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Social "Facilitation" as Challenge and Threat

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The authors conducted an experiment to test a theoretical explanation of social facilitation based on the biopsychosocial model of challenge and threat. Participants mastered 1 of 2 tasks and subsequently performed either the mastered (i.e., well-learned) or the unlearned task either alone or with an audience while cardiovascular responses were recorded. Cardiovascular responses of participants performing a well-learned task in the presence of others fit the challenge pattern (i.e., increased cardiac response and decreased vascular resistance), whereas cardiovascular responses of participants performing an unlearned task in the presence of others fit the threat pattern (i.e., increased cardiac response and increased vascular resistance), confirming the authors' hypotheses and the applicability of the biopsychosocial model of challenge and threat to explain these results.

Historical accounts of social psychology (e.g., Allport, 1954, 1968) credit Triplett (1898) with the first social psychology experiment. His explorations and labeling of social facilitation phenomena gave rise to an enduring theoretical puzzle that attracted the interest of many researchers (see Bond & Titus, 1983; Cacioppo & Petty, 1986; Geen & Gange, 1977; Kent, 1994; Sanders, 1984, for reviews). Generally, *social facilitation* refers to performance enhancement and impairment effects engendered by the presence of others either as coactors or, more typically, as observers or an audience. A wealth of published studies (more than 250 by the early 1980s) and more than a handful of theoretical accounts of social facilitation have emerged in the past century.

Triplett's (1898) article described a naturalistic observational study and an experimental investigation. His observational account of competitive cyclists reported faster times for those racing against other cyclists than those racing against the clock. The laboratory experiment consisted of children spinning a fishing line apparatus with other children or alone. The conclusion drawn most often from Triplett's experiment is that coactors enhance performance (e.g., Bond & Titus, 1983). However, examination of the results of Triplett's report indicates that half the children performed the same (25%) or worse (25%) with coactors than alone.

Triplett's identification of both socially induced enhancement and impairment effects presaged later experimental results indicating that the presence of others can induce both types of effects. Explaining the oppositional performance effects also provided substantial grist for later theories. Although coaction provided the key to Triplett's observations and explanation, it eventually proved unnecessary for social facilitation effects. Rather, only the presence of others proved necessary (Bond & Titus, 1983; Kent, 1994; Zajonc, 1965).

Key Factors

Investigators have debated two major issues in the social facilitation literature over the past 35 years: the role of physiological arousal and the extent to which social facilitation processes involve evaluative–cognitive mechanisms such as evaluation apprehension and attention. Both issues stem from the influential theoretical account and research of Zajonc (1965, 1980) and alternative accounts offered in reaction to his theoretical explanations (e.g., Carver & Scheier, 1981; Cottrell, 1972; Guerin & Innes, 1982; Sanders, Baron, & Moore, 1978).

Physiological Arousal

Both Thibaut and Kelley (1959) and Zajonc (1965) posited that the presence of others increases generalized drive or arousal. Independently, they claimed that arousal increases dominant responses, resulting in enhancement of simple or well-learned tasks but impairment of complex or unlearned tasks, a Hullian notion (Spence, 1956). In several studies, Zajonc, his colleagues, and other investigators (e.g., Benedict, Cofer, & Cole, 1980; Zajonc, Heingartner, & Herman, 1969; Zajonc & Sales, 1966) demonstrated that the presence of others enhanced performance of well-learned tasks and impaired performance of unlearned tasks in humans and other species, including insects. On the basis of the similarity between the results of animal and human studies, Zajonc argued that the drive or arousal state underlying social facilitation effects is primitive and unlearned.

Because Zajonc's (1965) adoption of the Hullian equation of learned drive with generalized arousal is critical to his theory, many investigators have attempted to identify physiological re-

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sponses as mediators of social facilitation effects. However, Bond and Titus's (1983) meta-analysis concluded that only very weak physiological effects had been demonstrated and the presence of others affected only palmar sweating. In addition, Cacioppo and Petty (1986) claimed that physiological responses may be elicited by the presence of an audience, but they conceded that more sensitive physiological measures need to be generated in order to empirically demonstrate these effects.

Carver and Scheier (1981) quite directly and appropriately attacked the utility of physiological assessments used in social facilitation research. They suggested that the general arousal construct was empirically meaningless, noting that researchers' interpretations of both increases and decreases from baseline physiological responses during task performance in the presence of others as "generalized arousal" are flawed because increases and decreases in these responses from resting levels are not equivalent physiologically. In agreement with Cacioppo and Tassinary (1990), Carver and Scheier argued that equating increases and decreases in physiological responses precludes the one-to-one correspondence between the construct (i.e., arousal) and the physiological measures necessary to draw strong inferences. Similarly, Sanders (1981) argued that generalized arousal was used as a hypothetical construct in social facilitation and could not be directly measured.

We agree with these arguments regarding arousal as used in social facilitation theory and research to date. Indeed, we have argued strongly that the use of arousal as a purely hypothetical or metaphoric construct precludes meaningful physiological assessment (Blascovich, in press; Blascovich & Katkin, 1982; Blascovich & Kelsey, 1990; Blascovich & Tomaka, 1996). However, specifying patterns of physiological responses on the basis of meaningful psychophysiological theory and sophisticated measurement techniques can inform our understanding of processes such as social facilitation.

Evaluative–Cognitive Mechanisms

Soon after Zajonc (1965) specified generalized arousal as an unlearned response to the presence of others, various theorists argued that, at least for humans, more than a general unlearned drive or arousal state engendered enhancement or impairment effects. Carver and Scheier's (1981) theory described the motivational effects of self-evaluation to understand the facilitation and inhibitory effects of the presence of others. They argued that if favorable assessment of one's ability to attain a goal is made, then one continues to pursue the goal and facilitation is exhibited. If an unfavorable assessment is made, then one does not continue to pursue one's goal and inhibition is exhibited. However, this motivational explanation does not include arousal as necessary to the motivational component of self-evaluation.

Cottrell (1968) hypothesized that the presence of others elicits a learned drive response or arousal, suggesting that such responses stem from anticipated evaluations from others. Cottrell, Wack, Sekerak, and Rittle (1968) tested this hypothesis and found facilitation effects only when the others present could evaluate participants' performance. Many conceptual replications followed (e.g., Henchy & Glass, 1968; Martens & Landers, 1972; Paulus & Murdoch, 1971; Worringham & Messick, 1983). Others, notably Sanders and Baron (1975), suggested that the presence of others increases drive or arousal because it provokes attentional conflict. Seta and Seta (1983) suggested that an audience may induce anxiety whenever the performer lacks confidence for meeting the performance criterion of the audience. Concern over task performance may result in worry that limits the availability of resources to perform the task (Paulus, 1983; Seta & Seta, 1983). Weiss and Miller's (1971) review led them to posit more strongly that an audience induces an aversive drive state due to the threat of evaluation.

The evidence suggests that both unlearned and learned responses to the presence of others can operate in humans. Sanders (1984) concluded that neither the learned nor the unlearned drive positions can fully account for the data and that both may operate. Though most theorists interpret the unlearned drive or general arousal position of Zajonc (1965) as one precluding evaluation apprehension, Guerin and Innes (1982) argued that "social monitoring" of conspecifics (i.e., same-species others) is itself an unlearned response and has adaptive significance. Indeed, in his later theoretical article, Zajonc (1980) himself allowed for the threatening nature of evaluative others. For example, alertness to others in one's environment includes threat of evaluation. Similarly, Baron (1986) identified possible threat as one reason conspecifics may distract performers and create attentional conflict.

The Biopsychosocial Model of Challenge and Threat

In our biopsychosocial model (Blascovich & Mendes, in press; Blascovich & Tomaka, 1996), challenge and threat represent person–situation evoked motivational states that involve the interplay of affective and cognitive processes. As motivational states, challenge and threat are related, at least conceptually, to approach–avoidance or appetitive–aversive states. Affectively, they involve positive and negative feelings and emotions, and cognitively, they involve attention and appraisal.

Challenge and threat occur in goal-relevant situations, ones that relate to self-evaluations perceived as relatively important. Challenge occurs when the individual experiences sufficient resources to meet situational demands. Threat occurs when the individual experiences insufficient resources to meet demands. In the latest revision of our theoretical model (Blascovich & Mendes, in press), we argue that the experience of demands and resources may operate via independent affective and cognitive processes, each of which may be unlearned or learned, conscious or unconscious. Thus, the presence of unlearned affective cues such as the presence of a predator or learned affective cues such as the presence of a pet may unconsciously influence experiences of demands and resources and, hence, threat and challenge.[1]

[1] Although a thorough discussion of the functionality of challenge and threat motivation lies beyond the scope of this article, some discussion is appropriate. Even though we have found empirically that challenged individuals outperform threatened individuals in the types of motivated performance situations we have used (see Blascovich & Tomaka, 1996, for a review), threatened individuals certainly outperform disengaged others (i.e., those for whom the task is not goal relevant). Hence, both challenge and threat represent motivational states that can drive behaviors and increase performance in many situations. Pathophysiologically, however, repeated threat motivation is likely to lead to physical malfunction of both the cardiovascular and immune systems (e.g., Blascovich & Katkin, 1993; Cohen & Williamson, 1991).

Though threat and challenge occur in a variety of performance situations, we have limited our empirical work nearly exclusively to nonmetabolically demanding performance situations. These situations are higher in psychological than physical demands and involve active performance (e.g., giving a speech, solving verbal and mathematical problems, or playing a game) rather than passive performance (e.g., viewing a scary film or listening to rousing music). Such active performance situations are ubiquitous in modern life and appear to match quite closely the types of tasks traditionally used in social facilitation research.

The cardiovascular system appears particularly attuned to challenge and threat. We have devoted much work to the delineation of cardiovascular response patterns evoked during challenge and threat. Drawing on Obrist's (1981) and Dienstbier's (1989) psychophysiological theories, we have developed indexes of challenge and threat on the basis of patterns of cardiovascular reactivity. During challenge, sympathetic neural stimulation of the myocardium enhances cardiac performance, particularly contractility as depicted in Figure 1. At the same time, adrenal medullary release of epinephrine causes vasodilation resulting in declines in systemic vascular resistance. This pattern mimics cardiovascular performance during aerobic exercise and represents the efficient mobilization of energy for coping. This pattern typically produces little or no change in blood pressure.

During threat, sympathetic stimulation also enhances cardiac performance, thereby increasing cardiac contractility. However, pituitary–adrenal cortical activity inhibits the adrenal medullary generated release of epinephrine. Consequently, during threat, increased cardiac performance occurs, but without accompanying decreases in systemic vascular resistance. Rather, no change or even slight increases in systemic vascular resistance occur. This pattern typically produces noticeably increased blood pressure. We have provided a more complete explanation of the autonomic and endrocrinological bases for these patterns elsewhere (Blascovich & Mendes, in press; Blascovich & Tomaka, 1996; Tomaka, Blascovich, Kelsey, & Leitten, 1993).

These cardiovascular markers have proved themselves in many theoretical and empirical contexts, including validational work (Blascovich & Tomaka, 1996; Tomaka et al., 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997) and theory-based work on a variety of social psychological processes related to task performance, including affective cues, attitude functionality, social support, and stigma (e.g., Allen & Blascovich, 1994; Allen, Blascovich, Tomaka, & Kelsey, 1991; Blascovich et al., 1993; Blascovich, Mendes, Lickel, & Hunter, in press; Blascovich, Spencer, Steele, & Quinn, 1996; Mendes, Blascovich, Watson, & Kelly, 1998; Mendes, Hunter, Lickel, & Blascovich, 1998).

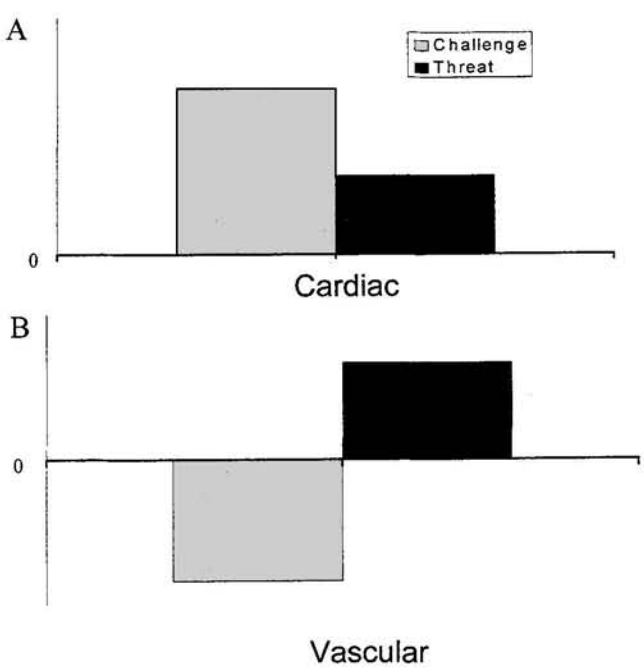

Figure 1. A: Theoretical pattern of cardiac activity during challenge and threat. B: Theoretical pattern of vascular activity during challenge and threat.

Challenge, Threat, and the Presence of Others

We believe that our biopsychosocial model of challenge and threat has direct relevance to social facilitation phenomena. By virtue of its incorporation of both learned and unlearned affective and cognitive processes, the biopsychosocial model of challenge and threat can account for both unlearned and learned processes such as those proposed by Zajonc (1965), Cottrell (1968), Weiss and Miller (1971), Sanders and Baron (1975; see also Baron, 1986), Carver and Scheier (1981), and Cacioppo and Petty (1986). More important for our purposes here, the biopsychosocial model offers ~~a~~ nonmetaphorical arousal construct (i.e., one based on psychophysiological theory) that, coupled with state-of-the-art physiological assessment techniques, offers the possibility of meaningful physiological indexing of specific motivational states (i.e., challenge and threat) potentially underlying social facilitation effects (i.e., enhancement and impairment).

Accordingly, we believe that the presence of others increases the goal relevance of performance. As Seta and Seta (1995) delineated, the presence of others "increases the value of task performance; performing well in front of an audience can lead to praise and recognition. Performing poorly can lead to negative outcomes, such as embarrassment and shame" (p. 97). Similarly, Cacioppo and Petty (1986) argued that "the presence of the observer precedes and influences the mobilization of temporary energy resources (i.e., effortful striving)" (p. 663). Thus, individuals should exhibit more arousal under audience conditions. However, the nature of this arousal should differ as a function of challenge and threat phenomenology.

Specifically, increases in the goal relevance of performance situations in turn increase the likelihood of challenge and threat responses. When individuals perform well-learned tasks in the presence of others, they should experience greater challenge and exhibit the characteristic cardiovascular response pattern that accompanies challenge because of the resources (i.e., task mastery) they bring to the performance situation. When individuals perform unlearned tasks in the presence of others, they should experience greater threat and exhibit the characteristic cardiovascular response pattern that accompanies threat because of a lack of resources (i.e., task unfamiliarity) they bring to the performance situation.

Overview of Experiment

In order to test these hypotheses, a 2 (presence of others: audience or alone) × 2 (task: unlearned or well-learned) between-subjects experimental design was used. The experiment consisted of a *learning* phase and a *testing* phase. Participants learned one of two randomly assigned tasks to a proficiency of 80% correct on two consecutive blocks of trials. Subsequently, participants were randomly assigned to perform a second task either alone or in the presence of a male and a female observer. In each audience condition, half the participants were randomly assigned to perform the task they had mastered (i.e., learned to criterion) and the other half, the unlearned task.

Method

Setting and Participants

The social psychophysiology laboratory in the Department of Psychology at the University of California, Santa Barbara, was the experimental setting. This laboratory contains separate control, participant preparation, and recording rooms, and a variety of physiological, audiovisual, and computer equipment. After a brief session in the preparation room, participants entered and remained in an adjacent acoustically and environmentally controlled recording room, approximately 3.0 × 3.5 m. The recording room contained video and audio equipment for monitoring participants' well-being and presentation of the instructions as well as a computer monitor and keyboard to record participant responses. During the experiment, participants sat upright in a comfortable upholstered chair.

We recruited 84 healthy undergraduate participants (41 men and 43 women) from University of California, Santa Barbara.[2] Students received either course credit or $10 for their participation.

Performance Tasks

Using results from extensive pretesting, we designed two tasks that were equivalent in difficulty but unique in their visual presentation and method of operation. Participants were randomly assigned to learn one of the tasks to criterion. Participants performed their assigned task in blocks, stopping only when they had successfully categorized 80% of the trials correctly in two consecutive blocks.

Number-categorization task. We adapted the categorization task from a perceptual boundary exercise (Maddox & Ashby, 1996). Each task trial consisted of the presentation of two 2-digit numbers on a computer monitor and required participants to categorize the stimuli into one of two groups. The task required participants to infer or learn the classification rules using feedback, consisting of a high-pitched tone following a correct response and a low-pitched tone following an incorrect response, provided after each trial. The classification rule was based on the distribution from which the numbers were sampled. Low numbers (below 68) belonged in Group 1, whereas high numbers (above 68) belonged in Group 2. The computer recorded participants' responses on each trial. During each trial, participants viewed the stimuli for 3 s, during which they responded by pressing one of two keys corresponding to category choices. If participants did not respond during the 3 s, they heard the low-pitched tone and the next trial commenced. After each block of 25 trials, the computer presented the percentage correct for that block.

Pattern-recognition task. The second task, a pattern-learning task, was developed in the laboratory. This task consisted of a series of 5 × 5 matrices of letters. Each matrix appeared on a computer screen, and a single word composed of adjacent (either horizontally, vertically, diagonally, or in mixed arrangements) letters was highlighted. The goal of the task was to determine if the physical juxtaposition of letters in the highlighted word was in the "correct" pattern (a right angle) no matter the pattern rotation and did not change across the blocks of trials.

Each matrix was presented for approximately 6 s along with "yes" and "no" buttons on the computer monitor. If participants thought the pattern was correct, they used the computer mouse to click the "yes" button; if they thought the pattern was incorrect, they clicked the "no" button. After responding, they received immediate feedback regarding their decision. A high-pitched tone signified a correct response, a low-pitched tone signified an incorrect response. If participants did not respond within 6 s, the trial was scored as incorrect and the task continued to the next trial. After 10 trials (i.e., a block), participants received feedback regarding their overall performance. Similar to what they were asked to do in the number-categorization task, participants were presented up to 10 blocks of trials to learn to criterion.

The tasks were constructed so they would be equivalent in difficulty. Pretesting of the tasks found that undergraduates took, on average, 5.5 (SD = 2.9) trials to learn the categorization task and 5.5 (SD = 2.2) trials to learn the pattern-recognition task to criterion. The two tasks were counterbalanced and nested within the experimental design.

Physiological Measures

Cardiac and vascular measures were recorded noninvasively using equipment that meets accepted commercial and hospital safety standards and using guidelines established by the Society for Psychophysiological Research (Sherwood et al., 1990). Cardiovascular signals were recorded using a Minnesota Impedance Cardiograph (Model 304B; Surcom, Inc., Minneapolis, MN) and a continuously inflated blood pressure monitor (Cortronics Model 7000; Cortronics, Kings Park, NJ); the signals were conditioned using Coulbourn amplifiers.

Impedance cardiographic (ZKG) and electrocardiographic (ECG) recordings provided continuous measures of cardiac performance. The ZKG uses a tetrapolar aluminum or mylar tape electrode system to record basal transthoracic impedance (Z0) and the first derivative of basal impedance (dZ/dt). Two pairs of ZKG electrodes completely encircle the participant's body. The two inner electrodes are placed at the base of the neck and the thoracic xiphisternal junction; the two outer electrodes are placed on the neck and abdomen, separated from the respective inner electrodes by at least 3 cm. The ZKG passes an AC current of 4 mA RMS at 100 kHz through the two outer electrodes, and measures Z0 via the two inner electrodes. A Standard Lead II configuration (right arm, left leg, and a grounded right leg) records the ECG signals.

The Cortronics blood pressure monitor collected continuous noninvasive recordings of blood pressure from the brachial artery of the participant's nonpreferred arm. An interactive MS-DOS microcomputer system and software program developed and tested in a similar laboratory (Kelsey & Guethlein, 1990) scored the cardiovascular data. On the basis of previous research (see Blascovich & Tomaka, 1996, for a review), we chose four measures of cardiovascular reactivity (i.e., changes from resting levels) to differentiate challenge and threat responses to potential stress. These included three cardiac performance measures, preejection period (PEP; an index of cardiac contractile force or inotropic performance), cardiac output (CO; liters of blood ejected from the left ventricle per minute), and heart rate (HR; a rate-based or chronotropic measure of cardiac performance), and one measure of peripheral vascular tone, total peripheral resistance (TPR). TPR is an index of systemic vascular resistance derived from blood pressure and ZKG recordings using the formula (mean arterial pressure/cardiac output) × 80 (Sherwood et al., 1990).

[2] Participants were screened for the existence of a heart murmur, pregnancy, or the use of medication that would affect their cardiovascular functioning.

Procedure

One of two female experimenters met the participant on his or her arrival, provided information regarding experimental procedures, and obtained informed consent.[3] In the consent form, we explained that we were interested in studying physiological reactions during various activities (e.g., quiet rest and cognitive tasks). The experimenter then attached the sensors and transducers necessary for physiological recording. Next, the participant entered the recording room and sat upright in a comfortable upholstered chair. The experimenter gave him or her the keyboard (for the number-categorization task) and the mouse (for the pattern-learning task) and instructed him or her how to perform both tasks. The keyboard had two clearly labeled keys, "G1" and "G2," representing categories Group 1 and Group 2, respectively. The experimenter then left the recording room.

The participant sat quietly during a 15-min baseline calibration and adaptation period. Cardiovascular responses collected during the last 5 min of this period were the resting, or baseline, levels of physiological responses. Physiological recording continued for the duration of the experiment.

Subsequently, the participant heard audiotaped instructions for the first task. From the control room, the experimenter informed the participant, via the intercom, that she or he would perform this task until 80% correct was achieved on two consecutive blocks. The participant then engaged in either the categorization or pattern-recognition task, according to random assignment. Once the participant reached criterion, he or she received instructions via the computer that the learning phase of the experiment was completed successfully. If after 10 blocks the participant still had not reached criterion, the computer instructed the participant that the learning phase was over, and the participant completed the rest of the experiment.

A 5-min period was the recovery period between the learning and the testing phases. The participant received instructions to relax quietly. Following this baseline period, the participant received audiotaped instructions explaining the testing phase of the experiment.

The participant received one of four sets of instructions, according to the combination of audience and task conditions to which she or he had been randomly assigned. In the observed conditions, the instructions indicated that "two students will be entering the room to observe your performance on the task." This was followed by either instructions for the learned condition, "you will be performing the same task that you just learned," or the unlearned condition, "you will be performing a different task than the one you just learned." In the alone condition, the instructions contained only information regarding which task the participant was to perform: learned or unlearned.

In the observed condition, two undergraduates (one female and one male) entered the recording room, took chairs from the corner of the room, and placed the chairs so that they could observe both the participant and the computer screen. The observers sat approximately 45.7 cm from the participant. The experimenter then instructed the participant that he or she would be performing this task for five blocks and to begin. In the alone condition, participants simply received instructions and engaged in the task. After completion of the testing phase, the experimenter returned to the room and removed the physiological sensors and debriefed, thanked, and paid the participant.

Results

Scoring and Data Reduction

Participant retention. Twenty-one participants did not learn to criterion. Proportionally equivalent numbers of men and women did not learn to criterion, $\chi^2(1, N = 84) = 0.00$, *ns*. In addition, proportionally equivalent numbers of participants completing the pattern-recognition task and the number-categorization task did not learn to criterion, $\chi^2(1, N = 84) = 0.00$, *ns*. After excluding the participants who did not learn the task to criterion, 63 participants remained.[4] Additionally, data from 2 participants were lost because of equipment failure. Data from a total of 61 participants (31 males and 30 females)—15 in the alone–learned, 17 in the alone–unlearned, 14 in the observed–learned, and 15 in the observed–unlearned—were used in the following analyses.

Cardiovascular measures. Mean PEP, CO, HR, and TPR values were calculated for each rest and task period. Multivariate and univariate tests for differences in baseline physiological levels between task and audience conditions with the last minute of each baseline period as the dependent measure again revealed no significant main effects or interactions (all $ps > .50$). As is typical in studies of psychophysiological reactivity in which baseline scores do not differ among levels of between-subjects factors, reactivity scores (differences from baseline) were used as the primary dependent variable (Kamarck et al., 1992). Reactivity scores were calculated for each cardiovascular measure by subtracting the average value from the last minute of the rest period from the average value from the first minute of the testing phase.

Performance measures. Accuracy scores from both the learning and testing phases were calculated for each block, converted to percentage correct, and then transformed using an arcsine function to correct for skewness associated with percentage conversions.

Learning Phase Analyses

Cardiovascular response measures. We conducted a repeated measures multivariate analysis of variance (MANOVA) to examine physiological responses during the learning phase of the experiment. We used the first and last minute of the learning phase for each participant. No effects for type of task (numbers or patterns) or the Task × Time interaction were significant. A significant multivariate effect for time was found, Wilks's $\lambda = .51$, $F(7, 57) = 3.47$, $p < .01$. An examination of the physiological variables revealed significantly greater reactivity in the first minute compared with the last minute of the learning phase. The pattern of physiological reactivity during the first minute of the learning phase was consistent with the challenge pattern of physiological reactivity (i.e., increases in cardiac activity coupled with decreases in vascular resistance).

Performance. The number of blocks completed before the participants reached criterion was submitted to a 2 (task type) × 2 (gender) analysis of variance (ANOVA) to determine any effects of task type, gender, or their interaction. No main effects or interactions were significant. The mean number of blocks completed before criterion was achieved was 5.5 ($SD = 2.9$).

Testing Phase Analyses

Cardiovascular reactivity: Goal relevance. We submitted the cardiovascular reactivity variables from each of the four experi-

[3] No experimenter effects were found.

[4] We conducted analyses with the people who never learned the task as if they had. The physiological results were attenuated compared to the analyses with these participants excluded; however, the multivariate main effect for the presence of an audience was still significant, $F(4, 77) = 3.10$, $p < .01$, as was the task by audience interaction, $F(4, 77) = 2.28$, $p < .05$. The nature of the interaction was identical to that of the restricted model.

Table 1
Mean Cardiovascular Reactivity Variables by Presence of Others

	Presence of others			
	Alone		Audience	
Variables	*M*	*SD*	*M*	*SD*
Preejection period (ms)	1.0	5.2	5.7	10.4
Heart rate (bpm)	0.0	5.2	5.3	6.0
Cardiac output (1 L per min)	−0.2	0.7	0.2	1.5
Total peripheral resistance (dyne-second × cm^{-5} × 80)	26.4	107	39.2	206

Note. bpm = beats per minute.

mental conditions to a multivariate test against the intercept. Results from this analysis revealed that only the conditions with an audience present resulted in reactivity that differed significantly from zero: observed–learned, Wilks's λ = .38, $F(4, 10) = 4.13$, $p < .03$; observed–unlearned, Wilks's λ = .41, $F(4, 11) = 3.93$, $p < .04$; alone–learned, $F < 2$; alone–unlearned, $F < 1$. Both audience conditions (learned and unlearned) yielded significant univariate analyses for all four cardiovascular reactivity measures used (PEP, HR, CO, and TPR); see Table 1 for means.

Cardiovascular reactivity: Challenge and threat. The cardiovascular variables (PEP, CO, HR, and TPR) were used as the dependent measures in a 2 (audience) × 2 (task) × 2 (gender) MANOVA. This analysis revealed no main effect for gender of the participant nor did gender interact with the other independent variables. Consequently, gender was omitted from further analyses using cardiovascular reactivity.

A 2 (audience) × 2 (task) MANOVA was conducted and two significant effects were found. The audience condition multivariate main effect was significant, Wilks's λ = .78, $F(4, 56) = 3.86$, $p < .008$, as was the Audience × Task interaction, Wilks's λ = .80, $F(4, 56) = 3.25$, $p < .02$. The multivariate main effect for task was not significant. The reactivity data are graphed in Figure 2.

A follow-up multivariate simple effects test for task for the alone condition was not significant, $F(4, 27) = 1.26$, *ns*. The multivariate simple effects test from the observed condition yielded a significant multivariate effect for task, $F(4, 24) = 3.44$, $p < .04$. As predicted and consistent with the challenge pattern of reactivity, participants in the audience condition performing the

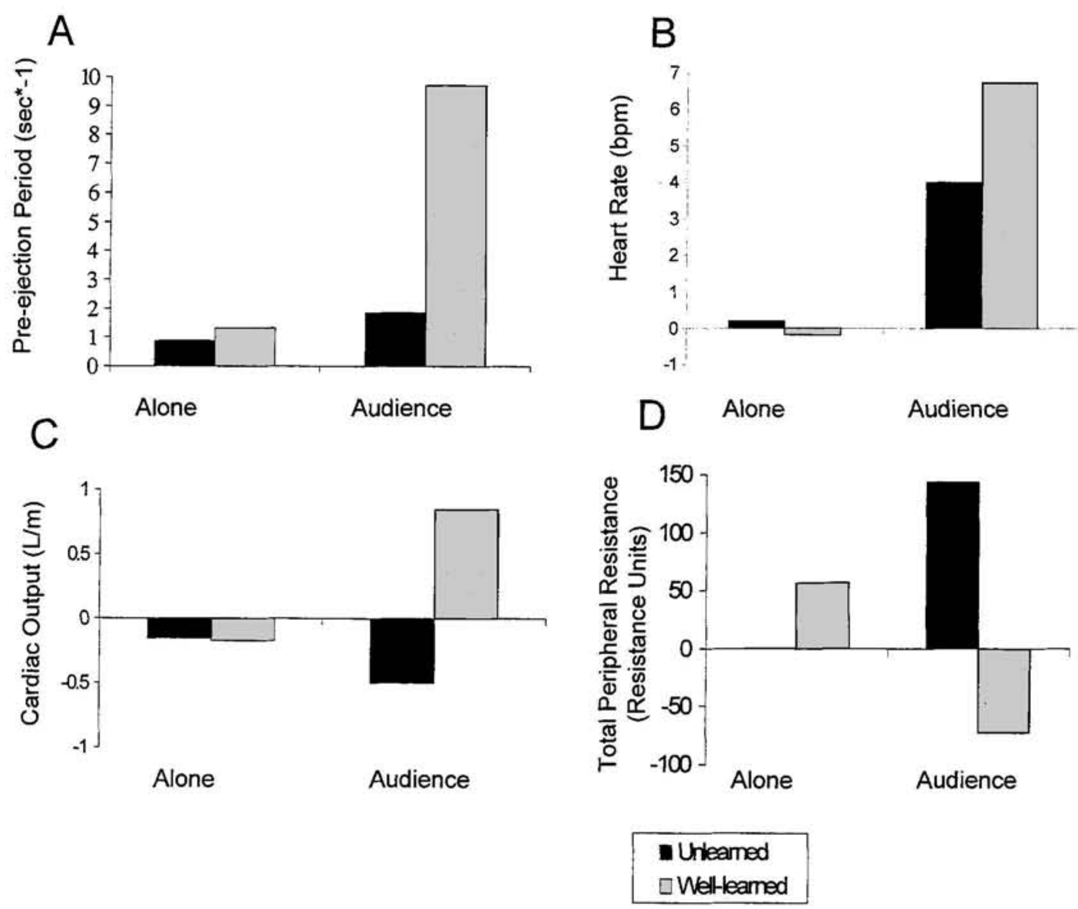

Figure 2. A–D: Physiological variables from the first minute of the testing phase. All variables are expressed as change scores from resting levels of response. Pre-ejection period is expressed in milliseconds per minute × −1, heart rate in beats per minute, cardiac output in liters per minute, and total peripheral resistance in resistance units.

learned task had higher cardiac reactivity (PEP, HR, and CO) and decreases in peripheral vascular resistance (TPR). Consistent with the threat pattern of reactivity, participants performing an unlearned task in front of an audience demonstrated increases in cardiac reactivity (PEP and HR) and an increase in peripheral vascular resistance (TPR). Although the mean CO was not greater than zero among participants performing the unlearned task in front of an audience, it was not significantly less than zero, $t(14) = -1.1$, *ns*. Typically, increases in CO in predicted threat conditions do not differ from zero (see Tomaka et al., 1993, and Tomaka & Blascovich, 1994, for similar findings).

ANOVAs from the audience condition were calculated to examine the effects of task mastery on each of the cardiovascular variables. All cardiovascular variables (except HR) contributed significantly to the multivariate test: PEP, $F(1, 27) = 4.66$, $p < .04$; CO, $F(1, 27) = 7.14$, $p < .01$; HR, $F(1, 27) = 1.47$, $p = .24$; and TPR, $F(1, 27) = 10.76$, $p < .003$.

To test for the incremental discriminatory power of the dependent variables after the effects of the other dependent variables have been accounted for, a series of step-down MANOVAs were conducted. Because a major assumption of MANOVAs is that the dependent variables are correlated, and in our case cardiac measures are positively correlated with each other and inversely correlated with the vascular measure, the independent effects of the dependent variables after controlling for the effects in the previous orderings are meaningful. The ordering is based on the impact of the cardiovascular variables from purely sympathetic to parasympathetic. Thus, PEP was entered into the model first, followed by CO, HR, and finally TPR. The results from step-down analyses yielded a clearly significant effect for task for PEP, $F(1, 27) = 4.66$, $p < .04$; and for CO, $F(1, 27) = 7.24$, $p < .003$; a nonsignificant effect for HR, $F(1, 27) = 1.22$, $p = .31$; and a significant effect for TPR, $F(1, 27) = 7.26$, $p < .003$. These results suggest that TPR contributed independently to the main effect of task mastery after controlling for all the cardiac variables.

Performance data. The mean percentage correct scores from the testing phase were first submitted to a 2 (stimuli type) × 2 (gender) × 2 (audience) × 2 (task) ANOVA to determine any effects of stimuli type, gender, or interactions with the main independent variables. No main effect for gender or for interactions with the main independent variables were found. There was a significant main effect for stimuli type, $F(1, 46) = 4.86$, $p < .05$. Participants performing the numbers task received higher average performance scores over the 10 blocks of the testing phase ($M = 84.9$) compared with participants performing the pattern task ($M = 76.0$). The type of task was not associated with any significant interactions with audience or task. Because no other significant interactions were found, we combined the two stimuli types and omitted gender from the following analyses.

Corresponding to the first minute of physiological data, task performance from the first block of the testing phase was submitted to a 2 × 2 ANOVA to determine the effects of the audience, task, and their interaction. The results are graphed in Figure 3. A main effect for task was found, $F(1, 57) = 75.02$, $p < .0001$. As expected, participants performed significantly better on learned tasks than unlearned tasks. A main effect for audience was also found, $F(1, 57) = 4.49$, $p < .03$. Participants performed better when alone ($M = 74.5$) than in the presence of an audience ($M = 63.4$). These main effects, however, were qualified by a

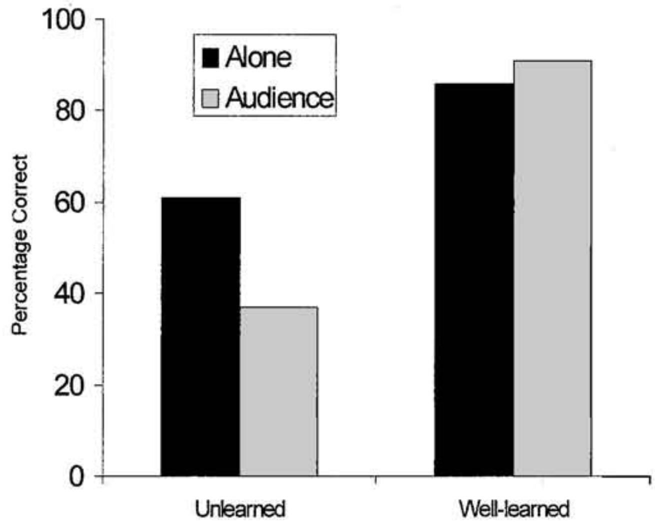

Figure 3. Untransformed means from the first minute of the performance task.

significant Audience × Task interaction, $F(1, 57) = 10.80$, $p < .002$. To further examine this interaction, simple effects tests were conducted. Among participants performing the unlearned task, the presence of an audience dramatically inhibited their performance ($M = 37.9$) versus participants performing the unlearned task alone ($M = 61.9$), $F(1, 29) = 12.35$, $p < .001$. Simple effects tests among participants performing the learned task were not significant ($F < 1$). Even though the means were in the predicted direction, performance of the learned in the presence of an audience was higher ($M = 91.0$) than alone ($M = 85.8$); the F test was not significant. This result is most likely due to ceiling effects associated with a learned task as described and discussed by Bond and Titus (1983) in their meta-analysis of social facilitation research.

Because ceiling effects may obfuscate performance facilitation during well-learned tasks, we adopted a more sensitive procedure to test for facilitation effects. We compared participants who received a perfect score on the first block of the testing phase with those who did not receive a perfect score. A significant association was found between participants performing in front of an audience and those receiving a perfect score, $\chi^2(1, N = 29) = 5.09$, $p < .02$; see Figure 4. Participants in the presence of others were significantly more likely to receive a perfect score (56%) than those performing alone (15%). This analysis demonstrates significant facilitation effects during the well-learned task.

Discussion

Results support the hypothesis that the presence of others during well-learned tasks is associated with a challenge pattern of cardiovascular reactivity, whereas the presence of others during an unlearned task is associated with a threat pattern of physiological reactivity. Participants performing the task alone, regardless of whether it was learned or unlearned, demonstrated no appreciable reactivity from baseline.

The performance data are consistent with both classic social facilitation studies and the behavioral performance patterns asso-

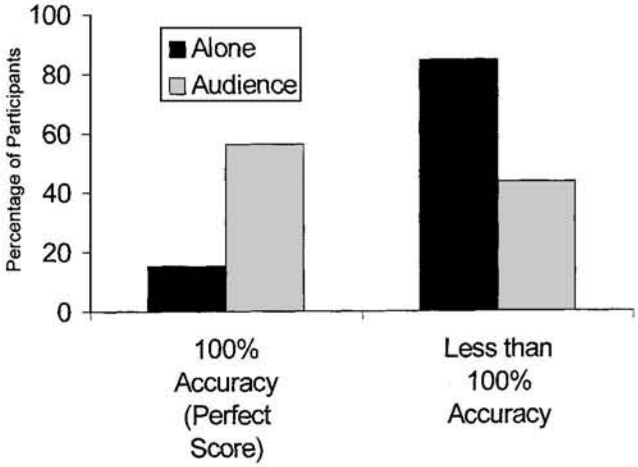

Figure 4. Percentage of participants performing the well-learned task during the first block of the testing phase obtaining 100% accuracy versus those not obtaining 100% accuracy by presence of others.

ciated with challenge and threat (Blascovich & Tomaka, 1996; but see Footnote 1 in the present article). Participants performing the unlearned task in front of an audience demonstrated a significant depreciation in their accuracy scores compared with participants performing the unlearned task alone. Participants performing the learned task in front of an audience did not perform significantly better than those performing the learned task alone. We attributed this finding to ceiling effects created by performing a well-learned task, a common problem in social facilitation research (see Bond & Titus, 1983). Therefore, we adopted a more sensitive nonparametric analytic procedure. By categorizing participants into those that obtained perfect scores (100% accuracy) and those that did not, we were able to demonstrate significant facilitation effects for participants performing in front of an audience versus those performing alone.

This experiment provides support for a challenge and threat explanation of social facilitation including both performance enhancement and impairment effects. The biopsychosocial model (Blascovich & Mendes, in press; Blascovich & Tomaka, 1996) describes challenge and threat motivational states, marked by distinctive cardiovascular response patterns, as resulting from the interplay of learned and unlearned affective and cognitive mechanisms. Challenge occurs when the individual experiences sufficient resources to meet situational demands in a goal-relevant performance situation. Threat occurs when the individual experiences insufficient resources to meet such situational demands.

The results of this study, which used sophisticated state-of-the-art cardiovascular measures, clearly show that increases in physiological responses occur when individuals perform nonmetabolically demanding goal-relevant tasks in the presence of others. These increases in physiological responses indicate increased goal relevance of the performance task brought about by the presence of others for reasons that Cacioppo and Petty (1986) and Seta and Seta (1995) described. Indeed, performers in the alone–learned task condition in the testing phase of these experiments did not differ in terms of cardiovascular responses from their last minute of performance during the learning phase.

If the generalized increases in the physiological responses due to the presence of others were the only reliable physiological results of the experiments here, our results would be neither new nor particularly meaningful in terms of social facilitation theory as Carver and Scheier (1981) and Sanders (1981) have argued (see *Physiological Arousal,* above). However, in the present experiments the theoretical specification and empirical verification of precise physiological patterns that distinguish socially facilitated enhancement effects (i.e., the challenge pattern) from impairment effects (i.e., the threat pattern) help resolve one of the two major controversial issues in more than a century of research: the relevance of physiological arousal.

Unlike Zajonc (1965), who argued that generalized drive or arousal is an unlearned response to others' presence, we cannot and do not yet claim that the cardiovascular patterns associated with socially facilitated enhancement and impairment effects identified in the present research necessarily mediate social facilitation effects. Rather, we maintain that challenge and threat motivation, involving the complex interplay of affective and cognitive factors, mediates social facilitation effects and that certain physiological response patterns index challenge and threat phenomenology.

As described elsewhere (Blascovich & Mendes, in press), challenge and threat result from the conscious or unconscious "appraisals" (both affective and cognitive), or both, of demands and resources. Demand appraisals involve the perception of danger, uncertainty, and required effort. Resource appraisals involve the perception of skills, abilities, and energy. The presence of others most likely affects the demand side of the equation more than the resources side in typical social facilitation research, though arguments can easily be generated suggesting that the presence of observers such as socially supportive others can affect the latter. Here, we speculate on the intricacies of dimensions suggested to underlie demand and resource appraisals.

Danger

The presence of conspecifics may invoke unlearned or primitive responses as Zajonc (1965) specified. However, consonant with Guerin and Innes's (1982) specification of a social monitoring mechanism, we believe such unlearned responses increase vigilance to potential danger in motivated performance situations. The presence of conspecifics may also invoke learned responses such as evaluation apprehension, as Cottrell (1972) and many others have specified, that affect the perception of danger, albeit social. However, we do not find support for Weiss and Miller's (1971) contention that audiences necessarily create an aversive drive state.

Uncertainty

Zajonc (1980), Guerin and Innes (1982), and Cacioppo and Petty (1986) argued that the presence of conspecifics increases the perception of uncertainty in motivated performance situations. We believe that the presence of others, especially strangers, increases the novelty and, hence, the uncertainty of motivated performance situations particularly. Several studies in our laboratory have shown that situational novelty increases threat (e.g., Blascovich et al., 1993; Lickel et al., 1998).

Required Effort

That the presence of others increases required effort on the part of the performer is part and parcel of distraction–conflict theory (Baron, 1986; Sanders & Baron, 1975) and Cacioppo and Petty's (1986) "effortful striving" concept. As demonstrated empirically (Sanders et al., 1978), the presence of others is distracting and demands attentional capacity from performers, a point consistent with Guerin and Innes's (1982) "social monitor."

As stated above, performers weigh the appraisal of personal resources (i.e., skills, abilities, and energy) against the increased appraisal of demand (i.e., danger, uncertainty, and required effort) brought about by the presence of conspecifics.[5] Generally, resource appraisals will be outweighed by demand appraisals for novel or unlearned tasks resulting in threat. However, for well-learned tasks, resource appraisals will outweigh or at least meet demand appraisals resulting in challenge. In the present experiments, task mastery provided sufficient resources to meet situational demands engendered by the presence of others in the group performing the learned task. The lack of task mastery in the group performing the novel or unlearned tasks did not. This is in line with Carver and Scheier's (1981) motivational explanation in terms of how appraisals may influence performance; however, our results indicate that cardiac reactivity is an integral part of the motivational component underlying social facilitation effects.

The research here indicates that the biopsychosocial model of challenge and threat affords identification of specific physiological response patterns associated isomorphically with distinct and oppositional social facilitation effects (i.e., enhancement and impairment). Moreover, this biopsychosocial model provides a framework for integration of major theoretical accounts of processes underlying social facilitation, including Zajonc's (1965), Cottrell's (1968, 1972), Guerin and Innes's (1982), Sanders and Baron's (1975), Carver and Scheier's (1981), Seta and Seta's (1983) and Cacioppo and Petty's (1986). Thus, rather than closing the door on social facilitation research, our theory and research paradigm opens the door for more precise and systematic testing of the possible operation of multiple factors affecting social facilitation.

[5] Typically, observers in social facilitation experiments are passive and nonobtrusive. This type of similar-other observers is probably perceived as nonphysically threatening. The extent to which observers are similar to the participant and passive most likely limits the extent to which the demand appraisals are increased. Indeed, Guerin and Innes (1982) delineated how the relative positions of the observers and the extent to which the observers are familiar or at least similar to the target person affect threat appraisals.

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