International Journal of Psychophysiology 81 (2011) 91–98

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Reported fatigue, difficulty, and cardiovascular response to an auditory mental arithmetic challenge ☆

Jason LaGory [a,*], Brandon B. Dearen [b], Katie Tebo [b], Rex A. Wright [b]

[a] University of Arkansas for Medical Sciences, United States
[b] University of Alabama at Birmingham, United States

ARTICLE INFO

Article history:
Received 10 January 2011
Received in revised form 2 May 2011
Accepted 19 May 2011
Available online 1 June 2011

Keywords:
Fatigue
Effort
Cardiovascular response
Active coping

ABSTRACT

Undergraduates scoring low and high on a questionnaire measure of relatively extended fatigue were presented four versions of an auditory mental arithmetic challenge, ranging in difficulty from low to impossibly high. Among Low Fatigue participants, blood pressure and heart rate responses assessed during the work periods first rose and then fell with difficulty. Among High Fatigue participants, blood pressure responses remained low across difficulty conditions, while heart rate responses rose weakly from the low- to the moderate difficulty condition and then declined. Findings are discussed in terms of a recent interactional analysis of fatigue influence on cardiovascular response.

1. Introduction

Recent research has investigated an interactional analysis concerned with fatigue influence on effort and associated cardiovascular (CV) responses in people confronted with performance challenges (e.g., Wright and Stewart, in press). The analysis assumes that sympathetically-mediated CV responses vary in part with effort (Light and Obrist, 1983; Obrist, 1976, 1981). It also assumes that effort varies non-monotonically with challenge difficulty – first rising and then falling sharply (Brehm and Self, 1989; Ford and Brehm, 1987) – and that difficulty appraisals increase with fatigue (Fairclough, 2001; Fairclough and Graham, 1999; Hockey, 1997).

The preceding assumptions suggest that fatigue has potential for augmenting, retarding, or leaving unchanged effort and CV responses, depending on the difficulty of the challenge at hand (Fig. 1). When fatigue does not alter a belief that success is possible and worthwhile, it should lead people to exert compensatory effort and experience heightened CV arousal as a result. By contrast, when fatigue causes success to appear impossible or excessively difficult, it should lead people to withhold effort and display minimal CV arousal. Finally, when fatigue reinforces a belief that success is impossible or excessively difficult, it should confirm people's disposition to exert low effort and experience minimal CV arousal. As will be discussed later, the interactional perspective is noteworthy in part because it offers an explanation for why fatigue has historically been associated with a diverse array of CV response patterns in performance contexts.

1.1. Evidence

Most studies designed to examine the interactional analysis have involved manipulations of fatigue (e.g., Stewart et al., 2009; Wright et al., 2003, 2007; Wright and Penacerrada, 2002; Wright et al., 2008; see also Marcora et al., 2008). An example is a study that evaluated mental fatigue influence at low and high levels of challenge difficulty (Wright et al., 2003). It first required participants to perform a minimally demanding (fatigue low) or highly demanding (fatigue high) counting task. Shortly thereafter, it presented participants arithmetic problems with instructions that they could earn a prize by attaining a low or high performance standard. Analysis of data collected during the arithmetic period indicated the expected fatigue × difficulty interaction for SBP responsiveness, with corresponding effects for diastolic blood pressure (DBP), and mean arterial pressure (MAP). Whereas Low Fatigue participants displayed relatively stronger responses when the standard was high than when it was low, the High Fatigue participants displayed the reverse. Comparisons at each standard level indicated that responses were or tended to be greater for High Fatigue participants when the standard was low, but were or tended to be greater for Low Fatigue participants when it was high. Effects were expected for SBP because SBP is powerfully influenced by heart contraction force, which – in turn – is powerfully influenced by sympathetic nervous system arousal (Berntson et al., 1993; Brownley et al., 2000; Fairclough and Mulder, in press; Kelsey, 1991, in press; Richter et al., 2008).

☆ This research was supported by National Science Foundation Grant BCS-0450941, awarded to Rex Wright. It formed the basis of a dissertation submitted by Jason LaGory to the Department of Psychology at the University of Alabama at Birmingham.

* Corresponding author at: Psychiatric Research Institute, University of Arkansas for Medical Sciences, 4301 W. Markham, #854, Little Rock, AR 72205, United States.
E-mail address: JLagory@uams.edu (J. LaGory).

0167-8760/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpsycho.2011.05.005

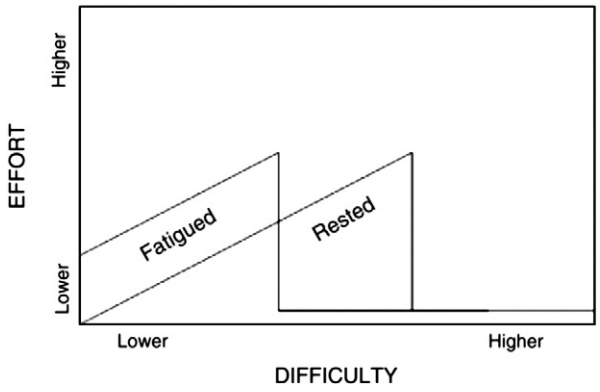

Fig. 1. Effort (and CV response) as a function of difficulty for fatigued and rested individuals.

To date, only one study in this research program has examined fatigue as a naturally-occurring – measured – variable, rather than as a manipulated variable (Nolte et al., 2008). It did so with the aim of documenting the external validity of earlier experimental fatigue findings, that is, their indication of what can occur in real world settings in which fatigue is induced spontaneously. Fatigue was operationalized in terms of (state) tiredness and energy ratings that participants provided at the start of a session in which they were presented an easy or moderately difficult memory task. Results indicated fatigue × difficulty interaction patterns for SBP, DBP, and MAP responses during the memory period. Among participants who provided low fatigue ratings, responses were stronger when the challenge was moderately difficult than when it was easy. Among participants who provided mid-range fatigue ratings, the opposite response pattern was observed. Participants who provided high fatigue ratings showed low responsiveness under both difficulty conditions, presumably because they viewed even the easy challenge as excessively difficult.

1.2. Present research

Central purposes of the present research were twofold. One was to examine further natural fatigue influence on CV response to a performance challenge, utilizing a more stable trait-like fatigue measure. The other was to extend previous difficulty findings by examining natural fatigue effects across four challenge difficulty levels, ranging from low to impossibly high. One reason for including four difficulty levels was to provide an opportunity for the full character of the low- and high ability CV response functions to emerge (see Fig. 1). A second reason was to evaluate the previously untested hypothesis that CV responsiveness should be low irrespective of fatigue where fatigue reinforces a belief that success is impossible or excessively difficult, given the benefit it may accrue.

We examined natural fatigue influence by comparing CV responses of individuals scoring low and high on a fatigue questionnaire completed prior to the experimental session. We manipulated challenge difficulty by presenting participants four cumulative mental addition tasks that varied in their speed and complexity. Measures of SBP, DBP, and HR were recorded at baseline and during each mental addition task period, with a special focus on SBP because of its special relation to sympathetic activation.

One set of predictions pertained to participants' difficulty appraisals (perceptions). We expected the appraisals to increase with the objective difficulty of the challenge and be higher for high- than Low Fatigue participants. Exact predictions with respect to the CV measures were difficult, given our inability to know precisely how fatigued our Low- and High Fatigue groups would be when they arrived and how much effort they would be willing to exert in the particular task situation. However, the following guiding ideas seemed reasonable: (1) effort-related CV responses for both fatigue groups should rise with difficulty to a point, and then fall; (2) effort-related CV responses should be stronger for high- than Low Fatigue participants so long as success appears possible and worthwhile to the High Fatigue group; (3) High Fatigue participants should reach their effort and CV response peak at a lower difficulty level than should Low Fatigue participants; (4) both fatigue groups should display minimal effort and CV responsiveness when confronted with the impossibly difficult challenge.

Given that we had four difficulty levels, with the highest being impossible, the preceding ideas translated into three tentative predictions. First, we expected effort-related CV responses for both fatigue groups to rise from the low- to the moderate difficulty condition, with responses for the High Fatigue participants being higher by a constant than responses for the Low Fatigue participants. Second, we expected effort-related CV responses to continue to rise from the moderate- to the high difficulty condition for Low Fatigue participants, but fall from the moderate- to the high difficulty condition for the High Fatigue participants. Third, we expected that effort-related CV responses would be low for both fatigue groups where difficulty was impossibly high.

Key to the preceding CV response predictions was the assumption that High Fatigue participants would view success as possible and worthwhile at the first two difficulty levels. If these participants in fact viewed success as possible and worthwhile only in the low difficulty condition, then one would expect them to show relatively elevated responses there and diminished responses at all difficulty levels thereafter. If the participants viewed success as impossible or excessively difficult even in the low difficulty condition (as the most fatigued participants appear to have done in the Nolte et al. study), then one would expect them to show diminished responses at all difficulty levels.

2. Method

2.1. Overview

Undergraduate volunteers who reported low- and high levels of relatively extended fatigue were invited to the laboratory and presented the four versions of the cumulative mental addition task. All task versions required participants to add numbers. However, the presentation pace and numbers to be added (addends) made the first version easy, the second more difficult, the third more difficult still, and the fourth impossible. We presented task versions in a fixed order to avoid differential mental fatigue effects associated with early presentation of more and less difficult versions. All participants were offered two USD for each sum they provided that was correct, thus, allowing the chance to earn a total of eight USD by the end of the session. The design was a 2 (fatigue group: low, high) × 4 (difficulty: low, moderate, high, impossible) mixed factorial in which difficulty was the within-subjects factor.

2.2. Participants

Participants were 108 students enrolled in Introductory Psychology. All received class credit for participating. In multiple preliminary mass screening sessions, large numbers of Introductory Psychology students were administered various questionnaires, with the final number of students screened exceeding 1000. Included among the questionnaires were ones that assessed demographic (gender, race) information and fatigue (see modified Fatigue Severity Scale – FSS – below). Students scoring in the upper (High Fatigue) and lower (Low Fatigue) quartiles of the fatigue (i.e., modified FSS) distribution were identified and invited to participate. Data from seven participants were excluded because of repeated CV recording errors. Data from two participants were excluded because the participants expressed suspicion and/or failed to follow instructions. Final analyses were