Neuroscience and Biobehavioral Reviews 35 (2011) 1603–1610

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

Challenge or threat? Cardiovascular indexes of resilience and vulnerability to potential stress in humans

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ARTICLE INFO

Keywords:
Resilience and vulnerability
Challenge and threat
Stress and coping
Psychophysiology
Cardiovascular reactivity
Motivated performance situations

ABSTRACT

Humans continually face situations that require actions to achieve valued goals with meaningful consequences at stake. Although the pursuit of such goals can be a negatively "stressful" experience, it is not necessarily so. According to the biopsychosocial model of challenge and threat, evaluations of personal resources and situational demands determine to what extent individuals experience a relatively positive (challenge) versus negative (threat) psychological state in this context. *Challenge* occurs when evaluated resources meet or exceed demands, whereas *threat* occurs when demands exceed resources. The challenge response thus reflects resilience in the face of potential stress. Because challenge and threat reliably result in distinct patterns of physiological changes, assessing cardiovascular responses in particular can provide valuable insight into underlying psychological processes. Research applying this methodology to individual differences (e.g., self-esteem level and stability and cumulative lifetime exposure to adversity) has implications for understanding how early life experience could contribute to resilience versus vulnerability to potential stress in daily life.

Contents

As humans in complex environments, we continually face situations requiring actions to achieve valued goals. *Motivated performance situations* are those in which an individual must actively perform instrumental responses to reach a goal that is self-relevant or important in some way. Examples include test taking, competition, public speaking, and social interactions. Motivated performance situations are highly important because they are ubiquitous and often have meaningful consequences, including both those part of everyday experience such as embarrassment and social acceptance, as well as more remarkable events such as college admission, job offers, and finding romantic partners. With such consequences at stake, motivated performance situations are potentially "stressful." Not only can subjectively important outcomes be gained or lost at any moment, but also the success of one's goal pursuit is fundamentally uncertain. However, despite the traditional, intuitively appealing view that these characteristics should create a negatively "stressful" experience, this is not necessarily the case. Situations that seem objectively similar can be experienced by different individuals in a range of ways, from invig-

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doi:10.1016/j.neubiorev.2011.03.003

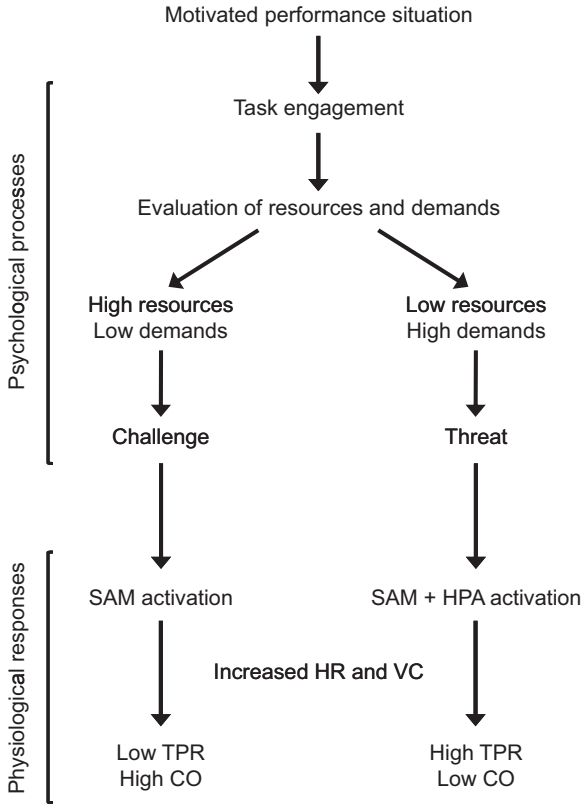

Fig. 1. Overview of the biopsychosocial model of challenge/threat. For the parallel paths following evaluation of resources and demands, each stage (e.g., challenge/threat) presents the two endpoints of a single continuous dimension, rather than two dichotomous states. SAM, sympathetic-adrenomedullary axis. HPA, pituitary-adrenocortical axis. HR, heart rate. VC, ventricular contractility. TPR, total peripheral resistance. CO, cardiac output.

orating excitement to overwhelming dread. The biopsychosocial model of challenge and threat (BPS; Blascovich, 2008a; Blascovich and Tomaka, 1996) provides a theoretical approach for understanding individuals' psychological responses during motivated performance situations, as well as how insight into psychological responses can be gleaned by measuring physiological (i.e., cardiovascular) changes. Fig. 1 presents an overview of the BPS.

1. The biopsychosocial model of challenge and threat

1.1. Psychological processes

According to the BPS (Blascovich, 2008a; Blascovich and Tomaka, 1996), the context of a motivated performance situation leads to the psychological state of *task engagement* to the extent that the task goal is subjectively self-relevant to the individual. As long as performance outcomes are uncertain, greater self-relevance or goal importance results in relatively greater engagement (see Seery et al., 2009). Self-relevance potentially derives from a variety of sources, ranging from monetary incentives to possible self-esteem boosts and decrements to simply wanting to make a good impression on another person. The relatively intangible consequences associated with impression making may often be particularly important. The need to form social bonds with others has been described as a fundamental human motive (Baumeister and Leary, 1995), and people can be substantially affected by instances of social acceptance versus rejection (Leary et al., 1995, 2006). Even a seemingly trivial motivated performance situation without a tangible incentive for performance (e.g., money) can thus create task engagement. Although motivated performance situations are marked by active instrumental responding, active responses alone do not necessarily create task engagement (e.g., Blascovich et al., 1999). Individuals are capable of carrying out a task without caring about their performance (i.e., without a self-relevant goal), so that they fail to experience task engagement during the task. For example, this could occur during a menial exercise such as counting coins. Importantly, task engagement is a prerequisite for the psychological states of challenge and threat. In the absence of a self-relevant goal and task engagement, individuals should experience neither challenge nor threat.

Given task engagement during a motivated performance situation, evaluations of personal *resources* and situational *demands* determine to what extent an individual experiences the psychological states of challenge versus threat. *Challenge* occurs when evaluated resources meet or exceed evaluated demands, whereas *threat* occurs when demands exceed resources. For example, all else being equal, someone who feels they have studied thoroughly for an important exam is likely to experience challenge, whereas someone who feels unprepared is likely to experience threat. Although they have discrete labels, challenge and threat actually represent the two anchors of a single bipolar continuum, rather than two dichotomous states. Relative differences in challenge/threat (e.g., greater vs. lesser challenge) are thus possible and meaningful. In fact, empirical investigations test relative differences in challenge/threat rather than the presence or absence of challenge and threat states in an absolute sense. In terms of resource and demand evaluations, this means that influences on motivated performance situations that lead to relatively higher versus lower evaluated resources and demands are of conceptual interest, rather than predicting whether evaluated resources are likely to exceed or fall short of evaluated demands in a given context.

There exists an array of possible influences on resource and demand evaluations. Early conceptions of the BPS attempted to identify categories of distinct factors separately for resources (e.g., skills, knowledge, and abilities) versus demands (e.g., danger). However, recent developments in theory and findings have emphasized that such influencing factors can often affect both resource and demand evaluations. Blascovich (2008a) suggested a number of bipolar factors that should have implications for both resources and demands, including psychological and physical safety/danger; novelty/familiarity; skills, knowledge, and abilities; and required effort. A heightened sense of safety, for example, could contribute to evaluations of higher resources and lower demands (and thus relative challenge), whereas a heightened sense of danger could do the opposite (and thus relative threat). This list of factors is not meant to be a comprehensive one, and any entries in such a list are not necessarily independent, in that they may overlap and interact with one another. For example, although possessing greater demonstrated skill than one's opponent in an athletic competition could contribute to higher resource evaluations, it could also lower demand evaluations because the contest seems less difficult than one against a more highly regarded opponent (i.e., lower required effort). Greater skill could also heighten expectations for one's performance, such that anything short of a decisive victory could be highly embarrassing, thus heightening demands (i.e., greater psychological danger). Given this complexity, delineating a list of categories of general influences on resources and demands may be less useful for predicting effects on challenge/threat than focusing on the expected overall resource and demand evaluations in a specific situation (e.g., relatively high resources/low demands).

Evaluations of resources and demands are affected by both affective and cognitive processes, and need not be logical or conscious (e.g., they are affected by subliminally presented stimuli; Weisbuch-Remington et al., 2005). Hence, although resource and demand evaluations may be influenced by elements of the motivated performance task itself, such as preparation and task

difficulty, evaluations may also be influenced by extraneous factors that seem to have little objective bearing on the performance task. For example, Seery et al. (2009) found that in the context of an otherwise identical motivated performance task, framing a monetary incentive in terms of potential for gain versus loss affected challenge/threat responses. Specifically, in the gain-framing condition, participants heard that they would start with no money, but would gain $0.50 for each correct answer on a test. In the loss-framing condition, participants heard that they would start with $5, but would lose $0.50 for each incorrect or skipped item. Despite equivalent potential for total earnings, the gain-framing condition led to relative challenge, whereas the loss-framing condition led to relative threat. Furthermore, the relative performance of others has a powerful effect on one's own evaluations of a situation, even when collaborating rather than competing. Mendes et al. (2001) found that during a cooperative task with a reward for meeting a joint performance criterion, upward comparisons (i.e., performing worse than one's partner during the task) resulted in relative threat, whereas downward comparisons (i.e., performing better than one's partner) resulted in relative challenge. Notably, having a high-performing partner increased the chances of reaching the joint performance goal, yet it resulted in relative threat. In sum, the evaluations that contribute to challenge/threat are influenced by a wide variety of factors, not limited to those that seem objectively and rationally most relevant for carrying out the task at hand.

Evaluations of resources and demands are thought to occur continually during motivated performance (see Quigley et al., 2002). Although individuals' initial evaluations could remain relatively consistent throughout the duration of the performance, this need not be the case. For example, a complex goal with multiple components could at first seem overwhelming, but once an initial subordinate goal is met, the path to completion could become substantially clearer. Similarly, trying to solve an insight problem (i.e., those in which correct answers seem obvious only once they are discovered; Bowden et al., 2005) could be initially frustrating, only to suddenly seem easily manageable. In either example, relative threat could transition to relative challenge mid-performance. The opposite transition could also occur, as could mid-performance decreases in task engagement. If the self-relevant goal loses its self-relevance, such as by becoming boring over time or seeming impossible to reach, disengagement could result, leading to lack of challenge/threat as well.

The foundations of the psychological component of the BPS lie in Lazarus's (e.g., Lazarus, 1991; Lazarus and Folkman, 1984) appraisal theory. Lazarus and colleagues suggested that cognitive appraisals of a potentially stressful situation determine how an individual responds to it. Lazarus divided appraisals into two broad categories: primary appraisals, which assess whether a situation is relevant to one's well being; and secondary appraisals, which assess coping resources and options. Although conceptually similar, it is important to note that the BPS departs from Lazarus's conception in several important ways. First, in Lazarus's terminology, "challenge" and "threat" are incorporated into primary appraisals, referring to perceived potential for gain and loss, respectively. In the BPS, in contrast, challenge/threat is the end result of what corresponds to Lazarus's appraisal process. Whereas Lazarus's theory treats challenge and threat as appraisals that *contribute* to the sense that a situation is self-relevant, the BPS holds that challenge/threat *only occurs* when a motivated performance situation has been evaluated as self-relevant (i.e., when task engagement exists). However, in both conceptions, challenge has a positive valence and threat has a negative valence. Second, recent accounts of the BPS no longer incorporate the term "appraisal," relying instead on "evaluation" in order to avoid confusion with Lazarus's theory and—consistent with the above discussion—to emphasize the role of nonconscious and affective processes in addition to cognitive ones in the determination of resources and demands (Blascovich et al., 2001).

Thus, the BPS focuses on evaluations (i.e., including but not limited to cognitive appraisals) during motivated performance and conceptualizes challenge/threat as an end state that is experienced as a result of these evaluations. Despite their shared labels, Lazarus's theory and the BPS can easily generate non-overlapping predictions. For example, a challenge appraisal in Lazarus's terms need not result in the experience of challenge in terms of the BPS because "challenge" has a different meaning in the two theories. Also, the two theories focus on different outcomes. Specifically, unlike Lazarus's theory, a core tenet of the BPS is that challenge/threat psychological states result in predictable patterns of physiological changes.

1.2. Physiological processes

According to the BPS, four cardiovascular measures are used to index the psychological states of task engagement and challenge/threat: heart rate (HR), ventricular contractility (VC), cardiac output (CO), and total peripheral resistance (TPR). VC is a measure of the left ventricle's contractile force based on the amount of time between the initiation of depolarization in the ventricle and the opening of the aortic valve (i.e., pre-ejection period). For presentational purposes, pre-ejection period reactivity is multiplied by −1, so that increases in contractile force (i.e., shortened pre-ejection period) correspond to increases in VC. CO reflects the amount of blood in liters pumped by the heart per minute. TPR is a measure of net constriction versus dilation in the arterial system (mean arterial pressure × 80/CO; Sherwood et al., 1990). It is standard practice to calculate and analyze reactivity values for these measures (i.e., changes from resting baseline to task performance; see Llabre et al., 1991, for psychometric justification for the use of change scores in psychophysiology). Increases in HR and VC from baseline are common across the challenge/threat continuum; larger changes reflect relatively greater task engagement. Given this reactivity, challenge is marked by higher CO and lower TPR than threat, such that relatively higher CO and lower TPR reflect relatively greater challenge or lesser threat. Thus, the heart beats faster and harder in both challenge and threat. During challenge, arteries in the body dilate, which facilitates the heart pumping relatively more blood (i.e., a pattern similar to what occurs during aerobic exercise), whereas during threat, arteries constrict and relatively less blood is pumped, despite increases in the heart's activity. The cardiovascular responses associated with challenge/threat do not equate to challenge/threat itself, but instead represent an indirect measure of the underlying psychological state.

The work of Dienstbier (1989) provides the basis for using physiological responses as markers of challenge/threat. Dienstbier argued that the body prepares itself in motivated performance situations via activation of the sympathetic-adrenomedullary (SAM) and pituitary-adrenocortical (HPA or PAC) axes, both of which serve to mobilize energy reserves. However, the product of SAM activation is the release of catecholamines, including epinephrine and norepinephrine, which have a half-life in the body of only a few minutes, whereas the product of HPA activation is the release of cortisol, which has a half-life in the body of over an hour. Thus, SAM activation allows for a fast spike of energy mobilization, whereas HPA activation does not. Prolonged physiological activation can result in negative health consequences (e.g., allostatic load; McEwen, 1998). A fast onset and offset of SAM activation is characteristic of what Dienstbier referred to as "toughened" individuals. Toughness and SAM activation—relative to lack of toughness and HPA activation—are, in turn, typically associated with favorable outcomes, including better task performance, greater emotional stability, lower anxiety, and improved

immune function. Importantly, toughness leaves individuals more likely to appraise situations positively (i.e., perceiving them as more manageable). In terms of the BPS, this suggests evaluating high resources, low demands, and experiencing challenge.

Both challenge and threat are hypothesized to result in heightened SAM activation, but threat is believed to also result in heightened HPA activation, thereby accounting for the differential patterns of cardiovascular responses associated with challenge versus threat. During task engagement—and thus across the challenge/threat continuum—SAM activation is thought to have two principal effects via direct innervation of tissue: (1) stimulating the heart muscle, which increases HR and VC; and (2) constricting veins and venules, which increases venous return, thereby further increasing VC and potentially increasing CO. During challenge, SAM activation is thought to also stimulate the preferential release of epinephrine from the adrenal medulla. The primary effect of this is to act on beta-2 receptors and cause vasodilation in skeletal muscle beds, resulting in relatively lower TPR and facilitating relatively higher CO (Brownley et al., 2000; Papillo and Shapiro, 1990). During threat, however, SAM activation is thought to be tempered by increased HPA activation. This is believed to inhibit the release of epinephrine and its vasodilatory effects, thereby resulting in relatively higher TPR and lower CO than challenge.

It is possible to speculate regarding the adaptive functionality of the cardiovascular markers of challenge/threat for coping with motivated performance situations. It is well understood that cardiovascular responses can outpace bodily metabolic demands during psychological stress (Obrist, 1981). A reasonable explanation for this phenomenon is that the body is preparing for the possibility of metabolically demanding physical activity, even if none is required at the moment. Challenge and its cardiovascular pattern could facilitate physical activity that is potentially necessary for active approach-related goal pursuit by increasing blood flow to the large skeletal muscles (e.g., in the arms and legs). This is consistent with evaluating high resources and low demands, which makes goals seem attainable. In contrast, threat and its cardiovascular pattern may in part reflect a vigilance response (Hunter, 2001; Williams et al., 1985). Monitoring for signs of deteriorating circumstances seems particularly appropriate in the context of evaluating low resources and high demands, as does a focus on loss avoidance rather than gain attainment (see Seery et al., 2009). Threat may partially facilitate the approach response of challenge (i.e., the motivated goal pursuit of task engagement) while simultaneously facilitating readiness for inhibition of action and withdrawal. Although the heart works faster and harder during threat than when at rest, vasoconstriction prevents increased blood flow and could thus help to more quickly down-regulate the cardiovascular system and inhibit physical action. During goal pursuit, a reasonable way to prevent loss may be to withdraw from pursuing the goal, especially when success seems tenuous, which creates adaptive value for threat and its accompanying vigilance.

Assessing challenge/threat with cardiovascular measures confers advantages because this approach does not rely on individuals' conscious attention or reflection. Conscious reflection is limited to the extent that individuals are unable to accurately report on their inner states (see Nisbett and Wilson, 1977), they are unwilling to do so, or the act of doing so interrupts the experience they would otherwise have. For example, the markers of challenge/threat vary more closely with relatively uncontrollable than with relatively controllable nonverbal responses (Weisbuch et al., 2009) and are not subject to the social desirability concerns that can influence self-reports (e.g., in interactions between Blacks and Whites, Blascovich et al., 2002). The markers have been validated and successfully employed in dozens of studies (for additional discussion, see Blascovich, 2008a). Initial research entailed correlational and experimental designs that demonstrated the predicted cardiovascular responses (Tomaka et al., 1993, 1997). Furthermore, using aerobic exercise and a cold pressor task to mimic the challenge/threat cardiovascular patterns failed to create differences in self-reported evaluations (Tomaka et al., 1997).

Preliminary work included VC and even HR as differentiating challenge from threat, but more focused research has supported only TPR and CO as reliably doing so. For example, two studies have used the BPS's cardiovascular markers to prospectively predict academic performance (Seery et al., 2010c) and athletic performance (Blascovich et al., 2004) outside of the laboratory, based on the idea that challenge is typically associated with better performance than threat (e.g., Blascovich et al., 1999; Chalabaev et al., 2009). In both studies, a combined index of TPR and CO predicted performance, but HR and VC did not. Measures from the same cardiovascular system are of course not entirely independent from one another, but TPR and CO most reliably index challenge/threat, whereas HR and VC most reliably index task engagement. A likely explanation for earlier findings that HR and VC paralleled TPR and CO is that relative challenge was confounded with greater task engagement in the experimental paradigms.

Notably, although calculation of TPR requires measuring blood pressure, blood pressure itself is not incorporated into the constellation of challenge/threat markers. Algebraic manipulation of the formula for TPR reveals why: TPR × CO = mean arterial pressure. Both higher TPR (consistent with relative threat) and higher CO (consistent with relative challenge) can lead to higher mean arterial pressure (i.e., blood pressure across the cardiac cycle). A change in blood pressure could therefore reflect either relative challenge or threat, depending on the balance of changes in TPR versus CO. Blood pressure is therefore an ambiguous measure in terms of challenge/threat. Indeed, in the studies of prospective academic and athletic performance described above (Blascovich et al., 2004; Seery et al., 2010c), all measures of blood pressure (systolic, diastolic, and mean arterial pressure) failed to significantly predict performance.

2. Resilience and vulnerability

In general, resilience refers to successful adaptation in the face of a potentially stressful experience, whereas vulnerability reflects lack of successful adaption, instead succumbing to the "stress" of the situation (Rutter, 2007; Silver, 2009). Resilience and vulnerability are often discussed in terms of major life adversity, such that a positive outcome (or lack of pathological outcomes) after experiencing such an event is viewed as evidence for resilience. However, as previous discussed, even relatively mundane motivated performance situations are also potentially stressful because they entail important consequences, yet are marked by uncertain chances for success. In this context, resilience versus vulnerability should not simply be reflected in the eventual performance outcome. For example, during a job interview, resilience should predict experiencing the potentially stressful situation as an exciting opportunity for career advancement rather than an overwhelming, anxiety-laden chance for embarrassing failure. For a variety of other reasons, an anxious interviewee could still secure a job offer, just as a confident interviewee could fail to do so, which suggests that resilience versus vulnerability may be most clearly manifested in individuals' responses *during* motivated performance. In terms of the BPS, resilience to the potential stress of motivated performance should lead to evaluations of high resources and low demands, and thus challenge. In contrast, vulnerability to this potential stress should lead to evaluations of low resources and high demands, and therefore threat. Two research examples that highlight the relationship between challenge/threat and resilience and vulnerability are discussed in detail.

2.1. Religious beliefs and mortality salience

A variety of theoretical perspectives suggest that the knowledge of our own inevitable mortality potentially paralyzes us with anxiety (Becker, 1973; Greenberg et al., 1997). Humans must thus engage in a variety of coping strategies in order to manage this existential terror (for a review, see Greenberg et al., 1997). One possible such resource is religious belief systems, which can impart order to an uncertain world and provide a source of comfort and reason for optimism during stressful situations (Durkheim, 1912/1995; Greenberg et al., 1997; James, 1902/1985). Although religious beliefs can facilitate successful coping, they can also result in negative consequences for coping, such as if they suggest that stressors result from divine punishment (Lazarus and Folkman, 1984; Pargament, 1997). In sum, in the face of contemplating one's own mortality—a potentially stressful situation—positive religious beliefs should contribute to resilience, whereas negative religious beliefs should contribute to vulnerability.

Weisbuch-Remington et al. (2005) tested this idea using the cardiovascular markers of challenge/threat, assessed while participants delivered a speech about their own death. This speech topic has been used successfully in previous research to create mortality salience and a variety of its effects (Greenberg et al., 1997). Results revealed that Christian participants exhibited cardiovascular responses consistent with relative challenge after subliminal exposure to positive Christian symbols (e.g., Christ ascending to heaven), but relative threat after subliminal exposure to negative Christian symbols (e.g., demons). In contrast, non-Christian participants were unaffected by symbol valence, and neither group of participants was affected by exposure to content-free control images. Thus, only symbols that cued relevant elements of existing religious belief systems affected participants' responses while speaking about mortality. Positive elements (i.e., heaven) should have been comforting, leading to resilience during this potentially stressful situation, whereas negative elements (i.e., eternal damnation) should have been frightening, resulting in vulnerability. The fact that a consistent pattern of challenge/threat differences emerged supports the idea that challenge/threat reflect resilience and vulnerability. Importantly, the use of subliminal presentation of religious symbols in this design provides evidence that subtle, nonconscious processes can influence challenge/threat.

2.2. Gender stereotype activation and math ability

Performing in a domain in which one's social group is the subject of a negative stereotype potentially creates *stereotype threat*, an experience of discomfort related to the knowledge that one's behavior can confirm the negative stereotype (Steele and Aronson, 1995). A substantial body of literature demonstrates that stereotype threat can adversely affect performance quality (e.g., Schmader et al., 2008; Steele and Aronson, 1995; Steele et al., 2002). For example, a stereotype exists that women are worse than men at math. Even if an individual woman does not believe the stereotype is true, simple knowledge that the stereotype exists coupled with activation of that knowledge can result in the experience of stereotype threat and performance decrements. During a potentially stressful test of intellectual ability (e.g., math), activating negative stereotypes about one's social group in that domain should contribute to vulnerability, whereas defusing those stereotypes should contribute to resilience.

Vick et al. (2008) tested the effects of stereotype activation on the cardiovascular markers of challenge/threat assessed during a math test. Results revealed that in the gender-biased condition—when the negative stereotype about women and math was activated (e.g., Spencer et al., 1999)—women exhibited cardiovascular responses consistent with threat relative to men. However, in the gender-fair condition—which explicitly contradicted the negative gender stereotype—women exhibited responses consistent with challenge relative to men. Activating a negative group stereotype should have heightened susceptibility to the possible negative implications of failing a test of important ability (e.g., fear of confirming the stereotype). In other words, vulnerability to the potential stress of the situation should have resulted. Discrediting the negative stereotype with specific information that it did not apply in the given context should have mitigated these burdens and thereby facilitated resilience. In this study, as in Weisbuch-Remington et al. (2005), challenge/threat findings confirmed hypotheses based on existing theory and research regarding a phenomenon with a clear link to resilience and vulnerability.

3. Early life experience

The research examples described above support that experiencing challenge versus threat reflects resilience versus vulnerability, respectively, in the face of a potentially stressful motivated performance situation. Notably, both examples depended heavily on experimental manipulation of situational factors among young adults. The central question of the current journal issue pertains to the role of early life experience in developing tendencies for resilience versus vulnerability. A substantial history of research on humans attests to the importance of, for example, family environment in this regard (e.g., Repetti et al., 2002; Rutter, 1979; Smith and Prior, 1995). Individual differences (e.g., personality traits) should be particularly likely to be related to both early life experience and propensity for resilience versus vulnerability later in life. Two investigations combining such individual differences with challenge/threat assessment are discussed in detail.

3.1. Self-esteem level and stability

The construct of self-esteem—referring to a global evaluation of overall self-worth—has reached a place of prominence in Western society. Across thousands of journal articles and hundreds of books written for popular consumption, self-esteem has been of substantial interest to researchers and the public alike. Much of this interest has been predicated on the presumed importance of high self-esteem for well-being, including as a coping resource (Taylor and Stanton, 2007). Considerable amounts of time, effort, and money have been invested into raising people's self-esteem, ranging from self-help books to government-sponsored policy initiatives (e.g., California Task Force, 1990). Despite the idea's intuitive appeal, controversy exists regarding the benefits of high self-esteem (Baumeister et al., 2003; Swann et al., 2007; Trzesniewski et al., 2006). There is agreement, however, that conceptualizing self-esteem as simply high versus low fails to capture its full relevance. One key distinction is between two types of high self-esteem: stable versus unstable.

Self-esteem stability refers to the magnitude of short-term fluctuations around a person's typical or baseline level of trait self-esteem; unstable high self-esteem thus corresponds to high trait self-esteem coupled with a high degree of variability in momentary or state self-esteem (Kernis, 2005; Kernis and Waschull, 1995). Unstable self-esteem entails a propensity to perceive events as self-relevant and link one's self-worth to them, therefore being more personally affected by the vicissitudes of life (Greenier et al., 1999). Relative to stable high self-esteem, unstable high self-esteem has been linked to greater defensiveness in a number of ways (Kernis et al., 1989, 1993, 1997). Taken together, the susceptibility to external events and the defensiveness associated with unstable high self-esteem suggests an underlying propensity for vulnerability. Rather than high self-esteem necessarily resulting in resilience, only stable high self-esteem may do so.

Seery et al. (2004) used challenge/threat to investigate this question. Young adult participants received manipulated success or failure feedback after taking what was presented as an important test of reasoning ability. Participants' challenge/threat responses during a second test provided insight into how they were affected by prior failure. Consistent with the hypothesis that *unstable* high self-esteem is associated with an underlying propensity for vulnerability to external events, these participants exhibited cardiovascular responses consistent with relative challenge after success on the first test, but relative threat after failure. In contrast, consistent with the hypothesis that *stable* high self-esteem should be associated with resilience, the responses of these participants did not differ as a function of feedback condition. Compared to participants with unstable high self-esteem, those with stable high self-esteem exhibited relative challenge after failure. In other words, they appeared resilient during an important test of reasoning ability, even when they had just performed very poorly on a prior test.

Previous research and theory implicate a specific link between early life experience and self-esteem stability. Waschull and Kernis (1996) found a relationship between self-esteem stability and reasons for anger in 10–11 year-old children, suggesting that processes comparable to those in adults are at work even at a young age. Kernis and Waschull (1995) speculated that the development of unstable self-esteem is rooted in receiving excessive noncontingent feedback from caregivers and peers during development. Noncontingent feedback (i.e., reward and punishment) does not follow directly from one's own merits or performance, but instead from other unpredictable or uncontrollable factors (e.g., inconsistent evaluation criteria and the evaluator's mood). When the reason for feedback is unclear to recipients, they may attribute the feedback to a wide variety of sources, thereby learning that seemingly irrelevant information is diagnostic of one's performance or merit. Noncontingent feedback is also particularly likely to overgeneralize, tying individuals' overall worth to a specific event (e.g., a parent saying a child is a failure after a poor performance on one exam). Essentially, noncontingent feedback should encourage children to gain a skewed perspective on what matters in life, which becomes internalized and persists over time. Otherwise trivial events seem important, and important events become self-defining, which results in unstable self-esteem. In combination with Seery et al.'s (2004) findings, this suggests that early life experience based on feedback from others can predispose individuals to subsequent resilience versus vulnerability, specifically in the context of coping with prior failure.

3.2. Cumulative lifetime adversity

Experiencing adverse life events (e.g., natural disaster and parental loss) is typically associated with subsequent vulnerability in the form of poor mental health and well-being (e.g., Emery and Laumann-Billings, 1998; Turner and Lloyd, 1995, 2004). However, Dienstbier's (1989) theory of psychophysiological toughness—on which the BPS is based in part—suggests that exposure to stressors during development can contribute to subsequent resilience in the form of toughness. As discussed above, toughness should leave individuals more likely to experience challenge. According to Dienstbier, both sheltering from all stressors and exposure to continuous stressors leads to lack of toughness (for a parallel perspective in terms of mastery and control, see Chorpita and Barlow, 1998; Mineka and Zinbarg, 2006). This is analogous to the effects of aerobic exercise on physical fitness. Excessive physical activity overwhelms the body's ability to recover and impairs fitness, just as excessive exposure to adversity overwhelms coping abilities and interferes with the development of toughness. Similarly, physical fitness does not improve in the absence of exertion, just as toughness does not develop without the experience of coping with or managing some adversity. This suggests a quadratic, U-shaped relationship between adversity exposure and resilience, such that individuals with a history of *some* adversity should exhibit greater resilience than those with a history of either *no* or *high* adversity. Indeed, a history of some adversity—relative to both less and more adversity—has been associated with better psychological well-being (Schnurr et al., 1993; Seery et al., 2010a), lower functional impairment and healthcare utilization (Seery et al., 2010b), and lower cortisol reactivity to a laboratory stressor (Gunnar et al., 2009), which is potentially consistent with Dienstbier's (1989) toughened physiological pattern (cf. Ellis and Boyce, 2008).

In a recently conducted study, Seery et al. (unpublished results) tested the relationship between cumulative lifetime exposure to adversity and challenge/threat in response to a potentially stressful motivated performance situation. Young adult participants reported whether they had ever experienced each of 37 negative events and the age(s) at which the events occurred. The measure was modified from the Diagnostic Interview Schedule trauma section (Robins et al., 1981), expanded to include a wider variety of stressful events using primary care patients' reports of lifetime stress (Holman et al., 2000). The list of events included seven categories: own illness or injury, loved one's illness or injury, violence (e.g., physical assault and forced sexual relations), bereavement (e.g., parent's death), social/environmental stress (e.g., serious financial difficulties and lived in dangerous housing); relationship stress (e.g., parents' divorce); and disaster (e.g., major fire, flood, earthquake, or other community disaster). Participants could report up to six instances of each event. Cumulative lifetime adversity scores were calculated by summing the total number of instances across all events (see Turner and Lloyd, 1995, 2004). Participants then completed what was described as an important test of "nonverbal intelligence"—an ability related to future success in life—during which challenge/threat responses were recorded.

In a regression analysis using cumulative adversity score to predict challenge/threat, the hypothesized quadratic relationship emerged. Participants who reported moderate levels of adversity exhibited cardiovascular responses consistent with relative challenge, whereas participants who reported either no adversity or high adversity exhibited cardiovascular responses consistent with relative threat. Importantly, the predicted challenge/threat values formed an inverse U-shaped curve (higher values reflected greater challenge) within the sample's range of adversity.

Given that participants were young adults, the reported events necessarily occurred relatively early in life (i.e., during childhood or young adulthood). Consistent with Dienstbier's (1989) arguments, these results thus suggest that experiencing moderate levels of adversity during development may help to promote subsequent resilience, such as during a potentially stressful motivated performance situation. This does not connote that intentional exposure to trauma should be endorsed, but instead that people are not necessarily doomed by adversity exposure. When individuals face adverse life events, distress and other negative consequences may follow in the short term. However, for most people, these acute effects subside with the utilization of coping strategies and the passage of time. In the absence of many other concurrent or subsequent adverse events—which can overwhelm coping abilities—individuals may likely feel that they have managed or "gotten through" the adversity. This could help refine coping skills and make future difficulties seem more manageable. In short, toughness develops, which generalizes across domains. For example, after dealing with a parent's serious injury or illness, an intelligence test may seem less intimidating than it formerly would have, resulting in evaluations of higher resources, lower demands, and relative challenge. In contrast, for individuals with a history of no lifetime adversity or a high level of adversity,

toughness is less likely to develop. Potentially stressful events of all types—including motivated performance situations—should be more likely to seem relatively daunting, leading to evaluations of lower resources, higher demands, and relative threat.

4. Conclusions and future directions

Motivated performance situations are potentially stressful for humans because they entail meaningful consequences and the success of one's efforts is uncertain. Such circumstances are not necessarily experienced as being negative, however. In other words, individuals may respond with resilience or vulnerability in the face of this potential stress. The BPS model of challenge/threat (Blascovich, 2008a; Blascovich and Tomaka, 1996) provides a way to conceptualize and assess resilience and vulnerability *during* potentially stressful motivated performance, which has methodological advantages. A growing body of literature supports that challenge reflects resilience in this context, whereas threat reflects vulnerability.

Investigations of challenge/threat have to this point relied almost exclusively on samples of young adults, which means that the implications of early life experience for subsequent likelihood of experiencing challenge versus threat must largely be inferred. Seery et al. (unpublished results) represent the best example of an exception in that prior lifetime adversity was assessed directly, albeit retrospectively. The ideal research design would be prospective in nature, measuring relevant life experience as it happens and predicting future challenge/threat responses. There seems to be no theoretical reason why the challenge/threat approach cannot be applied to children, the study of whom may be particularly revealing for better understanding developmental contributions to resilience and vulnerability.

Even among adults, further study of individual differences seems likely to have the most promise for elucidating chronic tendencies for resilience versus vulnerability to potential stress. Various facets of self-esteem have a theoretical link with early life experience (Kernis and Waschull, 1995) and a demonstrated relationship with challenge/threat (Seery et al., 2004). Similarly, lifetime adversity exposure should be related to the development of resilience (Dienstbier, 1989) and has also been associated with challenge/threat (Seery et al., unpublished results). Notably, the relationships between early experience and challenge/threat may be complex. Incorporating the ideas of Kernis and Waschull (1995) with the findings of Seery et al. (2004) suggests that an undesirable environment (i.e., excessive noncontingent feedback) can predict vulnerability. However, the results of Seery et al. (unpublished results) suggest that adverse events—which could certainly have short-term negative effects when they occur—may contribute to the beneficial development of subsequent resilience. The majority of existing challenge/threat research has focused on experimental manipulations of situational effects, but these two individual differences seem particularly worthy of further empirical attention.

The close association between challenge/threat and cardiovascular reactivity suggests possible implications for physical health. Blascovich (2008b) argued that the threat cardiovascular pattern—heightened cardiac activity coupled with arterial constriction—can result in turbulent blood flow and thus strain on the coronary arteries. This strain could lead to damage, scarring, plaque deposits, and eventually ischemic heart disease. The arterial constriction of threat could further promote hypertension more generally. Such effects assume the repeated experience of threat over time. Evidence already supports a relationship between early life experience and cardiovascular health (e.g., Buchmann et al., 2010; Felitti et al., 1998); the chronic experience of threat resulting from relatively stable individual differences in resilience versus vulnerability may represent an additional explanatory mechanism.

The development of resilience and vulnerability can be difficult to study in humans. The distinction between the two outcomes can be amorphous in practice, and humans' environments cannot be as tightly controlled as those of animal subjects. Nonetheless, understanding resilience and vulnerability is critically important, given the range of implications that coping with stress has for mental and physical well-being. The BPS model of challenge/threat provides valuable insight into resilience and vulnerability as they are experienced in the face of potential stress. This can in turn elucidate their development, their underlying mechanisms, and—ultimately—how to foster resilience.

Acknowledgement

I would like to thank Wendy J. Quinton for her comments on a previous version of this manuscript.

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