International Journal of Psychophysiology 119 (2017) 73–78

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Naturally-occurring fatigue and cardiovascular response to a simple memory challenge

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ARTICLE INFO

Article history:
Received 29 August 2016
Received in revised form 16 February 2017
Accepted 19 February 2017
Available online 22 February 2017

Keywords:
Fatigue
Difficulty
Effort
Cardiovascular response

ABSTRACT

Participants first completed a state affect checklist that included a fatigue (energy-tiredness) index and a measure of mental sharpness. They then were presented a simple memory challenge. In the first minute of the two-minute work period, heart rate responses (1) rose with values on the fatigue index, and (2) fell with values on the measure of mental sharpness. In the second minute of the work period, the responses were unrelated to fatigue index and mental sharpness values. Follow-up analysis indicated mental sharpness mediation of fatigue influence on heart rate in Minute 1. First minute findings add substantively to the body of evidence supporting recent suggestions that fatigue can lead people to try harder and experience stronger cardiovascular responses when confronted with simple challenges. They also support the suggestion that fatigue might exert its influence on cardiovascular responses to a mental challenge by diminishing cognitive clarity, that is, by obscuring thought. Second minute findings are contrary to the fatigue suggestions, but could indicate that memorization was accomplished in the first minute. A practical implication of the first minute results is that real-world fatigue could elevate health risk by enhancing CV responses to mundane daily tasks.

Recent studies have examined effects of fatigue on effort and associated cardiovascular (CV) responses in people presented different tasks under different performance conditions (Wright, 2009, 2014; Wright and Stewart, 2012). The studies have been guided by three core ideas. One is that certain CV responses – specifically those linked to beta-adrenergic stimulation of the heart - increase with effort (Obrist, 1976, 1981). Another is that effort should (1) correspond to task difficulty so long as success is possible and worthwhile, and (2) be low when these conditions are not met (Brehm and Self, 1989; Brehm et al., 1983; Wright and Brehm, 1989). The third is that difficulty perceptions increase with fatigue (Fairclough, 2001; Fairclough and Graham, 1999; Hockey, 1997).

An important suggestion is that fatigued performers should tend to try harder and experience stronger CV responses when presented easy tasks. That is, because fatigued performers should have higher difficulty appraisals, they should tend to exert more effort and experience enhanced CV responses as a result. This takes on health significance when one considers prevailing models of psychosocial health, which assume that chronically elevated CV responses confer risk for various adverse outcomes, including heart disease, stroke and dementia (de la Torre, 2010; de la Torre and Mussivand, 1993; Krantz and Manuck, 1984; Smith and Ruiz, 2002). These models imply that people who experience persistent fatigue might incur health risk because they have exaggerated CV responses when executing mundane tasks inherent in daily life.

1.1. Empirical support

Considerable empirical support has been garnered for the preceding suggestion (Marcora et al., 2008; Stewart et al., 2009; Wright et al., 2007; Wright et al., 2003; Wright et al., 2013; Wright et al., 2012; Wright et al., 2008; for reviews, see Gendolla et al., 2012; Richter et al., 2016; Wright and Stewart, 2012). However, most is from studies that involved laboratory manipulations of fatigue, which limits generalization of findings to real world settings. Further, studies designed to examine the influence of naturally-occurring fatigue have yielded inconsistent results. Generally favorable results were obtained in an early study by Nolte et al. (2008) that examined CV responses to a simple memory task, evaluating fatigue in terms of an index created by combining scores from the energy and tiredness subscales of Thayer (1989) Activation-Deactivation Checklist (ADACL). Analysis indicated that systolic blood pressure (SBP) responses increased with fatigue to a point and then fell, with responses for diastolic blood pressure (DBP) and mean arterial pressure (MAP) following in rough parallel. Special attention was paid to SBP responses because they are partially determined by heart contraction force, which is considered a “gold

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http://dx.doi.org/10.1016/j.ijpsycho.2017.02.011
0167-8760/

standard" index of beta-adrenergic activation (Brownley et al., 2000; Fairclough and Mulder, 2012; Kelsey, 2012). The initial rise of the responses with fatigue agrees straightforwardly with the easy task fatigue suggestion. The eventual fall agrees if one assumes that the most fatigued participants were so resource-depleted that they viewed even this easy task as requiring more effort than they could or would deploy.

More ambiguous results were obtained in later studies that employed similar tasks, but measured fatigue differently. Schmidt et al. (2010) included a multidimensional fatigue inventory (Gentile et al., 2003) and a measure of insomnia with possible fatigue implications (Blais et al., 1997). Results indicated no association between CV response and inventory scores, but positive correspondences between SBP and MAP responses, on the one hand, and insomnia scores, on the other. LaGory et al. (2011) pre-selected participants with upper and lower quartile scores on a scale modified to measure fatigue extended over a period of weeks (Krupp et al., 1989). It showed weaker SBP and DBP responses in the upper quartile group, possibly because members were so depleted that they perceived the easy task as requiring more than they could or would do.

1.2. Present research

The present research evaluated further the easy task fatigue suggestion, assigning participants a simple memory task and assessing fatigue primarily in terms of the ADACL energy-tiredness index that was employed in the first natural fatigue study (Nolte et al., 2008). We made use of the ADACL index primarily because of its promising predictive validity in the earlier Nolte et al. research and to expand the base of evidence relating to it. We also were mindful of the index's indirect character, that is, the fact that it is comprised of items that do not reference fatigue directly (see Method). This could be important for at least two reasons. One is because factors irrelevant to fatigue (e.g., inclination to claim a performance handicap – Smith et al., 1982) could sometimes affect endorsement of explicit fatigue items. Another is because indirect queries could sometimes reveal states of depletion that are not consciously identified as fatigue (Schachter and Singer, 1962). Thus, for example, people might sometimes feel lethargic and dull without overtly linked those feelings to the fatigue concept.

Notably, the multidimensional fatigue inventory used by Schmidt et al. (2010) also included indirect queries. However, inspection reveals that subscale items were mixed in terms of their relevance to momentary (state) fatigue and, in some cases, in terms of their relevance to fatigue at all. For example, respondents were asked not only to rate how tired and active they felt, but also to rate their personal fitness, their ability to keep their thoughts from wandering, how much they dread having to do things, and whether they thought they did a lot in a day. For our purposes, the ADACL index was a preferred measure.

In addition to the ADACL index, the present research included single-item measures of mental fatigue, physical fatigue, and mental sharpness. We included the explicit fatigue items to evaluate the predictive validity of direct queries. We included the mental sharpness item to investigate the possibility that fatigue influence on CV responses to a mental task might be mediated by *cognitive clarity* – something not addressed in previous studies. That is, we added the item to investigate the possibility that fatigue diminishes clarity of thought, requiring performers to focus more intensively when presented a mental task (Wright et al., 2007). This was of interest for theoretical reasons and also because it could have practical implications. Regarding the latter for example, positive findings would present the possibility that fatigue influence on CV response might be reduced or eliminated through (e.g., caffeine or Ritalin) interventions designed to limit or abolish the link between fatigue and clarity.

In choosing to include single-item measures, we accepted the measures' limitations (e.g., relative instability), but also drew on their strengths. Single-item measures tend to be viewed cautiously for legitimate reasons (Diamantopoulos et al., 2012). However, they can be as effective or nearly as effective as multi-item measures in assessing outcomes of interest (Bergkvist and Rossiter, 2007; Woods and Hampson, 2005; Youngblut and Casper, 1993; Zimmerman et al., 2006). Further, they enjoy the benefit of being especially easy to administer, which can have favorable implications for the quality of data obtained.

Bearing in mind our guiding reasoning and also the character of CV findings in the relevant fatigue literature, we selected as our CV measures SBP, DBP, MAP and heart rate (HR). We expected that effort and associated CV responses would rise with reported fatigue and fall with reported mental sharpness, assuming that fatigue did not run so high as to lead participants to withhold effort in response to even a simple task. We also expected that SBP would be especially likely to vary with fatigue. We did so because of the special relationship between SBP and heart contraction force. Although we expected SBP responses to be especially likely to reflect fatigue influence, we recognized that other CV outcomes could as well, including HR – which can increase with beta-adrenergic activation and has sometimes been found to correspond more closely to effort than SBP (Eubanks et al., 2002; Gendolla, 1998; Richter and Knappe, 2014; Richter et al., 2012).

2. Method

2.1. Participants and cardiovascular assessment

Participants were 46 UNT undergraduate volunteers recruited through the Psychology Department. Data from seven were excluded due to protocol or data collection difficulties. The final sample consisted of 13 men and 26 women. CV responses were assessed with a CNAP Monitor 500 (CNSystems), which utilizes an upper arm inflation cuff and a double finger sensor that allows noninvasive measurement of blood pressure and HR. The finger sensor includes balloon-like cuffs placed on the proximal joints of the index and middle fingers. Arterial pressure estimates obtained with this device have compared well with ones obtained by an intra-arterial catheter system (Jeleazcov et al., 2010).

2.2. Procedure

Participants were met by a male or female experimenter who seated them at a desk holding a computer monitor, an intercom, two consent forms and a preliminary mood checklist. The experimenter told participants to review and sign the forms, complete the checklist and press the intercom CALL button when they were finished. The mood checklist included items from the energy and tiredness subscales of Thayer's ADACL. Responses were made on 11-point scales containing endpoints of 0 (not at all) and 10 (extremely). Energy items were active, energetic, vigorous, lively, and full-of-pep. Tiredness items were sleepy, tired, drowsy, wide-awake (reverse scored), and wakeful (reverse scored). The checklist also asked participants to rate how mentally fatigued, physically fatigued, mentally sharp, fearful, nervous, challenged and threatened they felt (0 = not at all; 10 = extremely).

The CALL signal prompted the experimenter to return and convey a study overview. He or she elaborated that physiological responses being studied were blood pressure and HR and fitted the participants with a CNAP arm cuff and finger sensor. After attaching the monitoring equipment, the experimenter told participants the session would start with baseline period lasting 8 to 10 min. We offered a range of minutes to reduce the chance that participants would engage toward the end of the baseline period, elevating their base CV values. The experimenter provided participants bland magazines to pass the time and left. He or she sampled CV responses for 8 min, recording as baseline the average of values obtained in the final two.

Following the baseline period, the experimenter returned with folders labeled "Instructions" and "Questionnaire". The experimenter directed participants to read and follow the instructions and returned to the control room. Instructions stated that the task would be to