

Threat and challenge: cognitive appraisal and stress responses in simulated trauma resuscitations

Adrian Harvey,^{1,2} Avery B Nathens,^{1,2} Glen Bandiera^{1,3} & Vicki R LeBlanc^{1,3}

OBJECTIVES Training and practice in medicine are inherently stressful. Research into the effects of acute stressors has revealed significant variability in individual responses to stressors, with performance impairments occurring in those who demonstrate elevated subjective and physiological responses. Cognitive appraisals (subjective assessment of situational demands and available resources) of a stressor have been proposed as a predictor variable in stress responses. However, the relationship between cognitive appraisal and stress responses has not been tested empirically in complex realistic situations. The purpose of this study was to determine the extent to which cognitive appraisal affects a medical trainee's subjective and physiological stress responses to high-acuity simulated clinical situations.

METHODS Thirteen emergency medicine and general surgery residents participated in high (HS) and low (LS) stress trauma resuscitation simulations. Subjective (cognitive appraisal and State-Trait Anxiety Inventory [STAI]) and physiological (salivary cortisol) measures were

collected at baseline and in response to participation in each scenario.

RESULTS Post-scenario STAI scores, cognitive appraisal and cortisol levels were higher in the HS scenario compared with the LS scenario. For the participants who appraised the scenarios as 'threats' (in which the demands outweighed the resources), the ratio of perceived demands to resources was positively correlated with cortisol levels ($r = 0.59$, $p < 0.05$) and STAI responses ($r = 0.64$, $p < 0.05$). By contrast, for the participants who appraised the scenarios as 'challenges' (in which resources were sufficient to meet the demands), the perceived ratio of demands to resources was not correlated with either the STAI scores or cortisol levels.

CONCLUSIONS Subjective appraisals of a situation appear to play an important role in stress responses, which have previously been shown to impair performance. As such, training for high-acuity events should include interventions targeting stress management skills.

Medical Education 2010; **44**: 587–594
doi:10.1111/j.1365-2923.2010.03634.x

¹Wilson Centre, University of Toronto, Toronto, Ontario, Canada

²Department of Surgery, University of Toronto, Toronto, Ontario, Canada

³Department of Medicine, University of Toronto, Toronto, Ontario, Canada

Correspondence: Vicki R LeBlanc, Wilson Centre, University of Toronto, 200 Elizabeth Street, 1ES-565, Toronto, Ontario M5G 2C4, Canada.

Tel: 00 1 416 340 3054; Fax: 00 1 416 340 3792;

E-mail: Vicki.leblanc@utoronto.ca

INTRODUCTION

Education and practice in the field of medicine have long been perceived as stressful endeavours. Significant levels of stress have been well documented in medical trainees.^{1–7} Potential sources of stress are many and include working under conditions of sleep deprivation, managing family life in a busy schedule, overload from coursework, and demands related to caring for critically ill patients.^{1,4}

Although there has been significant research into the effects of chronic stress on the physical and mental health of medical trainees,^{5–7} there has been relatively little research into the effects of acute stress on performance during acute medical crises. An understanding of the impact of stress in this context is critical as performance impairments could have immediate effects on the care provided to patients. A review of the few studies looking at the effects of stress on the performance of health professionals reveals that performance under high-acuity situations can be either enhanced or impaired.⁸ The findings from related domains of research, such as the military and psychological domains, reveal similar equivocal results, showing that performance can at times be impaired, enhanced or unaffected under stressful conditions.^{9–11}

In an attempt to better understand performance under stressful conditions, researchers have explored the circumstances in which performance is impaired under stress. One consistent finding is that the activation of the hypothalamic–pituitary–adrenal (HPA) axis and the ensuing release of the hormone cortisol are associated with impaired performance during high-stakes events.^{12–16} Not everyone demonstrates a cortisol response in high-acuity events. Those participants who do demonstrate elevated cortisol responses to stressful events are more likely to exhibit performance impairments on tasks of memory, attention, decision making and clinical performance (A Harvey, G Bandiera, A Nathens, V LeBlanc, unpublished data, 2008).^{8,12–16} As such, it is important to understand and predict the circumstances in which activation of the HPA axis, and the ensuing cortisol response, will occur.

Cognitive appraisals have been proposed as an important predictor of stress responses under high-acuity conditions. The cognitive appraisal theory, currently the leading explanatory model of stress responses, states that when faced with a situation that threatens an important goal, an individual undergoes

a specific cognitive process.^{17–19} The individual subjectively assesses the demands of the environment (*primary appraisal*) and subsequently makes a determination of his or her resources that can be applied to the situation (*secondary appraisal*). If the individual determines that his or her resources are sufficient to meet the demands of the situation, the situation is appraised as a challenge and the potential for gain (i.e. elevated self-esteem, learning) is recognised. If the resources are not judged to be sufficient, the situation is appraised as a threat because of the significant potential for loss. Socio-evaluative stressors (when behaviour is potentially judged by others) and uncontrollable situations are more likely to be appraised as threats than challenges. Cognitive appraisals have been associated with indices of cardiovascular reactivity.¹⁸ Although some researchers have proposed that cortisol release is associated with the appraisal of a situation as a threat,^{20,21} the relationship between cognitive appraisals and stress responses has not been empirically tested.

The goal of this proof-of-concept study was to determine whether activation of the HPA axis, as determined by the elevation of salivary cortisol levels, is related to an individual's cognitive appraisal of a stressor during a high-acuity clinical event. The main hypothesis of the study was that cognitive appraisals are associated with stress responses and that threat appraisals are more likely to lead to elevated stress responses than challenge appraisals.

METHODS

General study design

Emergency medicine and general surgery residents were asked to participate in two different simulated trauma resuscitations of high stress (HS) and low stress (LS), respectively. The scenarios were separated by ≥ 85 minutes to allow cortisol levels, as measured by salivary samples, to return to baseline.²¹ Physiological and psychological measures of stress were recorded during each of the simulation sessions. (See Measures, below, for more details.) The experiment timeline is shown in Fig. 1.

A standardised 10-minute introduction to the simulation room and manikin were provided for each participant. The participant then sat quietly in a room, reading magazines of neutral content, for 30 minutes. Subjective and physiological baseline stress measures were obtained at 30 minutes,

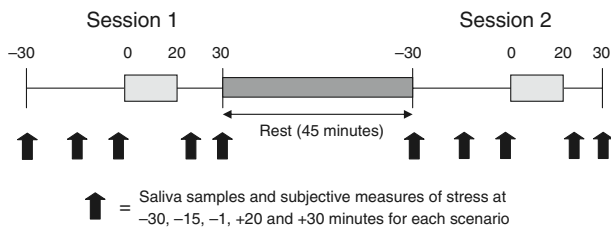


Figure 1 Timeline of experiment

15 minutes and 1 minute prior to the start of the scenario. The participant then entered the simulation room and managed a simulated trauma resuscitation. Each scenario was terminated when all of the appropriate management steps had been taken or after 20 minutes had elapsed, whichever was accomplished first. Subjective and physiological stress measures were obtained immediately following the simulation and 30 minutes after the start of the scenario. After the prescribed rest period, this procedure was repeated for the second scenario.

To control for any learning effects or carryover stress that might confound the results, the residents were randomly divided into two counterbalanced groups. Residents in Group A were assigned to the LS condition first, followed by the HS condition. Residents in Group B were assigned to the HS condition first, followed by the LS condition. Participants were blinded to the group allocation and randomisation was stratified by training level.

Participants

Thirteen general surgery and emergency medicine residents (from postgraduate years 1–4) enrolled at the University of Toronto were recruited for participation in this study. All residents had undergone advanced trauma life support (ATLS) certification and had completed a minimum of one clinical rotation in trauma prior to the study. As such, they had the basic knowledge and training required to be able to serve in the capacity of trauma team leader in the scenarios. Participation was voluntary. A small stipend was provided to all participants. The Health Sciences II ethics review board at the University of Toronto approved the study.

Simulated trauma resuscitations scenarios

The scenarios were run at the Allan Waters Family Patient Simulation Centre at St Michael's Hospital using the Laerdal SimMan® (Laerdal Medical Canada, Toronto, Canada) placed in a simulated trauma bay. All medications and equipment required

during the clinical scenarios were available in the simulated clinical environment.

The residents were instructed to assume the role of the trauma team leader and to carry out evaluation and management as they would in a real-life situation. In each scenario, one registered nurse and one respiratory therapist were present to aid in the resuscitation, but did not advise the participant. When participants requested procedures or tests that could not be performed on the manikin, the respiratory therapist was trained to intervene and provide results in an appropriate time-frame. Basic imaging (chest, neck and pelvic X-rays) were provided digitally in the simulated trauma bay. Ultrasound and laboratory results were phoned into the room following a predetermined time delay after the participant's request.

Scenarios were designed by three of the authors (AH, GB and ABN), all of whom had experience in trauma resuscitation. The scenarios were piloted using two medical trainees with backgrounds relevant to the tasks. This piloting was used to develop the roles of the actors, to ensure the smooth operation of the manikin and to confirm that the scenarios differed with respect to subjective stress.

The *low-stress* (LS) scenario involved a multiple trauma victim with a head injury caused in a motor vehicle collision. The patient's Glasgow Coma Scale score was < 8, requiring definitive airway management. Respiration was further compromised by rib fractures and a pneumothorax demanded oxygen therapy and chest tube placement. A low-grade splenic injury in conjunction with a femur fracture was the source of blood loss, resulting in mild transient haemodynamic instability, which responded promptly to fluid resuscitation. Overall, this patient was considered relatively stable.

A similar pattern of injury was seen in the *high-stress* (HS) scenario. The major difference referred to a more significant splenic laceration resulting in haemodynamic instability such that the residents would expect that the victim could potentially die from her injuries. We chose this approach in order to standardise the difficulty level of the basic approach to the two scenarios while increasing the ambient stress in the HS scenario. In addition, the HS simulated victim was identified early on as a young female paramedic who was 15 weeks pregnant. Although this did not affect the appropriate management steps (a foetus would be non-viable at this stage of pregnancy), it added emotional content to the scenario. Additional emotional content was included by scripting some

minor discord between the nurse and the respiratory therapist actors (ensuring that this caused no delay to or direct adverse effects on the management of the patient). A distraught paramedic (the victim's supervisor) was also present in the trauma room environment. This scripted role, played by a trained standardised patient, was developed in conjunction with an experienced paramedic. The purpose was to provide a critical observer to enhance concerns of negative performance evaluation (as the role was scripted to verbally challenge the trauma team's capability). Finally, noise was added by increasing the volume of the monitors, including all alarms.

Measures

Cognitive appraisals

Cognitive appraisal was assessed immediately before and after each scenario, using the method described by Tomaka *et al.*^{18,19} Primary appraisal was examined by asking the participants to answer the questions 'How demanding do you expect the upcoming task to be?' before the scenario and 'How demanding was the task you just completed?' after the scenario. Secondary appraisal was measured by asking the participants to answer the question: 'How able are [were] you to cope with this task?' The participants indicated their answers on an anchored 10-point Likert scale. An index of cognitive appraisal was then calculated as the ratio of the primary appraisal (demands) to the secondary appraisal (resources). If the resources were assessed as being equal to or greater than the task demands, the situation was appraised as a 'challenge' (ratio ≤ 1). If the task demands were appraised as being greater than the resources, the situation was appraised as a 'threat' (ratio > 1).

Subjective stress responses

Subjective measures of stress were recorded at 30 minutes, 15 minutes and 1 minute preceding the simulation, at completion and at 30 minutes post-scenario start time. The participants' subjective stress responses were measured using the 'state' form of the State-Trait Anxiety Inventory (STAI).

The state anxiety (S-anxiety) scale consists of 20 statements (e.g. 'I am tense'), with which respondents indicate their level of agreement in terms of how they feel *at the given moment* on a 4-point scale (1 = not at all, 4 = very much so). Each question is given a score of 1–4, which generates a total score of 20–80. The internal consistency of the S-anxiety scale is high, with an alpha of 0.92.²² In a previous

study with paramedics, the S-anxiety scale was sensitive to anxiety increases that resulted from participation in acutely stressful simulated scenarios.²³ When validated with working adults, mean baseline scores on the STAI were 35. Individuals who were asked to imagine sitting a high-stakes examination scored an average of 42 on the STAI.²²

Activation of HPA axis by cortisol levels

Activation of the HPA axis was measured using salivary cortisol levels, which have shown a close correlation with plasma cortisol levels.^{24–26} Samples were taken at 30 minutes, 15 minutes and 1 minute prior to the scenario to capture baseline levels. In addition, samples were collected 20 minutes and 30 minutes after the start of the scenarios because previous work has shown that cortisol response to stressors peaks during this timeframe.²¹ Participants chewed on a roll-shaped saliva collector (Salivettes, Sardstedt, Germany) until the collector was saturated with saliva (~ 30–60 seconds). The saliva collector was then placed in a collection tube and frozen. All participants had been asked to refrain from eating and drinking for 1 hour prior to the study period as this might interfere with the measurement of salivary cortisol. Duplicate analyses of the salivary cortisol levels were conducted using an enzyme-linked immunosorbent assay (ELISA) technique in a commercial laboratory. The average intra-assay coefficient of variability was 3.7%. In experimental studies, mean cortisol responses to acute stressors have ranged from 29% to $> 200\%$ above baseline levels.^{13–16}

Analysis

The subjective and physiological stress response measures were expressed as both absolute values and change parameters. The 'change' parameter consisted of the difference between the peak individual response after the scenario and the individual pre-scenario baseline score. The mean of the three pre-scenario cortisol levels was taken as a baseline measure. In addition, the highest post-scenario level was recorded as the peak level, in light of previous work showing individual variation in the time-course over which the cortisol response reaches its highest level.²¹

As a manipulation check, each of the subjective and physiological values was used as a dependent variable in separate general linear, repeated measures analyses. Scenario (HS versus LS) and time-point around each scenario served as independent variables. One-sample *t*-tests were used to determine whether the mean cognitive appraisals in each of the groups were

significantly different from 1. To test the main hypothesis of the study and assess the relationship between cognitive appraisals and stress responses, we calculated the Pearson correlation coefficients between each of the absolute and change measures of cognitive appraisals, STAI scores and cortisol levels.

All results are expressed as mean $\pm$ standard error of the mean (SEM) values. Statistical analyses were conducted using SPSS Version 15.0 (SPSS, Inc., Chicago, IL, USA). The level of statistical significance for this study was set at $p < 0.05$.

A power calculation was performed based on the results of a similar study with paramedics.²³ In that study, a difference of 10 points on the state scale of the STAI was observed between the LS and HS conditions, and the standard deviation (SD) was 15 points. Setting alpha at 0.05 (two-sided) and beta at 0.20, it was determined that 12 participants were required to attain sufficient power to detect a 10-point difference on our outcome measure with an SD of 15 points.

RESULTS

Participants

Overall, 13 residents volunteered to participate in the study; seven participants were emergency residents and six were general surgery residents. All participants completed both simulated scenarios. All participants were in postgraduate years (PGY) 1–4 (PGY1: $n = 4$; PGY2: $n = 4$; PGY3: $n = 3$; PGY4: $n = 2$). After randomisation, six residents were placed in Group A (LS scenario first) and seven in Group B (HS scenario first).

Subjective measures of stress

State-Trait Anxiety Index

Group means and SEMs for the STAI at all five time-points across both scenarios are shown in Fig. 2. Pre-scenario values were similar between both groups at 30 minutes, 15 minutes and 1 minute before simulation start times. By contrast, significant differences were noted between the HS and LS groups at both the immediate ($p < 0.05$) and 30-minute post-scenario ($p < 0.05$) time-points.

Cognitive appraisal

Group means and SEMs for the cognitive appraisals are listed in Fig. 3. Pre-scenario cognitive appraisal

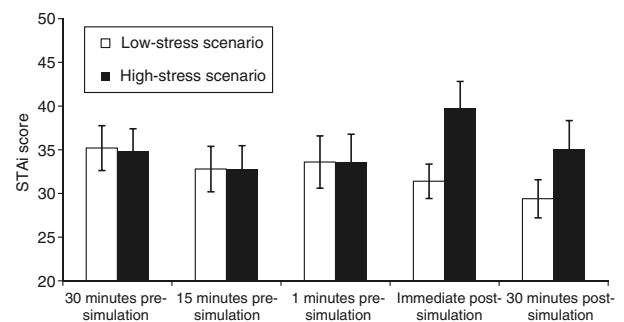


Figure 2 State-Trait Anxiety Inventory (STAI) scores at the five time-points for low- and high-stress scenarios

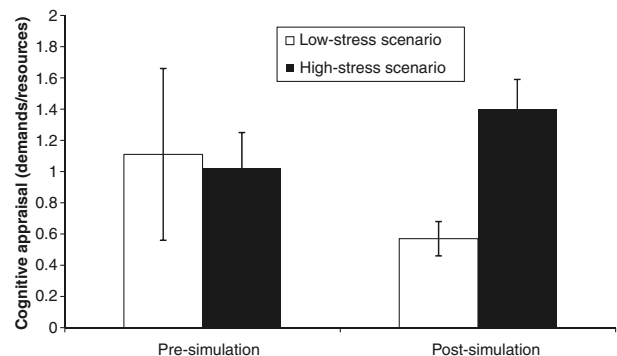


Figure 3 Pre- and post-simulation cognitive appraisal scores for low- and high-stress scenarios

scores did not significantly differ between the HS and LS conditions prior to the scenarios ($p = 0.34$). Following the simulations, appraisals in the HS group suggested a threat appraisal ($p < 0.001$). In the LS group, post-scenario appraisals indicated challenge appraisals ($p < 0.001$). Post-scenario cognitive appraisals were significantly different between the HS and LS simulations ($p < 0.04$). Over the course of the scenarios, cognitive appraisals increased in the HS group (0.39 ± 0.17 ; $p < 0.001$) and decreased in the LS group (-0.53 ± 0.17 ; $p < 0.001$).

Cortisol levels

Values for two participants were unavailable as a result of collection or laboratory measurement errors, leaving values for 11 participants. Group means and SEMs for the cortisol levels are listed in Fig. 4. Pre-scenario cortisol levels did not significantly differ between the HS and LS simulations. The analysis of average pre-scenario and post-scenario peak values revealed a significant interaction of scenario by time ($p < 0.05$). Cortisol levels increased as a result of participating in the HS scenario and decreased as a result of participating in the LS scenario

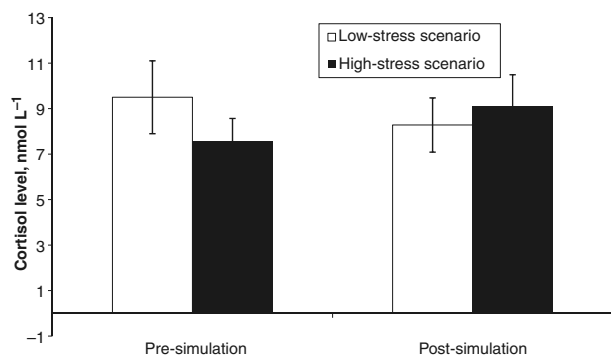


Figure 4 Pre- and post-simulation cortisol levels for low- and high-stress scenarios

(HS: 1.56 ± 1.09 nmol L⁻¹ [20% increase over baseline levels]; LS: -1.23 ± 1.21 nmol L⁻¹ [13% decrease from baseline levels]; $p < 0.05$).

Correlations between cognitive appraisals and stress responses

The relationship of cognitive appraisal to cortisol response was explored in both the HS and LS groups. In the HS group, post-scenario cognitive appraisal was significantly correlated with the increase in cortisol levels ($r = 0.68$, $p = 0.01$). In addition, the change in cognitive appraisal across the HS scenario was significantly correlated with the change in cortisol levels ($r = 0.621$, $p = 0.023$). In the LS group, post-scenario cognitive appraisal was significantly correlated with post-scenario peak cortisol levels ($r = 0.74$, $p = 0.004$), but not with the change in cortisol levels. Post-scenario cognitive appraisal and STAI scores were found to be positively correlated in the HS group ($r = 0.711$, $p < 0.006$). This correlation was not found in the LS group ($r = 0.290$, $p = 0.34$).

Irrespective of LS or HS scenario, all participants were then divided into challenge and threat groups depending on their post-scenario cognitive appraisal ($t/r < 1$ = challenge, $t/r \geq 1$ = threat). In the challenge group ($n = 14$), no significant correlations between cognitive appraisal measures and cortisol levels were noted. However, in the threat group ($n = 11$), post-scenario cognitive appraisal was significantly correlated with post-scenario peak cortisol level ($r = 0.586$, $p = 0.045$) and change in cortisol levels across scenarios ($r = 0.642$, $p = 0.025$).

DISCUSSION

The objective of this study was to determine whether trainees' appraisals of the perceived demands and

resources of high-stakes events would predict stress responses. Previous research has shown significant individual differences in response to acute stressors, with greater cortisol responses being associated with impairments on tasks of memory, attention and decision making.⁸ As such, it is important to identify factors that are associated with greater stress responses during high-acuity events. If we can identify which trainees are more likely to have elevated stress responses during high-acuity events, we can target stress management training and support to those in need of it.

Our findings confirm that cognitive appraisals of threat and challenge were differentially associated with cortisol responses. In the HS scenario, in which the majority of participants appraised the situation as a threat, cortisol responses were greater than those measured following the LS scenario. When the subjects were subsequently divided into 'threat' and 'challenge' groups ($t/r > /< 1$), a significant correlation between appraisal and cortisol level was evident only in the threat group. As such, this evidence lends support to the hypothesis that threat appraisals lead to activation of the HPA axis. In addition, it appears that there is a dose-response relationship in the threat group: the greater the threat appraisal, the greater the cortisol response.

The analyses conducted in this study are associative and therefore any conclusions regarding causal relationships must be interpreted with caution. However, cognitive appraisal theorists believe that the cognitive evaluation precedes, and contributes to, the physiological response.^{18,19} Tomaka *et al.*, in a series of three experiments, provided good evidence for the cognitive appraisal approach to stress.¹⁹ In these experiments, Tomaka *et al.* attempted to manipulate the subject's response to a mental arithmetic task by cognitive (instructions) and physiological (cold-water immersion) stimuli. The results showed that cognitive, but not physiological, stimuli were successful in influencing an individual's response to a stressful task. It appears that this appraisal precedes any physiological stress response. Thus, a potential way of modifying cognitive appraisal in high-stress scenarios might be to use interventions targeted at enhancing the subject's ability to interpret high-stakes events as challenges rather than as threats. One can impact cognitive appraisal by changing the perceived demands of the tasks or by altering the actual or perceived resources of the individual in a stressful setting. In this regard, it is encouraging that previous research demonstrated the ability to manipulate an individual's cognitive appraisals in

laboratory settings.^{18,19} Given our findings that cognitive appraisals are associated with cortisol responses, and that elevated cortisol responses have previously been linked with performance impairments, interventions aimed at modifying trainees' perceptions of the demands and resources of high-acuity events could significantly impact clinical performance. Opportunities are known to exist in this regard because it has been demonstrated that some residents feel unprepared for the acute care obligations they are faced with while on call.²⁷ Furthermore, deficiencies in preparation for practice (and thus ability to feel equipped to handle high-stakes situations) have been felt to exist throughout the medical education system.^{28,29} Further research will be needed to confirm this hypothesis.

The trend toward a higher pre-scenario cortisol level in the LS group highlights one of the limitations of the experimental design. Groups were counterbalanced with respect to the order of scenario and sufficient time was provided between simulations for the HPA axis to return to baseline. Previous work has suggested that persistent elevations of cortisol beyond 40–60 minutes are rare.²¹ However, although the HPA axis may have returned to baseline, there is invariably some memory of the previous situation which might have contributed to differing levels of pre-scenario anticipatory stress. In short, subjects entering the LS scenario always did so in one of two settings in which the LS scenario either served as the first simulation or followed the HS scenario. The HS scenario was encountered either as a first simulation or following the LS scenario. Thus, although levels of anticipatory stress would be similar in those entering their first scenario, subjects entering the LS scenario second would be doing so with the memory of the previous HS scenario. In these subjects, the memory of the previous 'threat appraisal' and potential for harm to the 'social self' might have resulted in higher levels of anticipatory stress compared with those who entered the HS scenario second with the memory of the preceding 'challenge appraisal'. Thus, we estimate that the observed difference in cortisol responses between the HS and LS scenarios is a conservative estimate.

The small sample size is another limitation of this study as it does not provide us with the statistical power required to conduct analyses into the contributions of the specialty or level of training of the participants. As such, the contribution of experience in mediating cognitive appraisals and stress responses is a matter for further studies.

CONCLUSIONS

In summary, the purpose of this study was to examine whether cognitive appraisals are associated with stress responses during high-acuity events. With few exceptions, participants appraised the HS scenario as a threat and the LS scenario as a challenge, and these patterns were accompanied by increases in subjective stress and cortisol levels in the HS scenario compared with the LS scenario. Subjective appraisals were strongly associated with subjective and physiological stress responses to the scenarios. The results of this study thus shed some light on a potentially important determinant of stress responses during high-acuity events, namely, individuals' subjective assessments of the demands of a situation in relation to their assessments of the resources available to meet those demands. Given that elevated stress responses are associated with impairments in performance, training that targets the emotional management and reappraisal of potentially threatening situations has the potential to improve the care provided to patients during high-acuity events.

Contributors: all four authors made substantial contributions to the conception and design of the study and to the interpretation of the data. AH was responsible for the acquisition and analysis of data. VRL oversaw all stages of the project. All authors contributed to the drafting and critical revision of the manuscript and approved the final manuscript for publication.

Acknowledgements: none.

Funding: funding for this project was generously provided by a research grant from the Physicians Services Incorporated Foundation, Toronto, Canada.

Conflicts of interest: none.

Ethical approval: this study was approved by the University of Toronto and St Michael's Hospital Research Ethics Boards.

REFERENCES

- 1 Dyrbye LN, Thomas MR, Shanafelt TD. Medical student distress: causes, consequences, and proposed solutions. *Mayo Clin Proc* 2005;**80** (12):1613–22.
- 2 Dyrbye LN, Thomas MR, Shanafelt TD. Systematic review of depression, anxiety, and other indicators of psychological distress among US and Canadian medical students. *Acad Med* 2006;**81** (4):354–73.
- 3 Lee J, Graham AV. Students' perception of medical school stress and their evaluation of a wellness elective. *Med Educ* 2001;**35** (7):652–9.
- 4 Niemi PM, Vainiomaki PT. Medical students' distress – quality, continuity and gender differences during a

- 6-year medical programme. *Med Teach* 2006;**28** (2):136–41.
- 5 Peterlini M, Tiberio IF, Saadeh A, Pereira JC, Martins MA. Anxiety and depression in the first year of medical residency training. *Med Educ* 2002;**36** (1):66–72.
- 6 Sawyer RG, Tribble CG, Newberg DS, Pruett TL, Minasi JS. Intern call schedules and their relationship to sleep, operating room participation, stress, and satisfaction. *Surgery* 1999;**126** (2):337–42.
- 7 Vierhapper H, Nowotny P. The stress of being a doctor: steroid excretion rates in internal medicine residents on and off duty. *Am J Med* 2000;**109** (6):492–4.
- 8 LeBlanc VR. The effects of acute stress on performance: implications for health professions education. *Acad Med* 2009;**84** (105) (Suppl):25–33.
- 9 Johnston JH, Driskell JE, Salas E. Vigilant and hypervigilant decision making. *J Appl Psychol* 1997;**82** (4):614–22.
- 10 Klein G. The effect of acute stressors on decision making. In: Driskell JE, Salas E, eds. *Stress and Human Performance*. Mahwah, NJ: Lawrence Erlbaum Associates 1996;49–88.
- 11 Keinan G. Decision making under stress: scanning of alternatives under controllable and uncontrollable threats. *J Pers Soc Psychol* 1987;**52**:639–44.
- 12 Buchanan TW, Tranel D, Adolphs R. Impaired memory retrieval correlates with individual differences in cortisol response but not autonomic response. *Learn Mem* 2006;**13**:382–7.
- 13 De Quervain DJF, Roozendaal B, Nitsch RM, McGaugh JL, Hock C. Acute cortisone administration impairs retrieval of long-term declarative memory in humans. *Nat Neurosci* 2000;**3** (4):313–4.
- 14 Lupien SJ, Gillin CJ, Hauger RL. Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: a dose–response study in humans. *Behav Neurosci* 1999;**113** (3):420–30.
- 15 Buchanan TW, Lovaglio WR. Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology* 2001;**26**:307–17.
- 16 Bohnen N, Houx P, Nicolson N, Jolles J. Cortisol reactivity and cognitive performance in a continuous mental task paradigm. *Biol Psychiatry* 1990;**31**:107–16.
- 17 Salas E, Driskell J. *Stress and Human Performance*. Mahwah, NJ: Lawrence Erlbaum Associates 1996;1–46.
- 18 Tomaka J, Blascovich J, Kelsey RM, Leitten CL. Subjective, physiological, and behavioural effects of threat and challenge appraisal. *J Pers Soc Psychol* 1993;**65** (2):248–60.
- 19 Tomaka J, Blascovich J, Kibler J, Ernst JM. Cognitive and physiological antecedents of threat and challenge appraisal. *J Pers Soc Psychol* 1997;**73** (1):63–72.
- 20 Kemeny ME. The psychobiology of stress. *Curr Dir Psychol Sci* 2003;**12** (4):124–9.
- 21 Dickerson SS, Kemeny ME. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychol Bull* 2004;**130** (3):355–91.
- 22 Spielberger CD. *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press 1983.
- 23 LeBlanc VR, MacDonald RD, McArthur B, King K, Lepine T. Paramedic performance in calculating drug dosages following stressful scenarios in a human patient simulator. *Prehosp Emerg Care* 2005;**9** (4):439–44.
- 24 Dorn LD, Lucke JF, Loucks TL, Berga SL. Salivary cortisol reflects serum cortisol: analysis of circadian profiles. *Ann Clin Biochem* 2007;**3**:281–4.
- 25 Francis SJ, Walker RF, Riad-Fahmy D, Hughes D, Murphy JF, Gray OP. Assessment of adrenocortical activity in term newborn infants using salivary cortisol determinations. *J Pediatr* 1987;**111** (1):129–33.
- 26 Simunkova K, Hampl R, Hill M, Doucha J, Starka L, Vondra K. Salivary cortisol in low dose (1 microg) ACTH test in healthy women: comparison with serum cortisol. *Physiol Res* 2007;**56** (4):449–53.
- 27 Hayes CW, Rhee A, Detsky ME, LeBlanc VR, Wax RS. Residents feel unprepared and unsupervised as leaders of cardiac arrest teams in teaching hospitals: a survey of internal medicine residents. *Crit Care Med* 2007;**35**:1668–72.
- 28 Acres JC. Preparing physicians for the real world. *CMAJ* 2004;**171**:709.
- 29 Gaies MG, Landrigan CP, Hafler JP, Sandora TJ. Assessing procedural skills training in paediatric residency programmes *Pediatrics* 2007;**120**:715–22.

Received 28 September 2009; editorial comments to authors 31 October 2009; accepted for publication 8 January 2010