Psychobiological responses to critically evaluated multitasking

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HIGHLIGHTS

- Critically evaluated multitasking provides an easily administered, ecologically valid laboratory stress paradigm
- Critically evaluated multitasking elicits greater psychological and cardiovascular reactivity than multitasking alone
- Not all situations that involve critical evaluation elicit cortisol responding

ABSTRACT

In order to understand psychobiological responses to stress it is necessary to observe how people react to controlled stressors. A range of stressors exist for this purpose; however, laboratory stressors that are representative of real life situations provide more ecologically valid opportunities for assessing stress responding. The current study assessed psychobiological responses to an ecologically valid laboratory stressor involving multitasking and critical evaluation. The stressor elicited significant increases in psychological and cardiovascular stress reactivity; however, no cortisol reactivity was observed. Other socially evaluative laboratory stressors that lead to cortisol reactivity typically require a participant to perform tasks that involve verbal responses, whilst standing in front of evaluative others. The current protocol contained critical evaluation of cognitive performance; however, this was delivered from behind a seated participant. The salience of social evaluation may therefore be related to the response format of the task and the method of evaluation. That is, the current protocol did not involve the additional vulnerability associated with in person, face-to-face contact, and verbal delivery. Critical evaluation of multitasking provides an ecologically valid technique for inducing laboratory stress and provides an alternative tool for assessing psychological and cardiovascular reactivity. Future studies could additionally use this paradigm to investigate those components of social evaluation necessary for eliciting a cortisol response.

KEYWORDS:
Multitasking; critical social evaluation; stress reactivity; ecological validity

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1. INTRODUCTION

The way in which individuals respond to daily stressors is a determinant of reactivity of the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes and contributes to allostatic load. In order to fully understand the reactivity of these axes it is necessary to observe individuals while they are experiencing stress. Naturalistic stressors provide ecologically valid measurement opportunities; however they can be expensive and lack control and standardisation. Alternatively, laboratory stressors allow for the controlled manipulation of stimuli and more specific assessment of the causal factors involved in psychobiological stress responding. A variety of laboratory stressors comprising cognitive challenge, public speaking, emotion induction and interpersonal stress are used for this purpose; however, these tasks typically serve no function outside of the laboratory (Chida & Hamer, 2008). To obtain a comprehensive snapshot of how an individual would respond to a stressor encountered in a real-life setting, laboratory stressors should have ecological validity and be representative of experiences in natural settings. Such settings rarely involve exposure to a single stressor as modelled in the laboratory, but instead individuals typically deal with multiple sources of stress (Chida & Hamer, 2008). Ecologically valid stressors should therefore comprise multiple stimuli and be representative of the types of situations encountered in everyday life.

The Multitasking Framework (Wetherell & Sidgreaves, 2005) comprises eight individual cognitive tasks and elicits stress via the manipulation of workload intensity by increasing the difficulty and number of tasks (up to a maximum of four during one presentation) that a user must attend and respond to. Although the Multitasking Framework does not simulate a specific environment, it comprises tasks that are required in many working environments, such as calculations, continuous visual and auditory monitoring, and relevant stimuli identification. Moreover, as successful performance requires sustained effort, repeated multitasking does not lead to habituation of responding (Wetherell, Harris & Hyland, 2004). Several studies have demonstrated the efficacy of the Multitasking Framework as an acute stressor as evidenced by increases in stress, anxiety and fatigue (e.g., Haskell et al., 2010; Johnson et al., 2011; Wetherell & Carter 2013); cardiovascular reactivity (e.g., Kelly-Hughes et al., 2014); and mucosal immunity (e.g., Wetherell & Sidgreaves 2005). Only one study; however, has reported an increase in cortisol reactivity following multitasking (Scholey et al., 2009). Compared with SAM responding, the HPA axis has a particularly high threshold for activation and acute increases in cortisol are typically observed in conditions of perceived uncontrollability involving motivated performance tasks accompanied by social evaluative threat (i.e. threats to a valued aspect of self-identity or where the self is at risk of being negatively judged by others; Dickerson & Kemeny, 2004). The Multitasking Framework is a motivated performance task and involves elements of uncontrollability; but, it does not involve social evaluative threat, and cortisol reactivity would therefore not necessarily be predicted.

All of the conditions necessary for reliably inducing a cortisol response are, however, present in other laboratory stressors notably, the Trier Social Stress Test (TSST), which involves a preparation period followed by the presentation of free speech and mental arithmetic to a socially evaluative panel whilst being recorded. This paradigm is associated with robust increases in cortisol and has become a standard protocol for stress induction in healthy (e.g., Kirschbaum, Pirke & Helhammer 1993; Kirschbaum et al., 1995) and clinical (e.g., Buske-Kirschbaum et al., 2003) populations of all ages (e.g., Kudielka et al., 2004; Jessop & Turner-Cobb, 2008). There is, however, a need to develop alternative stress protocols that involve other sources of stress and are appropriate for repeated testing (Kudielka & Wust 2010). In natural settings, exposure to social evaluation is omnipresent; for example, giving presentations and being monitored during the performance of tasks in the workplace are commonplace and involve perceived threats to ones abilities, competencies or traits (Gruenewald et al., 2004). A laboratory paradigm that is additionally representative of these settings would therefore be advantageous. As mentioned above, cognitive multitasking is analogous to a range of environments requiring attendance and response to multiple stimuli and is associated with cardiovascular and psychological stress reactivity. Given that critical social evaluation typically elicits HPA activation, the combination of multitasking and critical evaluation could therefore provide an easily administered acute stressor paradigm representative of everyday stressful situations. The aim of the current study is, therefore, to assess whether a critically evaluated multitasking paradigm elicits activation of psychological, cardiovascular and HPA reactivity.

2. METHOD

2.1 Participants

All recruitment and study procedures were granted ethical approval from the Faculty Ethics Committee in line with the regulations of the institution and relevant regulatory bodies. A total of 50 healthy participants (range 18-38, M_{age}= 19.6, *SD*= 2.83; females = 34, males = 16) were recruited from an undergraduate population and randomly allocated to either multitasking only (M_{age}= 19.89, *SD*= 3.93; female = 17, male = 8) or multitasking with critical evaluation (M_{age}= 19.32, *SD*= .85; female = 17, male = 8). Eligibility criteria included: aged 18-40; resting blood pressure less than 140/90 mmHg; not pregnant or breastfeeding; no self-reported anxiety or stress-related disorder. In addition, data were recorded for a number of factors that can alter HPA function; specifically, Body Mass Index (BMI); use of the contraceptive pill (N=21); menstrual cycle stage (first half = 8; second half = 14); and smoking status (N= 6) were also recorded as appropriate.

2.2 Materials

The Multitasking Framework (Purple Research Solutions, UK) is a platform for the presentation of performance-driven, cognitively demanding tasks and is analogous to working environments that require attendance and response to simultaneous stimuli. This study used four tasks: auditory monitoring, visual monitoring, number entry, and memory search. All tasks are points drive with points awarded for correct responses and points deducted for missed or incorrect responses. Participants are instructed to be as fast and accurate on all of the tasks as possible in order to achieve as high a score as they can. The running total score is displayed in the middles of the screen whilst the tasks are running. A full description of the Framework is provided in Wetherell & Carter (2013). Blood pressure and heart rate were recorded using an Omron M3 IntelliSense.

2.2.1 Questionnaires

The (10 item) Perceived Stress Scale (PSS-10: Cohen et al., 1983) measured how often in the last month participants felt that life was unpredictable, uncontrollable, and overwhelming. The 16 item Bond-Lader Visual Analogue Scales (Bond & Lader, 1974) measured the mood states of Alert, Content, and Calm. Two single item 100mm VAS measured the states Anxious and Happy. The NASA-TLX (Hart & Staveland (1988) assessed Mental, Physical and Temporal Demand, Effort, Performance and Frustration.

2.2.2 Salivary cortisol

Participants were asked to refrain from eating or drinking (other than water) for 1h preceding the study. Saliva was collected using Salivettes (Sarstedt, Germany). All samples were frozen (−20 °C) and assayed using the enzyme-linked immunosorbant assay method (Salimetrics-Europe, UK; intra and inter-assay coefficients <10%).

2.3 Procedure

All testing took place at least 1 hour following awakening and between 1200 and 1600. On arrival participants were seated, an inflatable cuff was placed on their non-dominant arm and they were familiarised with the procedure. Following a rest period of 15 minutes, participants were given a 2-minute demonstration of the tasks and were informed that they must be as fast and accurate on all of the tasks in order to obtain as high a score as possible. Each participant provided 4 saliva samples during the testing session: immediately before and after the framework (20 min) and 10 and 20 minutes following stressor cessation. Heart rate and blood pressure were recorded pre-stressor, mid-way and post stressor. Mood was assessed immediately before and after the stressor and perceived workload was assessed following stressor cessation. For the ‘multitasking only’ condition, the researcher left the room while the participant completed the task, re-entering only to take heart rate/blood pressure readings, whilst in the ‘critically evaluated multitasking’ condition the researcher remained in the cubicle, standing behind the participant and providing negative feedback throughout the session (see Table 1). Additionally, in the ‘critically evaluated multitasking’ condition a web-cam and a video camera was trained on participants’ side profile, and participants were informed that both devices would record throughout the session. All testing was conducted by a female researcher within the age range of participants.

INSERT TABLE 1 HERE

2.4 Treatment of data

Mood, cardiovascular parameters and cortisol were assessed using mixed ANOVAs with group (multitasking, critically evaluated multitasking), time (Mood: pre, post; Cardiovascular: pre, mid, post; Cortisol: pre, post, post+10, post+20), and sex (male, female). Perceived workload was compared using independent samples t-tests.

3. RESULTS

There were no significant between group differences in age, BMI, sex or levels of perceived stress and no significant effects of pill use, menstrual cycle stage or smoking status on cortisol reactivity in either condition. There were no significant sex X group or time interactions for any of the study variables.

Psychological Responses

Psychological indices in relation to critically evaluated multitasking and multitasking alone are presented in Table 2.

Mood

A post-stress increase was observed in anxiety ($F_{(1,48)} = 9.85$, $p = 0.003$, $\eta^2 = .17$) and post-stress reductions were observed for calmness ($F_{(1, 48)} = 66.63$, $p = < 0.001$, $\eta^2 = .581$), contentment ($F_{(1,48)} = 24.259$, $p = <0.001$, $\eta^2 = .336$), and happiness ($F_{(1,48)} = 8.2$, $p = 0.006$, $\eta^2 = .146$). Significant group x time interactions were observed for anxiety ($F_{(1,48)} = 4.9$, $p = 0.032$, $\eta^2 = .09$), calmness ($F_{(1,48)} = 13.56$, $p < 0.001$, $\eta^2 = .22$), contentment ($F_{(1,48)} = 4.9$, $p = 0.03$, $\eta^2 = .09$), and happy ($F_{(1,48)} = 9.14$, $p = 0.004$, $\eta^2 = .16$). Bonferroni corrected t-tests revealed significantly greater post-stress levels of anxiety ($p = 0.026$) and lower levels of contentment ($p = 0.05$) and calm ($p = 0.01$) following critically evaluated multitasking compared with multitasking alone.

Perceived workload

Critically evaluated multitasking led to significantly greater levels of mental ($t_{(48)}$ = -2.742, p = .009); physical ($t_{(48)}$ = -2.073, p = .044); and temporal demand ($t_{(48)}$ = -2.137, p = .038); effort ($t_{(48)}$ = -2.508, p = .016); frustration ($t_{(48)}$ = -5.000, p = <0.001) and reduced perceived performance ($t_{(48)}$ = 2.597, p = .012) compared with multitasking alone.

INSERT TABLE 2 HERE

Physiological Responses

Physiological indices in relation to critically evaluated multitasking and multitasking alone are presented in Table 3.

Cardiovascular parameters

Significant main effects of time were observed for heart rate ($F_{(2,47)}$ = 5.42, p = .009, η^2 = .182), and diastolic blood pressure ($F_{(2,47)}$ = 4.27, p = .020, η^2 = .154) . A significant group x time interaction was observed for systolic blood pressure ($F_{(2,47)}$ = 3.71, p = .032, η^2 = .136).

Cortisol

A significant reduction in cortisol was observed across the stressor period ($F_{(3,46)}$ = 37.6, p < .001, η^2 = .71). There were no between group differences or time x group interaction (p > 0.05).

INSERT TABLE 3 HERE

4. DISCUSSION

The current study assessed psychological, cardiovascular and HPA reactivity in response to critically evaluated multitasking and multitasking alone. Multitasking led to increased psychobiological reactivity; specifically increases in heart rate, diastolic blood pressure, and anxiety and reductions in positive mood states of calmness, contentment and happiness. Critically evaluated multitasking increased systolic blood pressure and anxiety, reduced contentment and calmness and led to greater perceived workload on all domains, over and above that observed following multitasking alone. Numerous studies (cf Dickerson & Kemeny 2004) have demonstrated that critical social evaluation elicits robust increases in cortisol, and alongside the other key stressor components of cognitive challenge and uncontrollability, forms an integral part of laboratory stressors such as the TSST. In this study, however, critically evaluated multitasking did not elicit a cortisol response. The reduction in cortisol observed during the stressor period is likely indicative of the decline associated with the typical diurnal decline of cortisol.

Physiological processes respond to meet the demands of the environment and terminate that response once the demands are met (Gunnar, Bruce, & Donzella, 2000). Furthermore, unlike the SAM axis, the HPA axis has a particularly high threshold for activation, and subsequently has longer-lasting effects (Shirtcliff et al., 2012). If the threat associated with a situation is perceived to be low, this will be reflected in the subsequent physiological responses. A situation of low perceived threat may, therefore, involve only brief withdrawal of parasympathetic inhibition or a brief rise in cardiovascular activity to activate the SAM-mediated fight-or-flight response. However, the situation may not be sufficiently threatening as to activate the 'second wave', HPA response (Sapolsky, Romero, & Munck, 2000). This may account for the observed profile of responding in the current paradigm, that is, cardiovascular responding indicative of activation of the fight-or-flight response, but insufficient perceived threat to activate the HPA axis, despite increased reports of anxiety and demand.

An absence of cortisol responding has also been observed in other paradigms involving challenging situations in the presence of others. Paradigms that incorporate friendly or inattentive rather than socially evaluative panels do not elicit cortisol reactivity (Wiemers et al., 2013; Dickerson et al., 2008), suggesting that the provision of critical social evaluation, rather than just the presence of others is necessary for HPA activation. The current paradigm incorporated a record of participation (video recording of participant) and critical evaluation of performance, and was perceived as demanding and anxiety provoking; however, it may not have been perceived as a threat to self. Perception of social evaluation was not explicitly measured in this study; however, the absence of cortisol responding, in an otherwise stressful and demanding paradigm, does suggest a missing stress eliciting component. That is, whilst the current manipulation comprises challenge and critique, it may lack the socially evaluative element that has been previously associated with HPA activation in other paradigms.

This may be evidenced by notable differences between the current paradigm and the TSST, which is associated with robust cortisol responding. Both paradigms incorporate a motivated performance task and the presence of critical evaluation; however, they differ in terms of the required response format of the performance task; and the position of the participant in relation to the evaluator. The TSST requires the participant to verbally perform a free speech task followed by a verbal mental arithmetic task; in contrast the Multitasking Framework requires responses via a computer with no verbal component. Public speaking is a significant stressor involving the risk of embarrassment and humiliation (Garcia-Leal et al., 2014), and as such, the requirement to verbalise responses may represent the salient challenge to self that is necessary for HPA activation. However, not all paradigms that evoke a cortisol response comprise public speaking. Cold pressor, a passive coping task typically associated with minimal HPA activity, leads to significant increases in cortisol when accompanied with social evaluation. Specifically, a standard cold pressor procedure whilst being video recorded and evaluated by an experimenter leads to significant increases in cortisol in participants tested alone (Schwabe et al., 2008) and in groups (Minkley et al., 2014), suggesting that social evaluation may represent a salient threat even in the absence of a critique of a motivated performance task or a verbal component.

The remaining notable distinction between this paradigm and the TSST relates to the nature of social evaluation. Evaluation in the TSST and socially evaluated cold pressor involves being directly observed by an evaluator, and in the case of the TSST involves standing directly in front of a panel. Direct social evaluation, even in the absence of critique leads to increased perceived vulnerability and cortisol increases are therefore likely in situations where there is a threat to self-presentation and a greater risk of negative evaluation (Schwabe et al., 2008). Although the current paradigm involved the observation and critique of performance, and therefore a potential challenge to one's self, this challenge was indirect. The participant was therefore able to avoid direct evaluation and focus on the tasks, as evidenced by increases in psychological and cardiovascular responding typical of motivated performance tasks.

The current study should be evaluated in the context of its limitations. First, although the sample is small, it was sufficient to observe meaningful differences in variables of interest in line with previous studies that have used the Framework (e.g., Wetherell & Carter 2013). Second, sex differences can impact upon acute stress responding, in particular reactivity of the HPA axis with males typically demonstrating greater reactivity than females (Kudielka et al., 2009). Although attempts were made to ensure balanced numbers of males and females across conditions, the current sample comprised a greater number of females than males. There were no observed sex differences for any of the psychological or physiological variables; however, future studies should use this paradigm in larger, more balanced samples.

Notwithstanding these limitations, the current paradigm affords several advantages and opportunities for stress testing. From a methodological perspective, in response to the call for the development of alternative stress testing protocols (Kudielka & Wust 2010); the Multitasking Framework provides an ecologically valid technique for eliciting psychobiological reactivity; it is appropriate for repeated testing; and it comprises inherent measures of performance (Scholey et al., 2009). In addition, critically evaluated multitasking offers a paradigm representative of everyday situations requiring attention to multiple stimuli whilst being monitored and evaluated. As the paradigm requires minimal physical and human resource it therefore offers an alternative, economical laboratory stressor. The paradigm can also be used to address a number of research questions relating to the role of social evaluation. The current study reported the effects of additional critical evaluation on psychobiological indices and perceptions of stress and demand; however, future studies could utilise the inherent performance measures to ascertain the impact of critical evaluation on actual task performance, thus providing a useful tool for modelling work-based performance during evaluation. The absence of cortisol reactivity following critically evaluated multitasking also presents a number of opportunities for assessing the salient social components that are associated with HPA activation in other paradigms. That is, it appears that the levels of interpersonal threat experienced in the TSST are not present in the current paradigm. Further manipulations regarding the nature of the critical evaluation received in addition to multitasking, for example, face-to face, rather than over-the-shoulder critical evaluation, or the requirement for verbal responding, would allow for a greater understanding of the role of interpersonal threat in relation to HPA activation.

In conclusion, the present study is the first to apply critical evaluation to the Multitasking Framework. The increases in perceived workload, anxiety and cardiovascular responding following multitasking with critical evaluation demonstrate the stress-inducing effects of this protocol. The current paradigm is an easily administered laboratory analogue of everyday situations involving the performance of multiple tasks whilst being critically evaluated, and therefore provides an ecologically valid paradigm for the assessment of psychological and cardiovascular stress responding. The absence of cortisol reactivity, however, suggests some added subtlety in the factors that elicit HPA responding, that is, not all critically evaluated situations are perceived as a significant threat to self, and direct observation is likely to provide the additional social evaluation that is associated with HPA activation. Future developments of this paradigm could therefore assess the importance of in person, face-to-face contact to an evaluative other whilst maintaining the ecologically valid components of the paradigm.

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Table 1. Verbal prompts during critically evaluated multitasking

Time point	Evaluative comment
Stressor commencement	When you click start, all of the tasks start at the same time. It is up to you how you spend your time, but you MUST be as FAST & ACCURATE on ALL of the tasks as you can in order to achieve as high a score as you can
+4 minutes	Remember, you must be as fast & accurate on all of the tasks as you can
+8 minutes	Your score is on the low side, you should speed up
+10 minutes	I am now going to take your blood pressure, please continue with the tasks
+12 minutes	You should be working faster than this
+16 minutes	Your score is still below the average
+18 minutes	You only have 2 minutes remaining and you must get as high a score as you can
20 minutes	I am now going to take your blood pressure

Table 2. Mean (s.d) values for physiological indices

		Multitasking N=25	Critically Evaluated Multitasking N=25
Cardiovascular			
Heart rate (bpm)	Pre	77.2 (13.7)	79.3 (9.8)
	Mid	77.3 (10.3)	83.8 (8.3)
	End	75.4 (8.9)	79.9 (7.3)
Systolic Blood Pressure (mm hg)	Pre	119.5 (12.8)	117.2 (12.2)
	Mid	117.2 (13.5)	119.2 (13.1)
	End	116.5 (11.5)	118.7 (13.5)
Diastolic Blood Pressure (mm hg)	Pre	74.1 (10.1)	72.4 (10.3)
	Mid	73.6 (8.1)	74.3 (8.7)
	End	71.0 (8.7)	72.6 (9.3)
Cortisol (nmol/l)	Pre	11.5 (8.3)	10.8 (5.7)
	Post	8.8 (5.4)	9.5 (7.1)
	+10min	6.7 (6.3)	7.1 (3.6)
	+20min	6.3 (4.0)	6.7 (3.5)

bpm = beats per minute; mm hg = millimetres of mercury; nmol/l = nanomoles per litre

Table 3. Mean (s.d) values for psychological indices

		Multitasking N=25	Critically Evaluated Multitasking N=25
Perceived Stress		16.8 (4.2)	17.4 (3.7)
Mood (mm)			
Alert	Pre	60.6 (10.1)	61.6 (16.4)
	Post	58.8 (14.6)	55.1 (16.5)
Content	Pre	71.8 (9.3)	71.6 (12.1)
	Post	66.5 (10.8)	57.7 (16.0)
Calm	Pre	64.1 (14.5)	68.1 (15.3)
	Post	52.9 (17.8)	38.6 (16.5)
Anxious	Pre	29.6 (20.8)	31.8 (22.2)
	Post	32.1 (17.7)	46.3 (21.2)
Happy	Pre	63.2 (16.6)	70.6 (16.9)
	Post	63.7 (18.8)	52.9 (19.6)
Perceived Workload (mm)			
Mental Demand **		55.0 (24.4)	71.8 (18.6)
Physical Demand*		20.9 (17.3)	32.9 (23.2)
Temporal Demand *		56.2 (22.9)	68.8 (18.4)
Effort *		55.4 (22.3)	70.9 (21.5)
Perceived Performance *		65.3 (20.9)	51.2 (17.3)
Frustration **		32.5 (16.0)	60.8 (23.3)

mm = millimetres

Between group differences: * $p < 0.05$; ** $p < 0.001$