women prefer to use submissive and deferential appeasement strategies to reduce social threats (e.g., Cupach, Metts, & Hazleton, 1986), they may use similar strategies to limit the subjective experience and physiological expression of anger. However, an equally plausible explanation is that feelings of embarrassment and humiliation fuelled anger, particularly in high trait anger subjects.

Table 2. *Significant Changes in Physiological Activity During the Task*

	Multivariate *F* ratio	Univariate *F* ratio				Multivariate *F* ratio (BP)	Univariate *F* ratio	
		FOR	FIN	EDA	HP		SBP	DBP
Condition	2.40	2.08	4.73*	1.80	0.79	5.99**	10.92**	0.61
Condition × Time	3.04*	8.46**	0.07	6.21*	2.55	0.74	0.59	0.01
Time	17.13***	1.58	19.85***	11.54***	27.89***	36.68***	57.43***	8.10**
Comment	11.69***	16.02***	4.62*	17.16***	4.35*			
Condition × Time × Comment	4.02**	0.86	0.01	6.87*	3.92			

FOR = forehead pulse amplitude; FIN = finger pulse amplitude; EDA = electrodermal activity; HP = heart period; SBP = systolic blood pressure; DBP = diastolic blood pressure.
*$p < .05$; **$p < .01$; ***$p < .001$.

Physiological Responses to the Task

Cardiovascular and electrodermal activity increased during the task, consistent with the pattern of activation during demanding tasks documented in many previous studies (e.g., Ax, 1953; Folkow, 1982). In addition, increases in systolic blood pressure, electrodermal activity, and vascular responses were greater in provoked subjects than in controls, indicating that the nature of the comments had a specific influence on physiological activity. Increases in blood pressure during harassment were similar to increases reported by Burns and colleagues (Burns, 1995; Burns & Katkin, 1993; Faber & Burns, 1996) but somewhat lower than those reported by Suarez et al. (1993) and Lai and Linden (1992), presumably reflecting differences in experimental methodology. For example, the timing and verbal content of harassment as well as other aggressive cues (e.g., the experimenter's tone of voice, posture, facial expression, and rapidity or volume of speech) may have influenced the perception of threat and hence cardiovascular activity to differing degrees in the various studies. Blood pressure and cardiac and electrodermal responses subsided during the second part of the task, possibly because the subject habituated to the task and the comments no longer came as a surprise. In contrast, vascular responses to the comments persisted throughout the task, suggesting that vascular changes were driven by some influence other than stimulus novelty. Harassment had a more demonstrable influence on physiological activity than on ratings of anger or embarrassment, perhaps because ratings were obtained too infrequently to reflect short-lived emotional responses to the provocative comments.

Forehead pulse amplitude increased substantially in harassed subjects as the task wore on, consistent with the development of facial flushing in response to provocation. However, because embarrassment ratings increased in parallel with anger ratings, the findings could be explained equally well by the development of a persistent blush. Partial correlation analyses failed to distinguish between these possibilities for subjects in the harassment condition; however, an association between anger ratings and increases in forehead pulse amplitude, independent of embarrassment ratings in the control condition, supports a link between anger and facial flushing. Facial blood flow increased transiently after the research assistant commented on the subject's performance, irrespective of the type of comment. Presumably this transient blush developed because subjects were reminded, either subtly or overtly, of their inability to solve the puzzle. In contrast to the face, finger blood flow decreased markedly during the task, and decreased further after each comment. Thus, the findings document a dissociation between responses in the facial and digital vasculature during provocation (see also Drummond, 1994). The extent of flushing varied substantially among individuals, perhaps overshadowing the more specific effects of harassment, trait anger, and mood studied here. Whether the basis of this individual variation is constitutional or acquired is uncertain.

The relationship among physiological variables provided some clues about the mechanism of facial flushing. In particular, the association between increases in facial blood flow and electrodermal activity suggests that a coordinated mobilization of the sympathetic nervous system contributed to flushing. Consistent with this interpretation, Nordin (1990) reported that increases in sympathetic traffic in the supraorbital nerve were associated with increases in blood flow and electrodermal activity in the forehead during "arousal stimuli" (mental arithmetic or trains of

Table 3. *Correlations Between Mood Ratings and Physiological Responses*

	EMB	FOR	FIN	EDA	SBP	DBP	HP
Anger	.34*	.05	.13	−.15	−.31	.06	−.15
Embarrassment (EMB)		.22	−.12	.31	−.22	−.14	.19
Forehead pulse amplitude (FOR)			.05	.38*	.16	−.43**	−.23
Finger pulse amplitude (FIN)				−.42**	−.33*	−.04	−.26
Electrodermal activity (EDA)					.25	−.21	.08
Systolic blood pressure (SBP)						−.01	−.19
Diastolic blood pressure (DBP)							−.27
Heart period (HP)							

*$p < .05$; **$p < .01$.

electric shocks over the median nerve). In patients with an injury to the sympathetic pathway to the face, increases in facial blood flow during embarrassment and body heating were diminished on the sympathetically denervated side of the face (Drummond & Lance, 1987; 1992), further implying mediation by sympathetic vasodilatation.

Increases in facial blood flow were greatest in subjects with the smallest increases in diastolic blood pressure. This interesting relationship raises the possibility of an additional sympathetic influence on facial flushing. Tonic sympathetic vasoconstrictor discharge normally applies a minor inhibitory influence on facial blood flow (Drummond & Finch, 1989), which increases during exercise but not during embarrassment (Drummond, 1997b). The opposing changes in facial blood flow and diastolic blood pressure in the present study suggest that an increase in sympathetic vasoconstriction in the facial circulation competed with active sympathetic vasodilatation. Perhaps the relative intensity of these two sympathetic drives determines whether flushing or pallor predominates when angry.

Functional Implications of Flushing

Episodes of anger double the risk of myocardial infarction for the next 2 hr (Mittleman et al., 1995), possibly by enhancing constriction in already narrow coronary arteries (Boltwood, Taylor, Burke, Grogin, & Giacomini, 1993). In addition, increases in cardiovascular activity during episodes of anger might have a cumulative detrimental effect on the cardiovascular system (Siegman, 1993). Whether facial flushing influences cardiovascular morbidity is uncertain; however, it is tempting to speculate that flushing has a protective effect by limiting increases in blood pressure during episodes of anger (illustrated in the present study by the negative correlation between increases in facial blood flow and diastolic blood pressure). Flushing greatly increases the loss of body heat by drawing warmth to the skin's surface (Rowell, 1977). Because an increase in facial warmth is judged to be unpleasant (Zajonc, Murphy, & Inglehart, 1989), increases in facial blood flow might heighten the aversive experience during acute emotional arousal; conversely, the comforting sensations that develop when flushing subsides might help to re-establish equanimity.

In addition to its physiological function, changes in facial blood flow may influence social interactions by signalling the participant's emotional state. For example, blushing sends messages of social discomfort which, in certain contexts, may be interpreted by others as an implicit (and genuine) apology for an unintended transgression. However, because anger also elicits increases in facial blood flow, the assumption that this response signals embarrassment and not anger is influenced by the social context and by the presence of other verbal and nonverbal signs of emotion. Nonetheless, given the nature of cultural stereotypes of anger, it is tempting to speculate that facial reddening would more often be interpreted as a sign of anger in men than in women.

Individual Differences in Anger Propensity

In contrast to a previous study in women (Suarez et al., 1993), trait anger scores were unrelated to physiological activity during the harassing task. The circumstances in which anger propensity or hostility influences cardiovascular reactivity to provocation in women require further investigation, particularly in light of the failure by others to identify an effect (Burns, 1995; Burns & Katkin, 1993). Suarez et al. (1993) selected subjects high or low on the Cook–Medley hostility inventory whereas groups were formed by a median split of trait anger scores in the present study; perhaps more extreme groups are needed to demonstrate an influence of anger propensity on cardiovascular reactivity in women.

A recent meta-analysis of the link between elevated blood pressure and personality indicated that the strongest association occurred for measures of defensiveness and anger, and suppression of negative affect (Jorgensen, Johnson, Kolodziej, & Schreer, 1996); however, these effects were variable across studies and were influenced by a range of factors including awareness of blood pressure status, age, gender, and occupation (see also Suls, Wan, & Costa, 1995). Both the expression and suppression of anger appear to influence cardiovascular reactivity, particularly during provocation when the subject's preferred mode of response (i.e., expressing or suppressing anger) conflicts with situational demands (Engebretson et al., 1989; Lai & Linden, 1992); however, this attractive generalization has been weakened recently by contradictory findings and qualifications (compare, for example, the findings of Miller [1993] with those of Larson and Langer [1997]). In some contexts, cardiovascular responses may be lower than normal in hostile individuals because they feel disinclined to engage fully in experimental tasks (Carroll, Smith, Sheffield, Shipley, & Marmot, 1997). In addition, the association between cardiovascular reactivity and anger suppression may be moderated by usual blood pressure level and gender (Vögele, Jarvis, & Cheeseman, 1997). Various studies have shown that a preference to express anger is associated with increased cardiovascular reactivity (Siegman, 1993), but the strength of this effect varies between males and females (Burns & Katkin, 1993; Faber & Burns, 1996; Lai & Linden, 1992). Thus, any link between hostility, cardiovascular reactivity, anger intensity, and the preferred and actual modes of anger expression is not straightforward (Felsten, 1995).[1]

Conclusions

The present findings demonstrate that facial flushing develops during provocation in women, although questions still remain about the relative roles of anger and embarrassment in producing this response. Harassment influenced facial blood flow and other physiological responses, but was no more effective in subjects with high than low trait anger scores. Because the link between anger propensity, provocation and cardiovascular reactivity is stronger in males than in females (Burns, 1995; Burns & Katkin, 1993), the propensity for flushing when provoked may be greater in hostile men than women.

[1]Although not the focus of this study, 30 subjects filled out the anger-in, anger-out, and anger control subscales of the state-trait anger expression inventory during the selection process. Low scores on the anger control scale were associated with large increases in facial blood flow, $r(28) = -.36$, $p < .05$, and with small increases in diastolic blood pressure, $r(28) = .42$, $p < .05$. No other significant relationships were identified.

REFERENCES

Ax, A. F. (1953). The physiological differentiation between fear and anger in humans. *Psychosomatic Medicine*, *15*, 433–442.

Boltwood, M. D., Taylor, C. B., Burke, M. B., Grogin, H., & Giacomini, J. (1993). Anger report predicts coronary artery vasomotor response to mental stress in atherosclerotic segments. *American Journal of Cardiology*, *72*, 1361–1365.

Burns, J. W. (1995). Interactive effects of traits, states, and gender on cardiovascular reactivity during different situations. *Journal of Behavioral Medicine*, *18*, 279–303.
Burns, J. W., & Katkin, E. S. (1993). Psychological, situational, and gender predictors of cardiovascular reactivity to stress: A multivariate approach. *Journal of Behavioral Medicine*, *16*, 445–465.
Carroll, D., Smith, G. D., Sheffield, D., Shipley, M. J., & Marmot, M. G. (1997). The relationship between socioeconomic status, hostility, and blood pressure reactions to mental stress in men: Data from the Whitehall II study. *Health Psychology*, *16*, 131–136.
Cupach, W. R., & Canary, D. J. (1995). Managing conflict and anger: Investigating the sex stereotype hypothesis. In P. J. Kalbfleisch & M. J. Cody (Eds.), *Gender, power, and communication in human relationships* (pp. 233–252). Hillsdale, NJ: Erlbaum.
Cupach, W. R., Metts, S., & Hazleton, V. (1986). Coping with embarrassing predicaments: Remedial strategies and their perceived utility. *Journal of Language and Social Psychology*, *5*, 181–200.
Darwin, C. (1872/1965). *The expression of emotions in man and animals*. Chicago: University of Chicago Press.
Drummond, P. D. (1994). The effect of anger and pleasure on facial blood flow. *Australian Journal of Psychology*, *46*, 95–99.
Drummond, P. D. (1997a). Correlates of facial flushing and pallor in anger-provoking situations. *Personality and Individual Differences*, *23*, 575–582.
Drummond, P. D. (1997b). The effect of adrenergic blockade on blushing and facial flushing. *Psychophysiology*, *34*, 163–168.
Drummond, P. D., & Finch, P. M. (1989). Reflex control of facial flushing during body heating in man. *Brain*, *112*, 1351–1358.
Drummond, P. D., & Lance, J. W. (1981). Extracranial vascular reactivity in migraine and tension headache. *Cephalalgia*, *1*, 149–155.
Drummond, P. D., & Lance, J. W. (1987). Facial sweating and flushing mediated by the sympathetic nervous system. *Brain*, *110*, 793–803.
Drummond, P. D., & Lance, J. W. (1992). Pathological sweating and flushing accompanying the trigeminal-lacrimal reflex in patients with cluster headache and in patients with a confirmed site of cervical sympathetic deficit: Evidence for parasympathetic cross-innervation. *Brain*, *115*, 1429–1445.
Engebretson, T. O., Matthews, K. A., & Scheier, M. F. (1989). Relations between anger expression and cardiovascular reactivity: Reconciling inconsistent findings through a matching hypothesis. *Journal of Personality and Social Psychology*, *57*, 513–521.
Everson, S. A., McKey, B. S., & Lovallo, W. R. (1995). Effect of trait hostility on cardiovascular responses to harassment in young men. *International Journal of Behavioral Medicine*, *2*, 172–191.
Faber, S. D., & Burns, J. W. (1996). Anger management style, degree of expressed anger, and gender influence cardiovascular recovery from interpersonal harassment. *Journal of Behavioral Medicine*, *19*, 31–53.
Felsten, G. (1995). Cynical hostility influences anger, but not cardiovascular reactivity during competition with harassment. *International Journal of Psychophysiology*, *19*, 223–231.
Folkow, B. (1982). Physiological aspects of primary hypertension. *Physiological Reviews*, *62*, 347–504.
Frodi, A. (1977). Sex differences in perception of a provocation. *Perceptual and Motor Skills*, *44*, 113–114.
Frost, W. D., & Averill, J. R. (1982). Differences between men and women in the everyday experience of anger. In J. R. Averill (Ed.), *Anger and aggression; an essay on emotion* (pp. 281–316). New York: Springer-Verlag.
Geddes, L. A. (1970). *The direct and indirect measurement of blood pressure*. Chicago: Year Book Medical.
Jorgensen, R. S., Johnson, B. T., Kolodziej, M. E., & Schreer, G. E. (1996). Elevated blood pressure and personality: A meta-analytic review. *Psychological Bulletin*, *120*, 293–320.
Keltner, D., & Buswell, B. N. (1997). Embarrassment: Its distinct form and appeasement functions. *Psychological Bulletin*, *122*, 250–270.
Lai, J. Y., & Linden, W. (1992). Gender, anger expression style, and opportunity for anger release determine cardiovascular reaction to and recovery from anger provocation. *Psychosomatic Medicine*, *54*, 297–310.
Larson, M. R., & Langer, A. W. (1997). Defensive hostility and anger expression: Relationship to additional heart rate reactivity during active coping. *Psychophysiology*, *34*, 177–184.
Lawler, K. A., Harralson, T. L., Armstead, C. A., & Schmied, L. A. (1993). Gender and cardiovascular responses: What is the role of hostility? *Journal of Psychosomatic Research*, *37*, 603–613.
Miller, S. B. (1993). Cardiovascular reactivity in anger-defensive individuals: The influence of task demands. *Psychosomatic Medicine*, *55*, 78–85.
Mittleman, M. A., Maclure, M., Sherwood, J. B., Mulry, R. P., Tofler, G. H., Jacobs, S. C., Friedman, R., Benson, H., & Muller, J. E. (1995). Triggering of acute myocardial infarction onset by episodes of anger. *Circulation*, *92*, 1720–1725.
Nordin, M. (1990). Sympathetic discharges in the human supraorbital nerve and their relation to sudo- and vasomotor responses. *Journal of Physiology*, *423*, 241–255.
Rowell, L. B. (1977). Reflex control of the cutaneous vasculature. *Journal of Investigative Dermatology*, *69*, 154–166.
Siegman, A. W. (1993). Cardiovascular consequences of expressing, experiencing, and repressing anger. *Journal of Behavioral Medicine*, *16*, 539–569.
Siegman, A. W., Anderson, R., Herbst, J., Boyle, S., & Wilkinson, J. (1992). Dimensions of anger-hostility and cardiovascular reactivity in provoked and angered men. *Journal of Behavioral Medicine*, *15*, 257–272.
Spielberger, C. D. (1991). *State-trait anger expression inventory professional manual* (rev. research ed.). Odessa, FL: Psychological Assessment Resources.
Suarez, E. C., Harlan, E., Peoples, M. C., & Williams, R. B. (1993). Cardiovascular and emotional responses in women: The role of hostility and harassment. *Health Psychology*, *12*, 459–468.
Suarez, E. C., & Williams, R. B. (1989). Situational determinants of cardiovascular and emotional responses in high and low hostile men. *Psychosomatic Medicine*, *51*, 404–418.
Suls, J., Wan, C. K., & Costa, P. T. (1995). Relationship of trait anger to resting blood pressure: A meta-analysis. *Health Psychology*, *14*, 444–456.
Vasey, M. W., & Thayer, J. F. (1987). The continuing problem of false positives in repeated measures ANOVA in psychophysiology: A multivariate solution. *Psychophysiology*, *24*, 479–486.
Vögele, C., Jarvis, A., & Cheeseman, K. (1997). Anger suppression, reactivity, and hypertension risk: Gender makes a difference. *Annals of Behavioral Medicine*, *19*, 61–69.
Zajonc, R. B., Murphy, S. T., & Inglehart, M. (1989). Feeling and facial efference: Implications of the vascular theory of emotion. *Psychological Review*, *96*, 395–416.

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