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BRIEF REPORT

On the Correspondence Between Physiological and Nonverbal Responses: Nonverbal Behavior Accompanying Challenge and Threat

Max Weisbuch · Mark D. Seery · Nalini Ambady · Jim Blascovich

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Abstract Little is known regarding the covariance between physiological and nonverbal responses to "stressful" situations. We argue that physiological *markers* are especially likely to be accompanied by psychologically-meaningful nonverbal behavior. Within "stressful" motivated performance situations, complex patterns of cardiovascular (CV) reactivity mark challenge and threat motivational states relevant to confidence. We expected the CV challenge and threat markers to be distinguished on the basis of facial and vocal confidence. In a test of this hypothesis, participants' cardiovascular (CV) responses were recorded during a videotaped social interaction. As expected, the CV challenge marker was associated with more vocal confidence and less facial confidence than the CV threat marker. These findings are related to the complexity of human responses to motivated performances.

Keywords Challenge and threat · Emotion · Nonverbal discrepancy · Psychophysiology · Confidence

Introduction

Speculation about the relationship between nonverbal behavior and physiology has a long history. Darwin (1872), James (1890/1908), and Cannon (1915) agreed that responses to what we would today call "stressful situations" are characterized by specific patterns of physiologic and nonverbal activity. For example, Darwin writes, "…terror causes the body

M. Weisbuch (✉) · N. Ambady
Department of Psychology, Tufts University, 490 Boston Avenue, Medford, MA 02155, USA
e-mail: max.weisbuch@tufts.edu

M. D. Seery
University at Buffalo, The State University of New York, Buffalo, NY, USA

J. Blascovich
University of California, Santa Barbara, CA, USA

to tremble. The skin becomes pale, sweat breaks out, and the hair bristles…the heart beats quickly, wildly, and violently…" (p. 77).

These early views suggest that physiological and nonverbal activity constitute an integrated response to environmental demands, implying covariance in physiological and nonverbal responses to stressful situations. Yet little evidence supports this conjecture—there are few if any published investigations on the topic. One possible explanation is that naturally-occurring physiological and nonverbal responses are independent. For example, nonverbal expressions may function as communicative responses that do not depend on underlying autonomic activity (Fridlund 1994). Alternatively, the difficulty of measuring complex physiological responses may account for the lack of physiological-nonverbal evidence. Simple physiological responses (e.g., changes in heart rate) can reflect a variety of psychological processes (Cacioppo and Tassinary 1990) and are thus unlikely to be reliably associated with psychologically meaningful nonverbal activity.

We examined the extent to which a stressful situation elicited covariance between *patterns* of nonverbal and physiological activity. Specifically, we examined if and how the cardiovascular markers of challenge and threat were associated with nonverbal behavior.

The Biopsychosocial Model of Challenge and Threat

Context-general *invariants* and context-specific *markers* are physiological patterns that reliably and selectively index specific psychological processes in general or within a specified context, respectively, whereas *correlates* (e.g., heart rate) can be associated with a variety of psychological processes (Cacioppo and Tassinary 1990). Accordingly, invariants and markers should be especially likely to covary with psychologically-meaningful nonverbal responses.

One set of empirically established markers are the cardiovascular patterns associated with the motivational states of challenge and threat (Blascovich 2008; Blascovich and Tomaka 1996). The challenge and threat markers are relevant within contexts that require instrumental cognitive responses to meet a self-relevant goal. Examples of such *motivated performance situations* include taking a test, giving a speech, and making a good impression. Hence, motivated performance situations include many of those situations that laypeople would consider "stressful." Challenge and threat motivational states follow from evaluations of resources to cope with the demands of motivated performance situations. Challenge occurs when coping resources (e.g., skills, dispositions, external support) are evaluated as meeting or exceeding the demands of the situation (e.g., required effort, danger, uncertainty). Threat occurs when the demands of the situation are evaluated as exceeding coping resources. Challenge and threat may thus roughly be understood as levels of context-specific "confidence."

The physiological markers of challenge and threat are based on Dienstbier's (1989) model of physiological toughness. This model suggests that the body activates the sympathetic–adrenal–medullary (SAM) and hypothalamic–pituitary–adrenocortical (HPA or PAC) axes to mobilize energy for performance. Whereas SAM activation can provide an efficient spike of energy mobilization, HPA activation results in a prolonged response. Exhibiting a fast onset and offset of SAM activation coupled with little HPA activation in response to stressors is associated with favorable outcomes, including better task performance and lower anxiety.

The biopsychosocial model describes cardiovascular patterns sensitive to relative activation of SAM and HPA axes. A constellation of cardiovascular measures differentiates challenge from threat: heart rate (HR); cardiac output (CO), the amount of blood in liters pumped by the heart per minute; and total peripheral resistance (TPR), an index of vascular constriction/dilation. During challenge, heightened SAM activation leads to increased HR from a resting baseline, dilation of arteries (lower TPR), and greater blood flow (higher CO). During threat, SAM activation increases HR but HPA activation inhibits the CO increase and TPR decrease that would otherwise occur.

Over 30 studies establish these cardiovascular indexes as *markers* of challenge/threat motivational states. Initially, studies showed that within (and only within) motivated performance situations, self-reports of challenge and threat (a) were correlated with the cardiovascular patterns, (b) were not caused by the cardiovascular patterns, and (c) increased in parallel with the cardiovascular patterns following challenging versus threatening instructional sets (Tomaka et al. 1993, 1997; for a review, see Blascovich and Tomaka 1996). Providing convergent evidence, these cardiovascular markers respond in a manner that is consistent with predictions from theories of social comparison, social facilitation, intergroup interaction, affective priming, emotional disclosure, social stigma, self-esteem, and more (Blascovich et al. 1999, 2001, 2002; Mendes et al. 2002, 2001, 2003; Seery et al. 2004; Weisbuch-Remington et al. 2005). Finally, the challenge/threat markers have predictive validity. The challenge motivational state includes more confidence in task coping and greater energy mobilization than threat, factors which should enhance performance. Indeed, challenge predicts better performance than threat, and this predictive power is greater than with any single cardiovascular measure (Blascovich et al. 2004; M. D. Seery et al. 2008, Unpublished manuscript).

In summary, the biopsychosocial model of challenge and threat describes a theoretically-based, empirically-validated, and psychologically-relevant cardiovascular pattern. Importantly, challenge and threat are indexed as responses to a specific type of “stressful situation”—a motivated performance.

The Current Research

Cardiovascular patterns of challenge and threat may correspond to equally complex patterns of nonverbal behavior. In comparison to early theories of nonverbal behavior (e.g., Darwin 1872), recent theories (Ekman and Friesen 1969) emphasize the role of higher-order cognitive processes in satisfying social constraints on nonverbal behavior. Facial behavior appears to be especially amenable to conscious control (Ekman and Friesen); consequently, facial responses may reflect social desirability more than subjective or physiological experience. Indeed, positive facial expressions can sometimes be more likely among people experiencing negative affect than among people experiencing neutral affect (Ansfield 2007; Cole 1986). In contrast, the voice appears to be substantially less amenable to conscious control and may be a more veridical indicator of psychological experience (Ekman and Friesen). Thus, facial and vocal channels may differ with regard to their relationship to physiological processes.

The face and the voice were examined here with regard to their relationship to the colloquial equivalent of challenge—confidence. In the context of a socially-situated task (i.e., interacting with and trying to make a good impression on a stranger), the face should portray socially-desirable confidence and perhaps especially among individuals experiencing threat. Those experiencing threat may put particular effort into creating a confident facial expression (cf. Ansfield 2007; Ekman and Friesen 1969) and may therefore appear more confident than challenged individuals. In contrast, the voice should portray confidence more veridically, such that individuals experiencing challenge sound more confident than those experiencing threat. This conflicting pattern should yield a complex picture in which cardiovascular reactivity consistent with threat is associated with more confidence in the face than in the voice, as compared to individuals experiencing challenge. In summary, we expected covariance in cardiovascular and nonverbal responses to a motivated performance task. This covariance should only be observable with complex cardiovascular patterns that index psychological processes.

Method

Participants

Ninety female students from an introductory psychology course at the University of California at Santa Barbara received partial course credit for participation. Although social interaction is engaging for both males and females, it is most likely to be considered a motivated performance for females as the latter are often more sensitive to interpersonal feedback (e.g., Williams and Sommer 1997). Of these 90 participants, 30 were selected for nonverbal analysis on the basis of their cardiovascular patterns (see section "Selection of Target Participants").

Measures

Physiological Measures

Physiological measurement devices were used to noninvasively record cardiac and hemodynamic signals allowing the recording or calculation of HR, CO, and arterial resistance (TPR). A Minnesota Impedance Cardiograph (Model 304B), a Cortronics continuously inflated blood pressure monitor (Model 7000) and a Coulbourn EKG amplifier/coupler (Model S75-11) provided physiological signals. Coulborn amplifiers (Model S79-02) conditioned the impedance signals.

The Cortronics blood pressure monitor provided continuous blood pressure readings. Cardiac performance was monitored by electrocardiographic (EKG) and impedance cardiographic (ZKG) recordings. A Standard Lead II configuration (left leg, right arm, and right leg ground) or the ZKG provided input to the EKG amplifier. The ZKG uses a tetrapolar aluminum/mylar tape electrode system. An interactive software program was used to record and subsequently score the data.

Nonverbal Measures

Participant behavior was recorded with a microphone and a video camera hidden behind tinted glass (directly facing the participant). From these recordings, two sets of video clips were created. In the first set, silent video clips were cropped at the participant's chin in order to isolate nonverbal behavior in the face (facial expression clips). In the second set, video was removed, as were high-frequency sounds (digitally), so that prosody, but not individual words, could be perceived (cf. Rogers et al. 1971). This set of "content-filtered" clips was created in order to isolate paraverbal behavior.

Twenty-four undergraduate students were randomly assigned to judge either video clips or content-filtered clips for the self-confidence and dominance (on 0–5 scales) exhibited by each target participant. Technical problems were encountered by the first six judges of content-filtered clips; the data from these judges were eliminated and the problems were resolved for the final six judges. Hence, 12 judges rated the video clips and 6 judges rated the content-filtered clips.

Inter-rater reliability was satisfactory for all ratings: facial self-confidence ($\alpha = .81$), vocal self-confidence ($\alpha = .59$), facial dominance ($\alpha = .74$), and vocal dominance ($\alpha = .56$). Consequently, ratings were averaged across judges; resulting facial self-confidence and facial dominance scores ($r = .52$, $p = .004$) were averaged to form a facial confidence index, whereas vocal self-confidence and vocal dominance scores ($r = .89$, $p < .001$) were averaged to form a vocal confidence index.

Procedure

Participants completed the experiment individually. Upon arrival at the laboratory, an experimenter greeted the participant and escorted her to a preparation room. Sensors necessary for physiological recording were applied and the participant was brought into a control room and seated upright in a comfortable upholstered chair. A 5-min rest period began when the experimenter left the room, during which baseline levels of physiological responses were assessed. After the rest period, the participant was informed that a member of the research team would now enter the chamber to engage the participant in a "getting to know you" exercise. A female experimenter unfamiliar to the participant entered the recording room, introduced herself, and sat down to start a conversation. The conversation lasted 3 min, during which physiological measurements were recorded. The interviewer asked the participant a pre-determined set of questions about herself. Questions included, "Tell me about your hometown," "How do you like college so far?" "What do you like to do in your spare time?" "What are your plans after college?" and "How do you think people that know you well would describe you?" This format encouraged the participant to actively engage in conversation. Upon completion, the sensors were removed and the participant was debriefed.

Selection of Target Participants

Mean HR, CO, and TPR values were calculated for each minute within the rest and task periods. Cardiovascular reactivity values were calculated for each measure by taking the value from the last minute of the baseline period and subtracting it from the value obtained for the social interaction. Although change scores (of which reactivity is one example) are sometimes discouraged on psychometric grounds, their use is preferable in psychophysiological research (Llabre et al. 1991).

As in previous research (Blascovich et al. 2004), TPR reactivity scores were standardized and subtracted from standardized CO reactivity scores to form a challenge/threat (CT) index, in which higher scores indicate greater challenge and lower scores indicate greater threat. Because both challenge and threat patterns require increases from baseline in HR, only participants whose HR increased from baseline were considered. Of the 90 initial participants, 88 exhibited increased HR and overall HR reactivity was greater than 0, $t(89) = 16.14$, $p < .001$, $r = .86$. Given HR increases, the 15 lowest and 15 highest CT scores were selected as prototypical of threat and challenge, respectively (see Table 1 for descriptive statistics). This strategy made it possible to examine the clearest instances of challenge versus threat without incorporating participants who exhibited an intermediate state.

Table 1 Cardiovascular baseline and reactivity data for the "challenge" and "threat" groups

Variable	Challenge group	Threat group	$t(28)$
Reactivity			
Cardiac output	76 (.50)	−1.62 (.47)	−13.43*
Total peripheral resistance	−64.33 (41.6)	174.92 (93.6)	9.05*
Heart rate	13.35 (8.09)	13.41 (6.64)	.02
Baseline			
Cardiac output	8.93 (3.04)	9.26 (2.34)	.33
Total peripheral resistance	821.72 (378.92)	780.99 (210.97)	−.36
Heart rate	68.21 (13.93)	87.30 (11.13)	4.14*

Note: Means are reported with standard deviation in parentheses. Univariate outliers (those exceeding 3.3 standard deviations from the grand mean) were transformed by assigning the deviant raw score to a value one unit larger or smaller than the next most extreme score (Tabachnick and Fidell 1996). To generate t statistics, mean values from the challenge and threat groups were tested against each other. When CT index scores were adjusted for baseline values, one participant in the challenge group no longer exhibited a strong challenge response; dropping this participant from analyses had no substantive effect on results

* $p < .05$

Results and Discussion

We predicted that participants who exhibited threat—consistent with experiencing lower confidence—should sound less confident but look more confident than challenged participants, a pattern that should result in an interaction. A two-way ANOVA with repeated measures on nonverbal channel revealed only a significant interaction, such that vocal confidence was *lower* and facial confidence was *greater* among threatened (versus challenged) participants, $F(1, 28) = 5.25$, $p = .03$, $r = .91$. Figure 1 depicts the marginal means responsible for the interaction (Rosenthal and Rosnow 1985). No effects for HR reactivity approached significance (ps $> .7$).

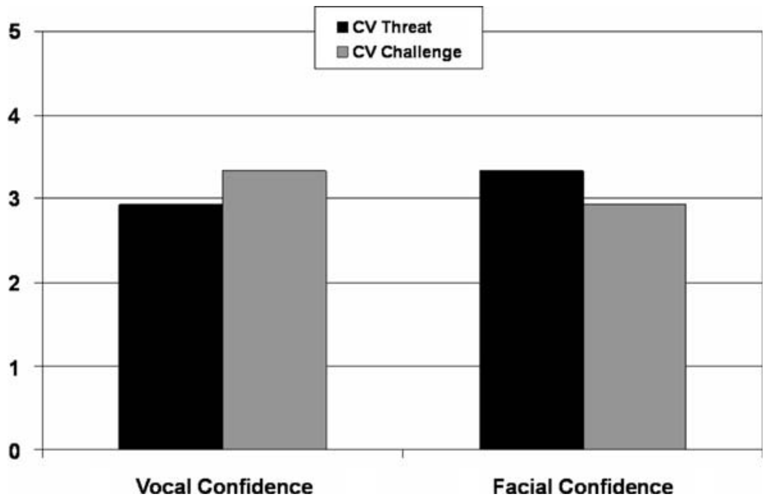

Fig. 1 Judged confidence as a function of cardiovascular pattern and nonverbal channel. Bars represent marginal means

For participants who exhibited threat, these results are consistent with attempting to mask an underlying lack of confidence—indicated by their vocal responses—with a relatively controllable facial nonverbal display. In contrast, the nonverbal pattern associated with challenge is consistent with actually experiencing higher confidence, coupled with a lack of concern for appearing confident. More generally, the discrepancy between vocal and facial confidence that was perceptually available to observers indicated a cardiovascular pattern normally observable only through sophisticated physiological measurement devices.

It is noteworthy that these observable nonverbal patterns occurred within a situation likely to elicit considerable impression management motives. In general, the relationship between psychological processes and nonverbal communication may be moderated by impression management motives in a channel-specific manner. Cole's (1986) study provides indirect evidence for this claim, in that children's positive facial responses to a disappointing toy changed markedly on the departure of the experimenter. Examining the conditions most likely to give rise to vocal-facial discrepancies may be a fruitful topic for future research.

More broadly, these results demonstrate that there is covariance in physiological and nonverbal responses but that this covariance may be best observed with a meaningful pattern of physiological activity. Conversely, facial expressions alone may often be misleading, especially as compared to vocal expressions (cf. Ansfield 2007; Cole 1986; Ekman and Friesen 1969) and may be particularly subject to motivational concerns, such as impression management. These considerations highlight the importance of utilizing complex, empirically-validated patterns of physiological reactivity in examining the relationship between physiological and nonverbal responses.

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