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Review

# Successful performance and cardiovascular markers of challenge and threat: A meta-analysis

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ABSTRACT

Cardiovascular responses to challenge and threat have been used extensively in psychophysiological research. In this meta-analysis, we scrutinized the body of evidence for the role of challenge and threat hemodynamic responses in predicting positive behavioral outcomes, i.e., performance quality. We accounted for cardiac output (CO), total peripheral resistance (TPR), and Challenge-Threat Index (CTI). With 17 articles covering 19 studies (total $N = 1045$), we observed that the literature might have been biased towards positive results. After we excluded outlying studies and compensated for missing null-effect studies, we found that the mean standardized coefficient, corrected with the trim-and-fill method, was $r = 0.14$ for CO, $r = -0.13$ for TPR, and $r = 0.10$ for CTI. This indicated relatively small but stable effects of cardiovascular responses in the facilitation of successful performance. Moderator analyses indicated that TPR and CTI produced stronger effects in non-experimental studies. We also found that effects were not moderated by levels of engagement (indexed by heart rate and pre-ejection period), task domain (cognitive vs. behavioral) and measurement method. In summary, our results supported the general validity of the biopsychosocial model in the prediction of behavioral outcomes. However, they also indicated limitations of the empirical evidence and a significant bias in the literature.

## 1. Introduction

The challenge and threat paradigm has become one of the leading theoretical frameworks for physiological responses during a motivated performance (Blascovich et al., 2004; Seery et al., 2009; Turner et al., 2012). Challenge and threat studies capitalize on cardiovascular (CV) biosignals that provide continuous and relatively unobtrusive access to the correlates of action-oriented cognitive processes (Seery, 2013). The challenge and threat cardvioascular response has been studied to identify inibiting and facilitating factors in several diverse contexts of daily life such as coping with stereotype threat among minority members and women (Mendes et al., 2008), training skills, e.g., laparoscopic surgery (Vine et al., 2013), practicing sports, e.g., climbing (Turner et al., 2014), taking exams (Seery et al., 2010), or negotiating (Scheepers et al., 2012).

The concept of healthy and unhealthy responses to demanding tasks, such a challenge vs. threat cognitive appraisal (Lazarus and Folkman, 1984) or eustress vs. distress (Selye, 1976), has been discussed in the literature for decades. However, there has been a more recent and ongoing debate within the literature regarding the physiological specificity of these cognitive processes (Wright and Kirby, 2003). For instance, theorists have argued for specific CV (Blascovich, 2008), hormonal (Jamieson et al., 2010), and behavioral (Jones et al., 2009) responses to challenge and threat appraisals as well as their role in the facilitation of goal-oriented actions. Some authors have claimed that CV markers of challenge and threat are superior in comparison to self-reported evaluations because an accurate report of inner states and experiences is likely to be problematic to some individuals and is not feasible for some research designs (Seery et al., 2010, Nisbett and Wilson, 1977). The validity of CV markers of challenge and threat has also been supported experimentally because individuals with stronger challenge-type CV responses are more successful at goal attainment (Gildea et al., 2007; Moore et al., 2012).

Building upon these works, we have used a metanalytical approach to test the overall strength and consistency of relationships between challenge and threat physiological markers and successful performance across different life domains. Scrutinizing the body of empirical evidence for the biopsychosocial model is worthwhile because it summarizes what studies have been conducted and evaluates their strengths and limitations, e.g., the diversity of tested populations, research designs, or methods of measurement. Meta-analyses are robust tests for theories that inform meaningful decision in further studies, e.g., which populations or types of activity are understudied or what effects sizes could be expected while determining the sample size. Finally, a meta-

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analysis is likely to provide an empirical test for the integrity of the literature, revealing or discarding the occurrence of any publication-bias.

### 1.1. Physiological responses to challenge and threat

Challenge and threat appraisals occur when individuals are motivated to engage in active goal pursuits and do their best, e.g., while taking school exams (Seery et al., 2010), negotiating prices (Scheepers et al., 2012), or learning new skills (Moore et al., 2014). Cognitive evaluations of the self and the environment feed the motivational system that mobilizes the physiological resources that are necessary for action (Mendes and Park, 2014). Increased goal-oriented motivation leads to increased sympathetic activation in the autonomous nervous system, which results in increased heart rate (HR) and shortened pre-ejection period (PEP) (Seery, 2011). Thus, individuals with stronger motivational intensity display higher HR and PEP reactivity. This initial physiological response is further modulated after individuals evaluate personal action resources (e.g., skills, knowledge, and abilities) and situational demands (e.g., solutions that need to be found using cognitive skills or motor actions that require considerable dexterity).

Challenge motivation occurs when individuals identify the sufficiency of resources to overcome demands. Adrenaline is released into the bloodstream, which results in widening of blood vessels (vasodilatation) and this then produces lower total peripheral resistance (TPR) (Brownley et al., 2000). It also results in higher cardiac output (CO) (i.e., the amount of blood pumped by the heart). In contrast, when demands exceed personal resources, individuals perceive the situation as threatening. Threat appraisal inhibits the release of adrenaline and instead releases cortisol. In these circumstances, the arteries narrow, despite the increased HR. This results in higher TPR with relatively lower CO. This CV pattern has been related to challenge and threat using several manipulations. For instance, challenge and threat was induced by changing the task difficulty (Fonseca et al., 2014), introducing the presence of an audience (Feinberg and Aiello, 2010), changing the gain and loss probability (Seery et al., 2009), or using downward and upward social comparison opportunities (Mendes et al., 2001).

The following four indexes of CV reactivity have been used within the challenge and threat paradigm: HR, PEP (i.e., time in the cardiac cycle from initiation of ventricular depolarization to the opening of the aortic valve and ejection of blood into the vasculature), CO (i.e., the amount of blood pumped by the heart per minute), and TPR (i.e., net constriction vs dilation in the arterial system). TPR has been typically calculated by dividing mean arterial pressure by CO and then multiplying the total by 80 (Sherwood et al., 1990). Several authors have used the Challenge-Threat Index (CTI), which integrates the TPR and CO information, based on the assumption that the TPR and CO are two related measures of the same underlying nervous system activation (Blascovich et al., 2004). For instance, CTI can be used in regression analysis by converting TPR and CO values into z-scores and summing them, with an assigned weight of −1 for TPR and 1 for CO. The theoretical framework for these CV responses was built upon Dienstbier's (1989) model of psychophysiological toughness, which has since been validated (see Blascovich, 2008; Seery, 2011 for reviews).

### 1.2. Challenge, threat, and performance

The challenge-type CV response is more efficient at energy mobilization than the threat-type because it provides greater blood flow to the periphery (Seery, 2011). Previous research has shown that individuals who endorse a challenge-type motivation are more likely to achieve a superior performance in cognitive tasks (Gildea et al., 2007; Mendes et al., 2008; Turner et al., 2012), and motoric activities (Blascovich et al., 2004; Moore et al., 2012; Moore et al., 2013; Turner et al., 2013). Furthermore, challenge and threat CV markers predict academic success (e.g., Seery et al., 2010). These findings indicate that challenge and threat CV responses predict a broad range of behavioral outcomes.

### 1.3. Present study

The present study aims to test whether or not CV responses to threat and challenge are related to a successful performance. While studies have reported significant effects (Turner et al., 2012) and some have reported null-effects (Moore et al., 2012), it was imperative to employ a meta-analytical approach that tests the robustness of the available findings. Furthermore, we examined the potential moderators that might explain the heterogeneity of the findings across different studies; that is, the domain of performance (cognitive vs. motor activity) and the CV markers of motivation intensity in participants to complete the task (HR and PEP reactivity). The metanalytical approach provides statistical tools that inform whether a publication bias (e.g., refraining from the publication of null findings) was likely to occur for this particular body of research (Duval and Tweedie, 2000). It is essential to account for this type of bias because the problem of poor replicability of findings in psychology has been observed (Francis, 2012). Publication bias has been indicated to be one of the main reasons for this problem.

## 2. Method

### 2.1. Search strategy

We performed a systematic literature search in PsychInfo, PubMed, and Google Scholar covering the period from 1993 (first attempt of using of challenge and threat CV markers) (Tomaka et al., 1993) to January 2017. We used the following terms: “challenge” or/and “threat” in combination with one of the other expressions: “performance,” “cardiovascular,” “CO,” “TPR,” “CTI” (for details, see Fig. 1). We also cross-checked the references in the studies that we retrieved and contacted 25 authors that had published papers on the question of challenge and threat. We asked these authors for any unpublished material. The search was restricted to peer-reviewed studies in English. A total of 20 authors responded to the request but they did not report any unpublished research results.

### 2.2. Selection of studies

We selected potentially eligible studies in two phases. First, we scrutinized the titles and abstracts. If the material was relevant to the subject of this meta-analysis, we then screened the full-text articles. All of the studies that were identified as potentially eligible during the first selection phase were then re-assessed in the second selection phase. The inclusion criteria were as follows: the study was developed within the challenge and threat paradigm; the performance was quantified; relevant CV markers were provided; available data of each study required for the calculation of effect sizes. If necessary, the authors were contacted for supplementary data. A total of 12 authors sent re-analyzed results with the requested coefficients.

### 2.3. Study coding

The first author coded all of the studies that met the inclusion criteria. The studies were then coded for the inclusion of CV reactivity measures, performed task, type of performance (cognitive vs. behavioral), type of measurement, research design (experimental manipulation vs no manipulation), number of participants, and age.

### 2.4. Data selection and extraction

This meta-analysis aimed to assess the effect of CV markers of challenge and threat on successful performance. Thus, we only considered those performances that had objective and quantifiable